Impact of ITS Applications on Green Logistics and Customer Service Performance

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Abstract

The paper presents the results of a study that evaluates the impact of intelligent transportation systems (ITS) on green logistics practices and their effects on customer service performance in freight transport enterprises. Based on a selection of ten ITS applications for management processes assistance and eight ITS applications for vehicle use support, we assessed the level of knowledge on these applications among freight transport managers, as well as the level of maturity of implementation in their companies. This study involves two-stage research conducted in 2023 in March-May and August-October with 840 and 640 freight transport enterprises in the Visegrad Group countries. A quantitative survey based on an online questionnaire was defined, and the collected data was then analysed using descriptive statistics methods and the SEM-PLS (Structural Equation Modelling-Partial Least Squares) methodology.

Keywords: intelligent transportation system applications, green logistics practices, customer service performance, management, freight transport enterprises.

1. Introduction

Nowadays, advanced information and communication technology (ICT) prevails as the catalyst for a leading paradigm transfer, positioning the enterprise's strategic priorities on enhanced customer service. ITC assists the progress of successful linkage between the services provided by the companies and the buyers' needs, resulting in the net raise in value offered to the customer in service performance [1], [6], [10], [14]. Such an expanding in prominence, proactive facilitators of processes coordination throughout time and space in freight transport business activity are intelligent transportation system (ITS) applications [15], [30], [38], [44], [45]. ITS is a system in which ICT solutions are implemented in the areas of the transport network, including *infrastructure, vehicles and the users, traffic management systems and mobility management, as well as the interfaces for other modes of transport* [11]. According to the research reported by Benevelo et al. [4] and Kadłubek [3], mainly related to customer service, ITS applications are devoted to managing processes aligned with the business objectives of freight transport enterprises.

Recent decades showed a growing public environmental awareness of freight transport customers' consciousness and market pressure, motivating companies to incorporate green

practices through diverse means, including ICT solutions [7], [37]. Within the logistics field, green practices are cross-functional and integrative initiatives of environmental protection, inclusive for both operational and strategic management levels [26]. The development of green logistics practices in cooperation with the freight transport sector has been integrated following the urgency of reduction of carbon dioxide and greenhouse gas emissions from vehicles, energy use, and other damaging impacts of transportation processes on the natural environment [19], [32]. As an efficiency recovery of numerous logistics areas of transport enterprises lies in the adoption of distinct ITS applications, these modern technological solutions are also supposed to transform the sector toward low-carbon mobility via green practices support [23], [40, 41]. Moreover, in line with the Resource-Based View theory (RBV), critical business operations combined with resources (such as ITS applications) and environmentally responsible logistics systems that correctly address customers' demands can serve as a stimulus for these enterprises' prospective and inclusive viability.

The primary aim of this paper is to present and discuss the assessment results on the influence of ITS applications on green logistics practices and customer service performance in freight transport enterprises. This study analysed ten ITS applications that support management processes assistance and eight ITS applications for vehicle use support, focusing on the level of knowledge about them among freight transport managers and the level of advancement of their implementation in these companies. Two-stage research was conducted in 2023 in March-May and August-October, with 840 and 640 freight transport enterprises in the Visegrad Group countries (V4). A quantitative investigation employing an online questionnaire framework was established, and the collected data was analysed with descriptive statistical techniques [16] and based on Structural Equation Modelling-Partial Least Squares (SEM-PLS) methodology [17], [39].

This paper presents the findings of part of a broader interdisciplinary research project in progress whose main objective is to determine IT support's effect on freight transport enterprises' performance in Visegrad Group countries.

The paper is organised as follows. Firstly, Sections 1 and 2 provide a brief introduction and literature review, including an overview of ITS applications and green logistics practices concerning customer service performance in freight transport enterprises. Afterwards, Section 3 defines the research objectives, questions and proposed hypotheses. Section 4 presents the research methods and tools, and Section 5 demonstrates the analysis of the research results. Finally, Section 6 summarises the key contributions, identifies the limitations of the study, and recommendations for future research.

2. Literature Review

Intelligent transportation systems (ITS) denote the integration of sophisticated technologies within applied information and communication, aiming to facilitate advancements in the transportation system across various dimensions [14], [25]. ITS attain a more accessible, advantageous, and productive transportation system, particularly in capabilities and validity. This is achieved through a compelling reduction of impediments and elucidation of transportation management challenges via adherence to pertinent standards.

European Telecommunications Standard Institute states that ITS *add information and communications technology to transport infrastructures and vehicles to improve their safety, reliability, efficiency and quality* [12]. Richard and Pulser [33] establish ITS as a general framework that directs the adoption of information and communication technologies within the road transport field. The escalation in the deployment of ITS applications has prompted a thorough examination and intricate compilation of information which serves to facilitate favourable outcomes, such as the monitoring of road freight and shipment conditions, analysis of traffic events, efficient and secure route management, coordination of infrastructure arrangements, oversight of accidents, supervision of truckloads, control of mobility, management of fleets, optimisation of energy efficiency in transportation, and mitigation of adverse environmental impacts associated with transport, as outlined by Guo and Guo [15], Njoku et al. [30], Veres and Moussa [38]. Regarding this evident differentiation, autonomous systems establish their functionalities by prioritising communication with external entities, while interdependent systems manage connections among ITS terminals located within

individual vehicles, sectors of transport infrastructure, central subsystems, and so forth [7].

