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Intelligent Transportation System Applications and Logistics Resources for Logistics Customer Service in Road Freight Transport Enterprises

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Abstract: Road freight transport involves many adversities, along with the growing effect of carbon dioxide transmitted by vehicles on the natural environment, greenhouse gas emissions, or extensive energy use. Within the smart mobility concept, the acknowledged management of enterprises' relationships with customers within their service is profoundly determined by the deployment of compelling Intelligent Transportation Systems (ITSs) applications in forming united cooperation with the customers. The paper proposes selected ITS applications as an advancement of logistics customer service in road freight transport enterprises that is divided into a group of six applications which are critical within the area of vehicle support, improving the energy efficiency of transport and reducing the negative impact of transport on the natural environment, reducing transport time but increasing connectivity and comfort, as well as a group of ten different applications chosen as crucial for general management support and increasing accessibility, cohesiveness, and control in management processes in road freight transport enterprises. The study also presents the effect of ITS applications on logistics customer service as dependent on an alignment between the group of ITS applications and logistics resources of road freight transport enterprises. The model proposed in the paper was analyzed based on the survey data obtained from 164 road freight transport enterprises in Poland.

Keywords: smart mobility; smart city; logistics customer service; management; Intelligent Transportation System application; logistics resources; road freight transport enterprise

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1. Introduction

Road freight transport involves many adversities, along with the growing effect of carbon dioxide transmitted by vehicles on the natural environment, greenhouse gas emissions, extensive energy use, or contribution to climate change.

Limiting the negative effects of transport is an important goal of smart mobility in many cities' regions. The main aspects of the activities are shifting transport to the least polluting and most efficient modes of transport, the use of more sustainable transport technologies, and infrastructure, and ensuring that transport prices fully reflect the negative environmental and health impacts. The transformation toward low-carbon mobility is supported by digitalization and modern technological solutions such as Intelligent Transportation Systems (ITSs). The main benefits of using Intelligent Transportation Systems undoubtedly include [1]:

- reduction in driving times and energy consumption by 40–70%;
- reduction in exhaust emissions by 30–50%;
- reduction in costs of road fleet management;
- improving road safety, thus reducing the number of collisions and accidents by 40 to even 80%.

Regarding transport, the need for a systems approach is underlined, inter alia, through the dissemination of ITS deployments to support the transition to low-emission transport and zero-emission vehicles, respecting the central role of electrification and renewable energy sources and enabling operational efficiency improvements. In particular, it calls for the better planning of road infrastructure due to the intense expansion of freight transport vehicles on the roads.

Increased competition in the market means that customer service is often what differentiates a company, product, or service in the consumer's mind the most—it allows it to be successful on the market or is the cause of failure. In current fast-moving and technology-enabled business conditions, the urgency to stipulate that exceptional customer service is a more and more pivotal diversifier in the marketplace [2–4]. The results of the survey research conducted by [5] among 13 thousand customers in different branches signified that over 66% of the customers leave the transport service provider because of deficient quality of service. Moreover, near 90% of representatives of the companies admit, as presented in the inquiry findings by [6], that a current crucial competition area for enterprises is the level of customer service.

Under the pressure of changes in the market, road freight transport service providers also offer their customers reliable deliveries, improving the energy efficiency of transport and reducing the negative impact of transport on the natural environment, reducing transport time but increasing connectivity, comfort, cohesiveness, and control in management processes in road freight transport enterprises. As remarked by [7], "shipping and delivery are usually the primary post-purchase services that are of concern to most customers during the purchasing process". The basis of this competitive offer is a high level of logistics customer service, supported by the appropriately developed logistics resources of the company. Building a more customer-oriented approach in the logistics management of enterprises means increasing requirements referred to the level of the service offered. According to [8], in logistics, customer service "physical as well as information technology is changing the landscape of material handling and transportation protocols".