Given that ITS applications encompass a variety of technological innovations designated for the transport sector, their focus is directed towards supporting various facets of transport activities. Consequently, these applications are classified using distinct approaches. Emphasis on inter-domain highlights distinct functional advantages, with a particular focus on those deemed most pertinent to the scope of this paper and as proposed by Mangiaracina et al. [25]. Specifically, vehicle management [14], [28], [31], [40], and comprehensive enterprise management [14], [30], [45] emerge as key classes of applications. The compilation of ITS applications falling into vehicle management and enterprise-wide management categories was curated based on recommendations from Benevelo et al. [4] and Kadłubek [3], selected with consideration of practices pertinent to enterprises engaged in road freight transport.

As noted by Kawa and Pierański [20], solutions in ICT are increasingly becoming integral components of the green logistics framework. As Mesjasz-Lech [27] discussed, green logistics encompasses endeavours associated with environmentally conscious management *of both forward and reverse flows of products and information from the point of origin to the point of consumption*. Green logistics aims to fulfil or surpass customer demand while adhering to eco-friendly practices. Following the insights from Çankaya and Sezen [5], the principles underlying green logistics strive to mitigate the environmental and energy impact of logistics operations, encompassing a spectrum of activities, such as material handling, warehousing, waste management, packaging, and transportation. In this domain, the principal advantages derived from the utilisation of ITS are characterised by Modelewski [29]: (i) decrease of driving durations and energy consumption by 40-70%; (ii) diminish of exhaust emissions by 30-50%; (iii) lowering of expenses associated with road fleet management; (iv) enhancing of road safety, consequently mitigating the incidence of collisions and accidents by 40 to as much as 80%.

Organisations progress their green logistics resources, encompassing ITS applications, to oversee and regulate the environmental and energy efficiency aspects of transportation modes [6], [19], [32]. This evolution aims to enhance performance by comprehensively understanding infrastructure services, spanning road or rail transport, multimodal transport, and their organisation, administration, and interfaces. The findings from the study by Lyu et al. [22] suggest that IT can contribute to cultivating strategic advantages for enterprises, thereby influencing competitive dynamics.

As analysed by Ma and Kim [24], the advancement of green logistics practices within a framework of integrated solutions supported by digital information flow currently affords customers exceptional visibility into potent market signals, thereby reshaping various facets of logistics. This transformation requires enterprises to reassess conventional notions of logistics customer service, effectiveness, and overall performance. The studies by Acosta-Prado and Tafur-Mendoza [1] and Yunhui et al. [43] have investigated the impact of increased digitisation on logistics customers and the consequential effects of customer service decisions on the overall performance of enterprises. Additionally, Coelho et al. [8] conducted a detailed examination of operations research applications that bolster the management processes of road freight transport companies, encompassing aspects such as intermodal transport activities, challenges related to truck loads, and considerations for rail, air, and oceanic transport. As indicated by Veres and Moussa [38], ITS applications play a pivotal role for enterprises within the logistics sector, showing their capability to enhance both internal and external effectiveness. Presently, this sector is experiencing notable growth attributed to high consumer demand. This scenario establishes the foundation for the profits attained, thereby influencing the continued development of transport services.

Nevertheless, the contemporary expectations from their customer base encompass the need for increasingly responsive transportation systems following prompt customer service, as highlighted by Daugherty et al. [10]. This requires a continuous adaptation of transportation relationships towards more diverse models of goods delivery, as discussed by Acosta-Prado and Tafur-Mendoza [1] and Costa et al. [9]. These adaptations include incorporating principles associated with the development of green transport [26], modern technologies facilitating environmental protection, and the strategic management of energy inherent in transportation means [37]. Furthermore, there is a growing emphasis on advancing logistics customer service through the integration of IT, considering the meaningful deployment of ITS applications.

3. Research Objectives and Hypotheses

Considering the literature review (concisely mentioned above), several studies have shown that the field of ITS applications in the practice of freight transport enterprises is limited and selectively raised. Furthermore, insufficient research concerning the assessment on the knowledge of these ITS applications and their implementation by freight transport enterprises has been identified. Recognition of these gaps led us to the following research questions:

RQ1: *What is the level of knowledge that freight transport enterprises have on ITS applications for management processes assistance and vehicle use assistance, and what is the level of advancement in their implementation?*

Additionally, considering the literature review, we verify that former studies did not analytically explore the influence of both ITS applications (i.e., management processes assistance and vehicle use assistance) on green logistics practices and customer service performance in freight transport enterprises. Accordingly, this issue exposes the second research gap considering the intersection between distinct areas such as ITS applications, green logistics, and customer service achievements. On these grounds, the second research question is defined as:

RQ2: *What is the influence of ITS applications (for management processes assistance and vehicle use assistance) on green logistics practices and customer service performance in freight transport enterprises?*

Furthermore, given the above questions, we define the following hypotheses:

H1a. *ITS applications for management processes assistance positively influence green logistics practices in freight transport enterprises.*

H1b. *ITS applications for vehicle use assistance positively influence green logistics practices in freight transport enterprises.*

H2a. *ITS applications for management processes assistance positively influence customer service performance in freight transport enterprises.*

H2b. *ITS applications for vehicle use assistance positively influence customer service performance in freight transport enterprises.*

H3. *Green logistics practices positively influence customer service performance in freight transport enterprises.*

Figure 1 illustrates the conceptual model of this research that shows the hypothesised interdependences between the key elements.

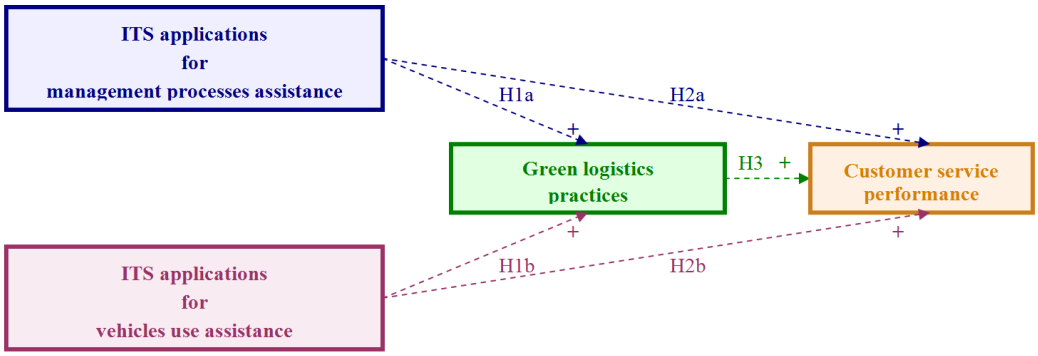

Fig. 1. Conceptual model of the proposed hypotheses.

4. Research Methods

The research was determined by the two research questions and five hypotheses (H1a-H3) introduced in the previous section. This research was carried out in two main stages: Stage 1 (March-May 2023) and Stage 2 (August-October 2023), and based on 10 ITS applications for management processes assistance (AppM.x) and 8 ITS applications for vehicle use assistance (AppV.y), as summarised in Table 1.

Table 1. ITS applications for management processes and vehicle use assistance in freight transport enterprises.

Id.	Application's name and objective
AppM.1	**The Fleets and Logistics Management application** allows organisations to optimise and rationalise the operations of fleets of vehicles and logistics processes.
AppM.2	**The Control of Urban Traffic application** manages the real-time spatiotemporal data derived from the traffic conditions of urban road networks, enabling the acquisition of comprehensive and high-quality foundational data and detailed evaluation of traffic management efficacy.
AppM.3	**The Automatic Incident Detection application** manages the real-time identification of events and incidents within the traffic flow of transportation infrastructure, encompassing accidents, traffic congestion, and jamming.
AppM.4	**The Traffic Data Management application** manages the acquisition of real-time data to facilitate traffic management and inform infrastructure development decisions, including identifying transportation requirements and traffic patterns, assessing the efficacy of traffic network operations, and fostering data-centric decision-making in urban planning endeavours.
AppM.5	**The Mobility Management application** supports the real-time management and surveillance of urban mobility. It serves as a tool for orchestrating interventions in mobility plans and infrastructures, facilitating the simulation of future scenarios and validating their effectiveness.
AppM.6	**The Video Surveillance application** supports observing and classifying traffic flow behaviours, with subsequent alert triggering.
AppM.7	**The Fleet Documents Management application** supports tracking and managing documents related to the fleet and facilitates the organisation and control of documents to streamline administrative tasks related to truck fleet management, ensuring compliance with regulations and facilitating efficient operations.
AppM.8	**The Variable Message Signs application** supports disseminating obligatory and advisory messages regarding temporary events and current traffic conditions to drivers at roadside locations.
AppM.9	**The Integrated Parking Guidance application** provides information regarding parking space availability and the security and safety attributes of parking facilities.
AppM.10	**The Demand Control Systems application** (cordon pricing, congestion pricing, electronic tooling, electronic tooling with GPS, pay as you drive) supports enhancing the efficiency of transportation systems by reducing travel demand or redistributing it spatially or temporally.
AppV.1	**The Eco-driving applications** allow the modulation of the velocity of a vehicle under traffic dynamics and the selection of routes that optimise fuel efficiency.
AppV.2	**The Automotive Navigation application** is an integral component of the automobile controls or a third-party add-on utilised for spatial orientation within an automobile.
AppV.3	**The Hire and Ridesharing Services application** supports one-directional transportation arrangements encompassing a spectrum of shared rides spanning short to long distances, conducted via car or van, with comparable origin-destination pairings.
AppV.4	**The Car Sharing application** supports a model of shared vehicle ownership aimed at furnishing participants access to personal transportation without the financial burdens and commitment inherent to individual car ownership.
AppV.5	**The Vehicle Automated Driving application** allows autonomous performance of driving tasks within defined operational design domains, gradually reducing the need for human intervention.
AppV.6	**The Track Stations Fuels application** allows for tracking alternative fuel stations such as LNG (liquefied natural gas), CNG (compressed natural gas), hydrogen stations, and others.
AppV.7	**The Vehicle Emission Monitoring application** allows monitoring of vehicle condition and emissions and provides data on performance and compliance with European emissions standards for pollution.
AppV.8	**The Electric Vehicle Charging and Monitoring application** allows for processing and controlling the flow of electrical energy in hybrid and plug-in electric vehicles, as well as controlling the speed of the motor and the torque it produces.