The modern environment in which road freight transport enterprises currently operate presents them with new challenges in Poland—one of the European leaders in the field of truck fleets and road freight transport. The contemporary market of road freight transport services is constantly changing, especially due to the environmental and information habitat [9]. Currently, the sector of these services is characterized by high expansion, which is identified with relatively high consumer demand. Such a situation generates the basis for the profits achieved by individual entities, which determine the further development of the transport services sector. However, their current customers' demands comprise the necessity of more responsive transport systems consecutive to the prompt customers' service [10], steadily modifying transport relations in order to more diversified models of goods delivery [11,12], including the implementation of the principles of sustainable transport development [13], the use of modern technologies allowing for environmental protection, and the management of the energy potential of transport means [14], as well as more advancements in logistics service, sustained by applications of information and communication technology.

According to the above concisely signalized practical implications, the aim of the paper is to present the results of the analysis of the effect of ITS applications on logistics customer service in road freight transport enterprises as determined by alignment with logistics resources: logistics information, logistics location, and logistics knowledge. The paper proposes selected ITS applications as an advancement of logistics customer service in road freight transport enterprises are divided into a group of six applications critical within the area of vehicle support: four applications dedicated to improving the energy efficiency of transport and reducing the negative impact of transport on the natural environment, two applications dedicated to reducing transport time but increasing connectivity and comfort, as well as a group of ten different applications chosen as crucial for general management support: six applications dedicated to controlling in transport management processes, three applications dedicated to increasing accessibility and comfort of transport, and one application dedicated to improving cohesiveness and control in transport management processes. A critical review of the extensive literature on the subject confirmed no recognition of research findings on the proposed interdependence between the explicit objectives, which signifies an identified research gap in these areas of logistics management science. As perceived by [15], logistics customer service may be classified as a multi-dimensional construct of divergent components which comprises diversified approaches and is influenced by a considerable range of variables. By sharing such an approach to the broad scope of logistics customer service, the article's goal is to present it as a construct remaining in specific relations with ITS applications, also conditioned by the above-mentioned logistics resources.

The paper is structured as follows: In Section 2, the literature review is presented, and the hypotheses are established. Next, in Section 3, the methods used in the research procedure are indicated, and, in Section 4, the results of the research are described. The discussion about the results, findings, and implications are presented in Section 5, followed by conclusions in Section 6.

2. Literature Review and Hypotheses Frame

Within the extent of road freight transport, a considerable array of technological solutions has been submitted to intensify the flow of products and information more efficiently and support enterprises' management. As particularly auspicious outcomes, the ITS applications are considered, the use of which by enterprises has been evolving. The consideration of ITS applications' increase has led to scrutiny and compound information assemblage, which assist in advantageous implications, e.g., by referring to road freight and shipment conditions, traffic events, efficient and secure route management, arrangements of infrastructure, accidents oversight, truckload supervision, mobility control, fleet management, energy efficiency management of transport means, control of negative environmental effects of transport and many others. In regards to this apparent distinction, independent systems settle their functionalities above communicating with the exterior areas and interdependent systems handle connection within ITS terminals set up within singular vehicles, domains of transport infrastructure, central ITS subsystems, etc., [16]. To organize, integrate, and regulate the transport system sufficiently, highly developed technological solutions of ITS applications transform data for conversion and progression for the purpose of transport proficiency. Undoubtedly, ITS applications' aptitude for advancement is an essential goal in the management processes and for extending the transportation systems of whole types.

Based on currently available solutions and implementations in road freight transport, it can be assumed that ITS will play a major role mainly in two areas, i.e., [17]:

- in agglomeration transport and mobility management;
- in inter-agglomeration and international transport—in information systems on public roads and motorways, in road toll systems, as well as in the field of interoperability.

As ITS applications encompass diversified technological innovations assigned for the field of transport, they are addressed to upholding different spheres of transport activity, and, due to this, they are categorized in distinct approaches. The only and irrevocable proposal on this subject has not been approved in literature recommendations yet; therefore, researchers of the concern assume designations that are favorable for given research purposes. Inter-domain explications are emphasized by certain functional advantages, along with the most meaningful in the context of this paper and that suggested by [18], namely vehicle management [19–22] and general management in the enterprises [23–27].

The list of ITS applications belonging to the categories of vehicle management and general management in the enterprises were selected based on the proposals by [28] and [29], which have been chosen with consideration of practices relevant for road freight transport enterprises. As presented in Figure 1, six ITS applications were selected as critical within the area of vehicle support, and ten different applications were chosen as crucial for general management support in road freight transport enterprises.

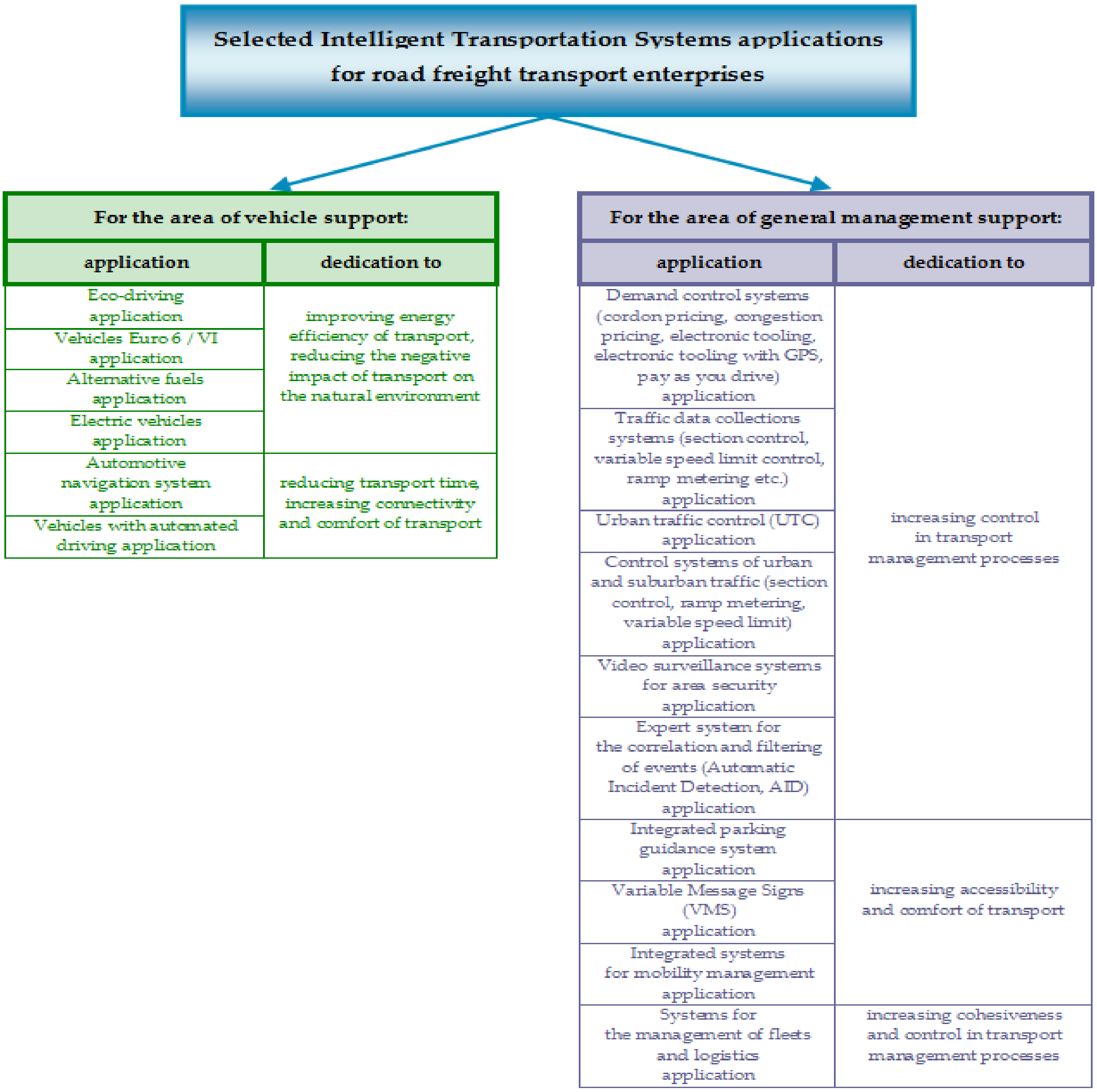


Figure 1. Selected ITS applications dedicated to vehicle support and general management in road freight transport enterprises. Source: own elaboration based on: [28,29].