Stage 1 was developed to answer the research question RQ1. A quantitative survey based on an online questionnaire (Survey 1: https://doi.org/10.5281/zenodo.12272558) was established based on the results of extensive literature studies on ITS applications in freight transport enterprises. The respondents were asked to estimate their levels of knowledge and advancement in implementing the 10 ITS applications for management processes assistance (AppM.x) and 8 ITS applications for vehicle use assistance (AppV.y). Ten applications were selected to support general processes management in road freight transport enterprises (see Figure 2), predominantly focused on optimising driving comfort, enhancing accessibility, cohesion, and oversight in managerial operations. On the other hand, eight ITS applications were selected for vehicle support (see Figure 3), as dedicated solutions geared towards enhancing transport energy efficiency and mitigating the adverse environmental effects of transportation or diminishing transport duration while concurrently enhancing connectivity and comfort levels. A Likert scale of 1-5 was used to assess the replies to questions about the level of knowledge of these18 ITS applications, where 1 means "I do not know" and 5 means "I know precisely"; for the inquiry about the level of advancement in the implementation of selected applications, 1 means "not implemented" and 5 means "comprehensively implemented".

The questionnaire was e-mailed to freight transport enterprises in the Visegrad Group countries, i.e. Czech Republic, Hungary, Poland, and Slovakia. For all four Central European members of the regional alliance within V4, the assumed statistical minimum sample size of the responses from the freight transport sector was 97 enterprises. 840 representatives of managerial staff of the target companies participated in the study (212 from the Czech Republic, 195 from Hungary, 246 from Poland and 187 from Slovakia). The reliability analysis of the collected data was conducted, and its reports confirmed its appropriateness for further study, using descriptive statistics methods [16].

Stage 2 of the research answers the second research question, and a comprehensive review of the literature was extended, including areas of green logistics practices and customer service performance. The effects of the studies allowed for the recognition of the research gaps, the development of the hypotheses and the research conceptual model. The second survey was evolved (Survey 2: https://doi.org/10.5281/zenodo.12272558), containing only the ITS applications that in the previous stage of the research received the average level of advancement by implementation in freight transport enterprises assessed of a minimum of three points on the 1-5 scale. It was addressed only to the companies that indicated the average level of advancement in implementation, which was assessed at a minimum of three points in the first stage of the research. The questionnaire form comprised 1-5 Likert-scale measurement items for 4 constructs: (1) ITS applications dedicated to supporting the management processes; (2) ITS applications dedicated to vehicle use assistance; (3) green logistics practices; (4) customer service performance. We received 460 responses (118 from the Czech Republic, 111 from Hungary, 122 from Poland and 109 from Slovakia) from members of executive boards of the freight transport enterprises in V4 countries.

The collected data underwent an analysis following the Structural Equation Modelling-Partial Least Squares (SEM-PLS) methodology [17], [39] using the SPSS Amos version 26.0 software [18] and R lavaan library [21]. SEM-PLS explored the intricate interrelations among variables and indicators and their associations with other variables. SEM-PLS was used to scrutinise the proposed model, aligning with our research objective of assessing the selected information technology field's impact on logistics practices and organisational performance areas. SEM-PLS stands out in multivariate analysis within complex relationships between variables due to its dual focus on explanation and prediction. It offers several advantages over many statistics methods [2], [34, 35], as it is preferred when dealing with compound models, focusing on forecasting, handling non-normally distributed data, incorporating formative constructs, and enhancing the understanding of theoretical models. Additionally, SEM-PLS requires smaller sample sizes, accommodates both formative and reflective measures, models numerous variables and relationships, and possesses statistical prediction capabilities [24], [36], [42]. Thus, SEM-PLS was deemed suitable for employing measurements in operationalising the proposed constructs, given our focus on capturing diverse information and managerial research fields.

5. Research Results Analysis

5.1. Stage 1

In Stage 1 of the research, the respondents' characteristics were scrutinised, as shown in Table 2: the enterprises mainly were from Poland (29%) and the Czech Republic (25%). Distribution of the main activity of enterprises was similar in all V4 countries, with a dominance of transportation activity (over 66%) followed by shipping (over 27%). The respondents were mainly managers (80%) from small enterprises employing less than 50 people, constituted the research sample of over 60%, while IT managers represented over 7% of medium and large enterprises.