Of the selected ITS applications for the area of vehicle support in road freight transport enterprises, listed in Figure 1, the first four applications are solutions dedicated to improving the energy efficiency of transport and reducing the negative impact of transport on the natural environment due to the requirements of the European sustainable transport policy. Beginning with the eco-driving application, the effects of its use should determine the essential environmental benefits by reducing the carbon dioxide produced and by reducing the consumption of fuel and the mechanical parts of the vehicle such as brakes and tires. Similarly, vehicles euro 6 application, which aims to support the reduction in toxic exhaust emissions provided by vehicles powered by petrol or diesel engines, along with hybrid cars, as they too exploit petrol or diesel engines parallel to their electrical elements. Currently, transport still depends on oil for 94% of its energy commitment, while research and technological progress has led to auspicious confirmations of effective alternative fuel solutions for all transport modes. Regarding the development of the European alternative fuels strategy, for the long-term replacement of oil as an energy source in all modes of transport, the next two applications refer to alternative fuels used in road freight transport and electric vehicles. Alternative fuels within the meaning of the European Union are fuels or energy sources that serve, at least in part, as a substitute for crude oil-based energy sources in transport and which have the potential to contribute to decarbonizing transport and improving the environmental performance of the sector. The world is facing serious energy challenges because the global energy demand will increase by over 30% by as early as 2040 [30]. Transport accounts for a third of this demand, while the number of cars on the road is expected to double over the next thirty years to two billion [31]. A serious challenge is therefore the reduction in carbon dioxide emissions to the atmosphere and the improvement of air quality, for which it is necessary, among others, to increase the role of alternative fuels concerning gasoline and diesel oil and the use of electric vehicles, which also support the mentioned applications.

The remaining two applications for the area of vehicle support in road freight transport enterprises help to reduce transport time but increase connectivity and comfort. The first one is the most popular automotive navigation system application, which allows for setting routes, monitoring vehicles in motion, managing a car fleet, reacting to emergency situations, managing traffic, and supervising the transport of goods. The second application, among the listed ones, is used in vehicles with an automated driving application, and is a much less popular solution but with a predicted growing trend in use, such as by assigning the qualification to drive (i.e., convenient monitoring and action functions) to the vehicle automation system.

Ten applications that were chosen as crucial for general management support in road freight transport enterprises are primarily oriented towards increasing the driving comfort of road freight transport, increasing accessibility, cohesiveness, and control in management processes. They take into account various areas of road transport facilities, largely related to control in the transport management processes within six applications, i.e., demand control systems, traffic data collections systems application, an urban traffic control application, control systems of an urban and suburban traffic application, video surveillance systems for the area security, and expert system for correlation and filtering of events application. The solutions covered by the applications related to the increasing accessibility and comfort of transport are assisted by three apps, such as integrated parking guidance system, variable message signs' application, and integrated systems for mobility management. A separate application also supports the management of fleets and logistics in the transport enterprises as an improvement in cohesiveness and control in transport management processes.

ITS applications belong to logistics infrastructure resources in the enterprise, as well as other information technology solutions in cooperation with various value-added services [32]. They maintain in the enterprise valued, and rare automatic systems are formed by precedent occurrences, decisions, and preferences which shape the organization in the enterprises, including its management processes. Effective implementation of these technological solutions commonly intensifies the distinction of their functions with the effect of a more compelling association with other functions in the enterprise. According to [33], information technology solutions and related value-added services are indispensable for enterprises to enhance and upgrade logistics customer service potential, which is considered in terms of both its level and capability. They may offer rare and intermutual experiences within immensely inventive services which help to build relationships with customers. As remarked by [34], information technology solutions, as part of logistics infrastructure, ensure the energy efficiency of transport and reduce the negative impact of transport on the natural environment, reducing transport time but increasing connectivity and comfort, increasing accessibility, cohesiveness, and control in management processes, which support enterprises in attaining customer satisfaction. Enterprises evolve their infrastructure assets, including ITS applications, to manage and control the environments and energy efficiency of transport modes [35], improve performance compelled by comprehending infrastructure services, among other road or rail transport, multimodal transport, and their arrangement, management, and interfaces. The results of the research presented by [36] indicate that information technology solutions may help to develop strategic conveniences for enterprises and alter competitive edges.

The review of the literature on the subject in the field of theoretical and empirical references to the use of information technology solutions in managing the area of logistics customer service for enterprises indicates that very few scientific studies have been published [37,38]. One of the representatives of this issue is the publication on the identification of digital transformations within logistics customer service [39]. The areas and level of information and communication technologies used in the management of customer-oriented logistics services in Ukrainian companies were presented in the paper, especially focused on CRM system advantages. Moreover, the most important barriers to digital growth in enterprises were indicated in six possible areas, among which the transport sphere was included.

Based on a study by [40], information technology is one of the most important factors of logistics service efficiency. As confirmed by [41], information technology in the logistics area of enterprises primarily influences logistics operations and activities' capabilities in terms of effectiveness and customer service quality, as well as supports collaboration in supply chains. The findings of [42] explained the comprehension of the success of logistics process realization through information and communication technology adaptation by the companies, which should result in their competitive advantage enhancement. Especially significant areas of information technology for the logistics due to the results of the research are among other contacts and their coordination between customers and suppliers, as well as management processes. According to the results of the study, information and communication technology helped to increase the quality of customer service in the analyzed large enterprises. Nevertheless, [43] specified that the handling of information technology in logistics enterprises may support them in attaining the internal integration of different areas, including logistics customer service.

As concluded by [44], the development of logistics in a frame of integrated technological solutions sustained by the digital information stream is, at present, providing the customers' exceptional discernibility into potent market signals, transforming most logistics areas. This alteration is obliging enterprises to reevaluate conventional perception of logistics customer service, as well as resource effectiveness. The authors of [45]'s exploration of the subject suggests an outcome to question of how expanded digitization alters logistics customer and its service segmentation, as well as the influence of customer service decisions on the enterprise's performance.

When considering ITS applications as a kind of additional benefit and as part of logistics customer service, the results of the research conducted by [46] should be pointed out. The authors' findings prove that additional services and undertakings given to main accounts are required as an option for accelerating a higher level of customer satisfaction and loyalty in comparison to the regular customer service offer.

Along with these findings, considerably significant for the objective of the paper are the conclusions of the research by [47], according to which software and technology are facilitating current customer service and outpace customers' requirements. Ref. [48] adopted middle-range theory and refined the background and schedule for the contemporary design of logistics customer service, including possibilities of technological innovations. The authors also indicated examples of different forms that expanded digitization-influenced logistics customer service. In this way, an ongoing obligation to customer orientation designates and assists the effect of impatient customer formation with expanding expectations [8]. In response, more and more enterprises choose to follow varied, innovative attitudes for serving the buyers. One of the ultimate solutions is the mobile applications used, for example, in Alibaba, with the retail involvement of the customers and with additional offers which provide visibility of genesis, past events of the goods and facilitate orders, delivery, and other transaction elements of logistics customer service [49]. Another suggestive instance is IBM and DHL's cooperation in big data use in the customers' segmentation process, combining the use of applications with the intent to anticipate analysis, as well as applications of artificial intelligence (AI) in ordering and supplies management to advance the achievements in customers' commitment [50].

Essential tips for managers of the road transport enterprises towards the use of various research operations applications, which already are, and may be in the future, adopted in the specialized software dedicated to the vehicle routing and classified for several areas of business activities, are presented by [51]. Due to the authors' recommendations, they are dedicated to performance improvement in the management of the enterprises, as well as to decreasing costs, energy use minimization, and conclusively enlarging competitive advantage. Moreover, trends and directions for the future development of the applications were suggested, where one of the indicated trends is routing with time-dependent travel time with accessible traffic information, and another important direction is data processing and the integration of customer service quality. Moreover, [52] scrutinized operations research applications, supporting the management processes of road freight transport companies including intermodal transport activity, truck-loads issues, rail, air, and oceanic transport. According to [37], ITS applications are imperative for the operations of logistics sector enterprises, with an aptitude to escalate the effectiveness inwardly and outwardly. Nevertheless, their possibilities for achievement of meaningful competitive advantage of the companies in a supportive manner [52], as feasible assets due to suggestions of resource-based view theory principles, their ambiguous effect can be considerable.