Stage 1's inquiry is the level of knowledge on ITS applications for management processes assistance (AppM.x) by the representatives of the freight transport sector (Figure 2a). The average grade of familiarity with these ITS applications was 3.26 on a 1-5 scale. This result shows that many managers know ITS solutions, but the awareness is rather depthless. The level of knowledge is also very diversified, particularly the highest for the AppM.8 (Variable Message Signs application) and AppM.4 (Traffic Data Management application) with average assessments, respectively 4.47 and 4.08.

Table 2. Characterisation of the respondents.

Feature	Visegrad Group Countries:			
	Czech Republic	Hungary	Poland	Slovakia
	Number of enterprises (%)	Number of enterprises (%)	Number of enterprises (%)	Number of enterprises (%)
The main activity of the enterprise:				
Transportation	144 (17.15%)	117 (13.9%)	160 (19.05%)	139 (16.55%)
Shipping	53 (6.3%)	72 (8.6%)	64 (7.6%)	39 (4.65%)
Third-party logistics	15 (1.8%)	6 (0.7%)	22 (2.6%)	9 (1.1%)
The size of the enterprise:				
Large	34 (4.05%)	16 (1.9%)	35 (4.2%)	17 (2%)
Medium	70 (8.3%)	56 (6.7%)	66 (7.9%)	38 (4.5%)
Small	108 (12.8%)	123 (14.65%)	145 (17.3%)	132 (15.7%)
The role in the enterprise:				
Director	15 (1.8%)	24 (2.9%)	27 (3.2%)	30 (3.6%)
Manager	191 (22.7%)	150 (17.8%)	199 (23.7%)	140 (16.7%)
IT Manager	6 (0.7%)	21 (2.5%)	20 (2.4%)	17 (2%)

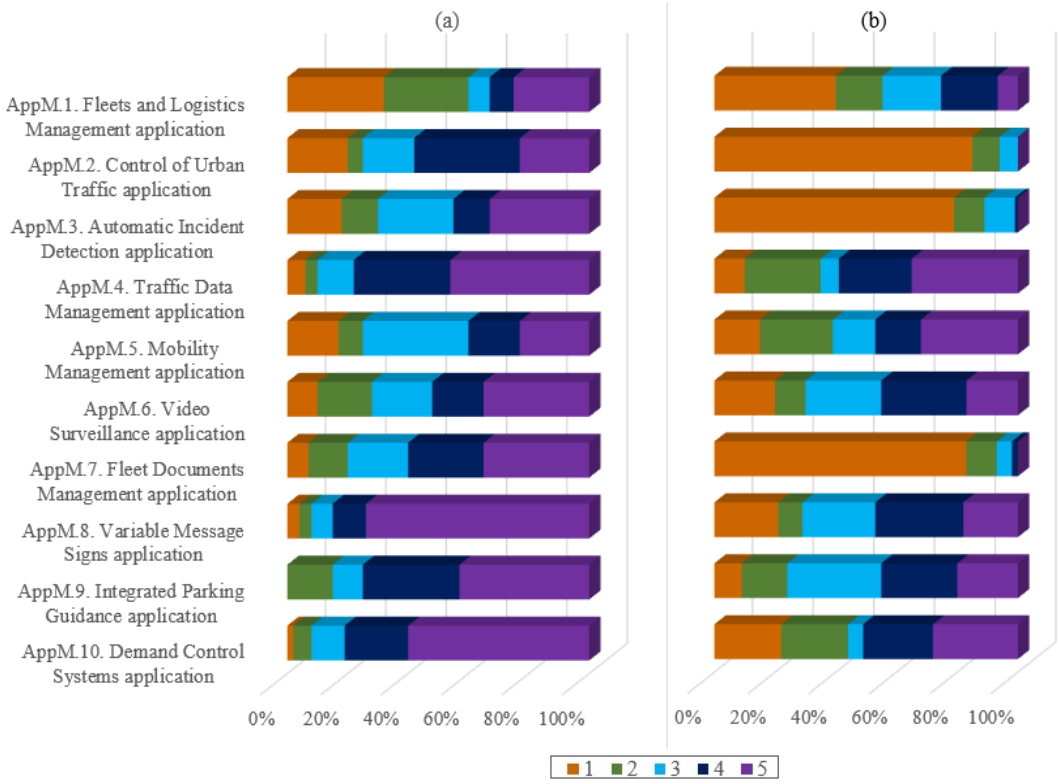

Fig. 2. ITS applications for management processes assistance in the freight transport enterprises: (a) level of knowledge, (b) level of advancement in implementation.