Within the area of city logistics, current improvements, realized through the ITS applications, are the field of research, among others, of [19,53,54]. Moreover, [55] presents ITS as an advancement especially crucial for the components' series of city logistics such as the vehicle–infrastructure–pedestrian environment. Particular possibilities for the support of intelligent road infrastructure in urban city logistics were under consideration in the research of [56]. In reference to selected ITS applications' use in various areas of city logistics, [57] determined the conditioning of the effectiveness of an application of the exact route optimization for the evaluation of a city logistics truck ban. Ref. [58] proposed a data-mining and optimization-based methodology for a real-time mobile intelligent routing system for the city logistics. The application of simulated annealing was analyzed by [59], regarding the routing problems in city logistics.

Based on the above prior arguments' considerations related to ITS applications and logistics customer service in enterprises' management, the influence of both ITS applications dedicated to a vehicle and general management support in road freight transport enterprises on logistics customer service is hypothesized below:

Hypothesis 1 (H1). *The use of ITS applications dedicated to vehicle support in road freight transport enterprises: improving the energy efficiency of transport and reducing the negative impact of transport on the natural environment (four applications), reducing transport time but increasing connectivity and comfort (two applications), leads to higher levels of logistics customer service.*

Hypothesis 2 (H2). *The use of ITS applications dedicated to general management in road freight transport enterprises: controlling the transport management processes (six applications), increasing accessibility and comfort of transport (three applications), and improving cohesiveness and control in transport management processes (one application), lead to higher levels of logistics customer service.*

Hypothesis 3a (H3a). *Logistics information positively moderates the positive effect of the use of ITS applications dedicated to vehicle support in road freight transport enterprises: improving the energy efficiency of transport and reducing the negative impact of transport on the natural environment (four applications), reducing transport time but increasing connectivity and comfort (two applications), on logistics customer service.*

Hypothesis 3b (H3b). *Logistics information positively moderates the positive effect of the use of ITS applications dedicated to general management in road freight transport enterprises: controlling the transport management processes (six applications), increasing accessibility and comfort of transport (three applications), improving cohesiveness and control in transport management processes (one application), on logistics customer service.*

Hypothesis 4a (H4a). *Logistics location positively moderates the positive effect of the use of ITS applications dedicated to vehicle support in road freight transport enterprises: improving the energy efficiency of transport and reducing the negative impact of transport on the natural environment (four applications), reducing transport time but increasing connectivity and comfort (two applications), on logistics customer service.*

Hypothesis 4b (H4b). *Logistics location positively moderates the positive effect of the use of ITS applications dedicated to general management in road freight transport enterprises: controlling the transport management processes (six applications), increasing accessibility and comfort of transport (three applications), and improving cohesiveness and control in transport management processes (one application) on logistics customer service.*

Hypothesis 5a (H5a). *Logistics knowledge positively moderates the positive effect of the use of ITS applications dedicated to vehicle support in road freight transport enterprises: improving the energy efficiency of transport and reducing the negative impact of transport on the natural environment (four applications), reducing transport time but increasing connectivity and comfort (two applications), on logistics customer service.*

Hypothesis 5b (H5b). *Logistics knowledge positively moderates the positive effect of the use of ITS applications dedicated to general management in road freight transport enterprises: controlling the transport management processes (six applications), increasing accessibility and comfort of transport (three applications), and improving cohesiveness and control in transport management processes (one application) on logistics customer service.*

3. Materials and Methods

In Section 3, the materials and methods used in the research procedure are presented. In Section 3.1, the conceptual model is proposed. Next, in Section 3.2, crucial information about sample and data collection is introduced. In the last section, Section 3.3, the description of the measures and research procedure is provided.