To compare the level of advancement in the implementation of these ITS applications dedicated to management processes support in the freight transport companies (Figure 2b), the average assessment was 2.60, which is much lower than the level of knowledge about particular solutions. Moreover, there are more discrepancies in the assessments of the levels of advancement in the implementation of the ITS applications, with 7 applications assessed at minimum 3 points affirming much as incomplete implementation and 3 applications with much lower assessments, namely, AppM.2 (Control of Urban Traffic application) (1.21), AppM.7 (Fleet Documents Management application) (1.26), and AppM.3 (Automatic Incident Detection application) (1.33).

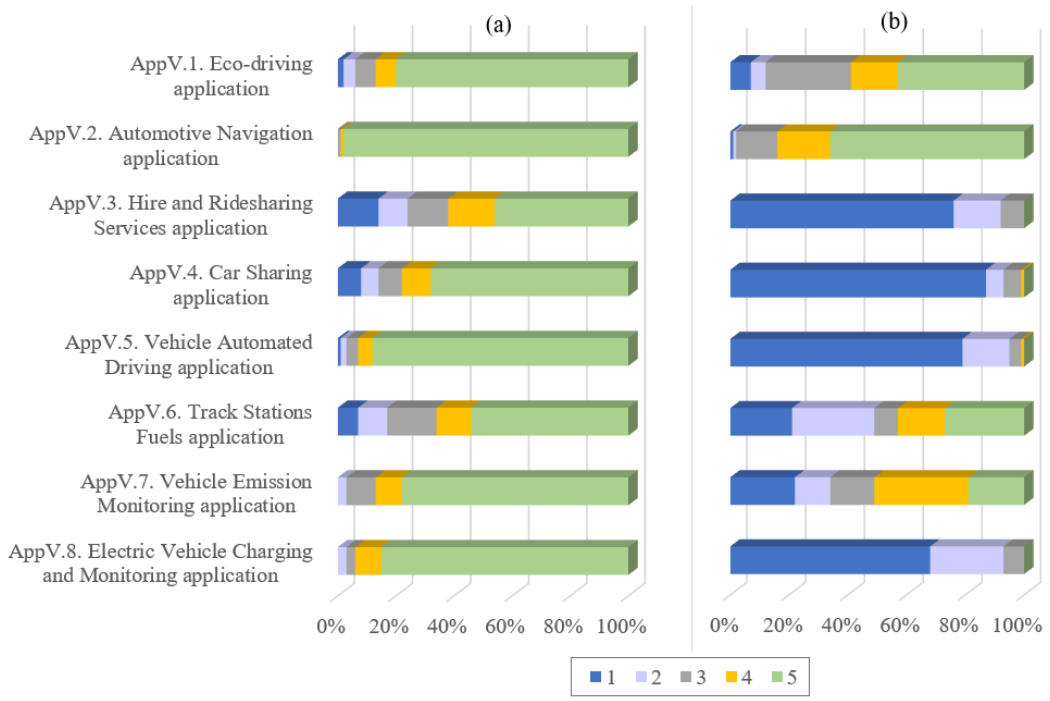

Fig. 3. ITS applications for vehicle use assistance in the freight transport enterprises: (a) level of knowledge, (b) level of advancement in implementation.

The level of knowledge on the ITS applications for vehicle use assistance (AppV.y) indicated by the respondents is shown in Figure 3a. In this examination, the results obtained clarify the average assessment at 4.41 level, which, within a 1-5 scale, suggests significantly apparent awareness of proposed information and communication technology solutions. A moderate spread of convergent results is also characteristic, confirming the prevalence of selected ITS applications with the dominance of AppV.2 (Automotive Navigation application) at a 4.94 average grade.

The level of advancement in the implementation of ITS applications dedicated to vehicle use support is shown in Figure 3b and presents a decrease with an average of 2.45. Among these 8 ITS applications, only 4 obtained a minimum of 3 points, which confirms at least partial implementation. The lowest in implementation was AppV.4 (Car Sharing application) (1.21), AppV.5 (Vehicles Automated Driving application) (1.24), AppV.3 (Hire and Ridesharing Services application) (1.32), and AppV.8 (Electric Vehicle Charging and Monitoring application) (1.39), which also validates the inceptive phase of the expansion of ITS applications in the freight transport market.

5.2. Stage 2

Based on the findings of research of previous Stage 1, an average level of advancement in the implementation of ITS applications, which resulted in a minimum of 3 points within a 1-5 scale, served as a criterion for the qualification of the particular IT solution for further examination. Only 7 ITS applications for management processes support (i.e. AppM.1, AppM.4, AppM.5, AppM.6, AppM.8, AppM.9, and AppM.10) and 4 ITS applications for vehicle use assistance in the freight transport enterprises (i.e. AppV.1, AppV.2, AppV.6, and AppV.7) received minimum 3 points, so they were considered as recognised by the freight transport managers and minimum partially performed within their companies' activities. Finally, the survey of Stage 2 involved 1-5 scale Likert-based construct items referred to 11 ITS applications of both types, 7 green logistics practices, and 4 categories of customer service performance in freight transport enterprises, as presented in Table 3. This questionnaire was distributed to 460 enterprises from V4 countries, and in Stage 1, it confirmed the average level of advancement in the implementation of ITS applications with a minimum of 3 points.