3.1. Conceptual Model

Figure 2 presents the conceptual model proposed, as supported by quintessential literature cited and discussed in previous Section 2. In the suggested model, both types of ITS applications dedicated to vehicle support and general management support in road freight transport enterprises have a positive effect on logistics customer service. Simultaneously, the effectiveness of both types of ITS applications is determined by logistics resources with reference to logistics information, logistics location, and logistics knowledge. In contrast, in the control function of logistics customer service, the categories of the area of enterprise's activity, size of enterprise, and enterprise's age are proposed.

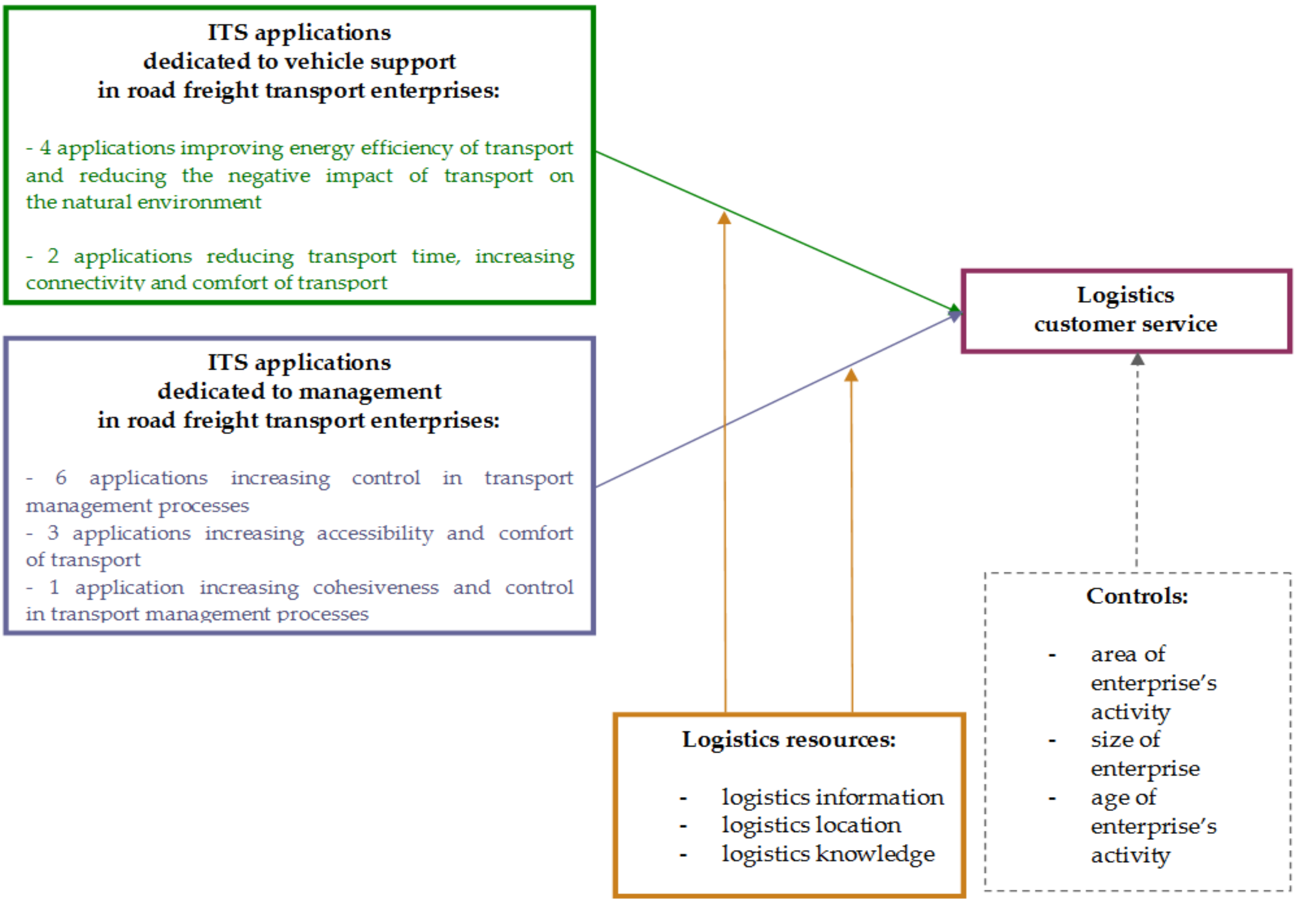


Figure 2. Conceptual model. Source: own elaboration.