Table 3. List of measurement items.

Variables	Items' acronyms	Constructs
ITS applications for management process assistance [3, 4]	**AppM.1**	The Fleets and Logistics Management application is used to increase the cohesiveness of transport processes' accomplishment.
	AppM.4	The Traffic Data Management application is used to monitor the accomplishment of transport processes.
	AppM.5	The mobility management application is used to increase the coordination of transport processes.
	AppM.6	The Video Surveillance application is used to increase the supervision of the accomplishment of transport processes.
	AppM.8	The Variable Message Signs application reduces the risk in transport processes' accomplishment.
	AppM.9	The Integrated Parking Guidance application is used to increase the provision of information on the accomplishment of transport processes.
	AppM.10	The Demand Control Systems (cordon pricing, congestion pricing, electronic tooling, electronic tooling with GPS, pay as you drive) application increases the control of transport processes' accomplishment.
ITS applications for vehicle use assistance [3, 4]	**AppV.1**	The Eco-driving application is used to reduce the consumption of fuel and mechanical parts of the vehicles.
	AppV.2	The Automotive Navigation application reduces transport time, improves energy efficiency, and increases connectivity.
	AppV.6	The Track Stations Fuels application is used to improve combustion efficiency and exhaust emissions of engines.
	AppV.7	The Vehicle Emission Monitoring application reduces toxic exhaust emissions from diesel vehicles.
Green logistics practices [19], [26], [32]	**GLP.1**	Practices of shortening the transport routes
	GLP.2	Practices of quantifying the environmental impact of transport processes
	GLP.3	Practices of reduction of overall hazardous emissions in transport processes
	GLP.4	Practices of avoiding areas of traffic congestion
	GLP.5	Practices of facilitating transport processes design supported by environmental analyses
	GLP.6	Practices of investing in ICT to promote environmentally friendly solutions throughout the organisation, including contractors.
	GLP.7	Practices of prioritising environmentally friendly solutions in the management strategy as the potential to provide profits.
Customer service performance [9, 10]	**CSP.1**	Measurement indicators of logistics customer service, among others, time of transport and delivery, flexibility, frequency, accuracy and reliability of transport services, conveniences of orders, complaints, availability of information, facilitation of order placement, innovativeness of transport services, environmental friendliness of transport services, sustainability of transport services.
	CSP.2	Measurement of customer satisfaction.
	CSP.3	Maintaining relationships with current customers and attracting new contacts.
	CSP.4	Offering transport services that enhance sales revenue.

According to the factor loading presented in Table 4, the estimation for all adopted measurement items exceeded 0.4, resulting in profound loads for latent factors, according to Hair et al. [17]. Simultaneously, for all the constructs, the Composite Reliability and the Average Variance Extracted values were higher than the suggested thresholds by 0.8 and 0.5 [13], signifying approval of the results for further testing.

Afterwards, a full collinearity test was assessed with variance inflation factors generated for the latent variables of the structural equation model lower than 3.3, which affirms that common method bias was not present in the input materials [39]. The imperative results of the model, as indicated in Table 5, were scrutinised. The condition of the structural equation model was evaluated after creating a collection of 6000 randomised cases with reinstatement from the obtained data sample using the bootstrap method procedure. In consecutive processes, including testing and verifying the model by using collinearity, goodness-of-fit, explanatory power, and significance of path coefficients, the effects of assessments confirmed the model's validity.

Table 4. Measurement model.

Item	Loading	p-value	Mean	Standard Deviation (SD)	Average Variance Extracted (AVE)	Composite Reliability (CR)
ITS applications for management processes assistance					0.639	0.925
AppM.1	0.806	****	3.02	1.39		
AppM.4	0.806	****	3.00	1.42		
AppM.5	0.785	****	3.05	1.41		
AppM.6	0.808	****	3.04	1.44		
AppM.8	0.776	****	3.06	1.41		
AppM.9	0.822	****	3.07	1.39		
AppM.10	0.793	****	3.08	1.40		
ITS applications for vehicle use assistance					0.626	0.870
AppV.1	0.794	****	3.01	1.41		
AppV.2	0.753	****	3.03	1.34		
AppV.6	0.767	****	3.07	1.39		
AppV.7	0.845	****	3.02	1.38		
Green logistics practices					0.590	0.910
GLP.1	0.795	****	2.96	1.31		
GLP.2	0.818	****	3.05	1.34		
GLP.3	0.738	****	2.95	1.35		
GLP.4	0.760	****	3.09	1.34		
GLP.5	0.752	****	3.02	1.35		
GLP.6	0.744	****	3.05	1.37		
GLP.7	0.761	****	2.98	1.35		
Customer service performance					0.543	0.824
CSP.1	0.741	****	3.17	1.35		
CSP.2	0.737	****	3.16	1.36		
CSP.3	0.794	****	3.14	1.30		
CSP.4	0.671	****	3.12	1.31		

**** significant value at $p < 0.001$.

Conclusively, the accomplished adjusted r2 of the latent variables for green logistics practices was 0.38 and for customer service performance 0.57, which exposes that both ITS applications for management processes support and vehicles use assistance in the freight transport enterprises considerably influence green logistics practices, which supports the hypotheses established in the conceptual model. The results of the measurements also affirmed the direct dependency between ITS applications for vehicle use assistance in freight transport enterprises and customer service performance. Simultaneously, the hypothesis that ITS applications for management processes assistance positively influence customer service performance was not supported by the results of research, which can be expounded by the supervisory commitment of ITS applications intended for the freight transport enterprises' staff principally and limited use by the customers directly. The scrutiny results also indicate that green logistics practices mediate the dependency between ITS applications dedicated to management processes support and ITS applications for vehicle use assistance and customer service performance.

Table 5. Results of the model.

Hypothesis	Impact	Dependency	B	β	p-value
H1a	Direct	ITS applications for management processes assistance → Green logistics practices	0.311	0.324	<0.001
H1b	Direct	ITS applications for vehicle use assistance → Green logistics practices	0.515	0.526	<0.001
H2a	Direct	ITS applications for management processes assistance → Customer service performance	0.001	0.001	0.983
H2b	Direct	ITS applications for vehicle use assistance → Customer service performance	0.438	0.484	<0.001
H3	Direct	Green logistics practices → Customer service performance	0.354	0.382	<0.001
	Indirect	ITS applications for management processes assistance → Customer service performance	0.110	0.124	<0.001
	Indirect	ITS applications for vehicle use assistance → Customer service performance	0.182	0.201	<0.001

6. Conclusion

In the presented findings of the two-stage examination, its inceptive phase sought to analyse both the level of knowledge about ITS applications and the level of advancement in their implementation in freight transport enterprises. Within management processes assistance and vehicle use support by ITS applications, the recognised average status of managers' awareness was of intermediate degree or slightly higher, respectively. The selected ITS solutions are acknowledged to some extent, but the insight is not extensive. Moreover, the comprehension assessments about individual applications are very diversified, suggesting the areas in which much may be completed. The average level of implementation of ITS applications in the freight transport sector was much lower than the determined level of knowledge about the same technology solutions. Only 7 out of 10 proposed ITS applications for management processes support and only 4 out of 8 selected ITS applications for vehicle use assistance in the target companies were analysed as identified by the freight transport managers and at least partially accomplished within enterprises' activities. The reported discrepancy in the measurements may also suggest the arguments for the low implementation of particular ITS applications in Visegrad Group countries, such as cost of utility, difficulties in usage, lack of standardisation, reduced investment opportunities, not discovered potential of innovations, etc.

In the second stage of the research, the investigation explored the significance of ITS applications for these logistics activities, which aim to eliminate the negative impact on the natural environment and customer service performance in freight transport sector endeavours. In this domain, the paper submits empirical endorsement of the influence of ITS applications on green logistics practices and the achievements within the customer service area as a relevant contribution to the literature. Regardless of the authorised implicit value of published findings on various information and communication technology solutions concerning environmentally-friendly logistics businesses and their recipients' service, the literature review exposes that few examinations have been completed within particular facilitation of ITS applications.

Another contribution of the research is that selected ITS applications positively affect green logistics activities, which can significantly impact thorough achievements within the customer service area. This implication suggests that paradigm modification seems to be anticipated regarding ITS applications as solutions to support environmentally-friendly logistics practices considered in alternate interconnections terms instead of a facilitator only or an obstacle.

Supplementary to the abovementioned effects, managerial implications also appeared in the study. Foremost, the choice of ITS applications with the purpose of encouragement arrangement to both management processes and vehicle use assistance seems to stimulate green logistics practices in terms of customers' performance, which for the freight transport enterprises may be a prompt for the new forms of potential enhancement of environmentally-friendly logistics practices, improving market reputation, and further, sectorial parity in the competitiveness of enterprises. The research results may also postulate proposals of innovative fields for investment in chosen ITS applications as the direction of information systems development by featuring novel advantages of their usage.

Potential implications derived from this study seem to underscore the substantiation of implementing ITS applications into management processes as benefits in enhancing overall performance within customer service areas while promoting green practices in logistics. Adopting cutting-edge technology may support the positioning of enterprises as leaders in providing a comprehensive solution to meet specific requirements, differentiating the organizations in the market by customer service improvement scaled as the business grows, and environmental contribution advancing regulatory compliance and standards.

In future works, the extent of considered ITS applications can be broadened, as well as their scope of assistance in freight transport enterprises and their number. The impact of additional green logistics practices in companies may also be explored in other sectors of business processes, as well as an in-depth analysis of the influence of ITS applications on particular green logistics practices. Moreover, further investigation opportunities may involve cross-sector resemblance concerning the achievement of selection of the sectors in which the level of advancement in the implementation of ITS applications is better assisting green logistics practices and achieving greater customer service performance.

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