3.2. Sample and Data Collection

The main aim of the research was to determine the effect of selected ITS applications dedicated to vehicle support and general management support in road freight transport enterprises on logistics customer service as determined by alignment with logistics resources: logistics information, logistics location, and logistics knowledge. The paper proposes selected ITS applications as an advancement of logistics customer service in road freight transport enterprises divided into a group of six applications critical within the area of vehicle support: 4 applications dedicated to improving the energy efficiency of transport and reducing the negative impact of transport on the natural environment (eco-driving application, vehicles euro 6 application, alternative fuels application and electric vehicles application), 2 applications dedicated to reducing transport time but increasing connectivity and comfort (automotive navigation system application and vehicles with an automated driving application), as well as a group of ten different applications chosen as crucial for general management support: 6 applications dedicated to control in transport management processes (demand control systems application, traffic data collections systems application, urban traffic control application, control systems of urban and suburban traffic application, video surveillance systems for the area security application and expert system for correlation and filtering of events application), 3 applications dedicated to increasing accessibility and comfort of transport (integrated parking guidance system application, variable message signs application, and integrated systems for mobility management application), and 1 application dedicated to improvement in cohesiveness and control in transport management processes (systems for the management of fleets and logistics application).

The data from road freight transport enterprises from the southern region of Poland were obtained using the key informant technique [60–62]. The target group of research participants was the managerial staff of the enterprises, and was supposed to have the widest knowledge about enterprises' activities as considered from the perspective of the issues included in the research aim. Within the focus group, the interview was conducted, which identified the managers of the enterprises, directors, presidents, and IT managers as the most competent in the review of the logistics customer service area, the influence of ITS applications, and the state of companies' logistics resources.

An inquiry form was prepared in regards to the literature studies. Three months (September–November 2020) focused on Computer-Assisted Telephone Interviewing (CATI) with 267 representatives of the road freight transport companies. Among all the data collected, information from 103 questionnaires was not complete or correct and was not included in the research sample. Finally, 164 interviews with representatives of business entities provided basic research information.

The crucial component of the questionnaire was designed to obtain information about all the variables of the model, and it was separated into six parts: ITS applications dedicated to vehicle support in road freight transport enterprises, ITS applications dedicated to general management in road freight transport enterprises, logistics information, logistics location, logistics knowledge and logistics customer service (Appendix A). Moreover, the inquiry form involved the questions about the fundamental attributes of the business entities, which answers the results presented in Table 1.

Table 1. Fundamental attributes of the responding enterprises.

Attribute	Response	Share
Position	Chief Executive	7.9%
	Director	22%
	Manager	57.9%
	IT Manager	12.2%
Size of the company	Large (250 or more employees and net revenues of more than 50 million Euros)	6.1%
	Medium (50–249 employees and net revenues less than or equal to 50 million Euros)	18.9%
	Small (10–49 employees and net revenues less than or equal to 10 million Euros)	75%
Predominant business profile	Transportation	67.1%
	Shipping	28%
	Third-party logistics	4.9%
Region of business activity	Domestic	6.8%
	International	73.2%
Age of business activity	Less than 3 years	17.1%
	3–8 years	56.1%
	9–19 years	23.2%
	20 years or more	3.6%
Progress in using ITS applications	Advanced	10.4%
	Intermediate	79.9%
	Beginner	9.7%

Source: own elaboration; compare with [29].

3.3. Measures and Procedure

The measures engaged for the research are, for the most part, an adaptation of the items indicated in the literature on the subject. In some cases, where no proposals were found in the literature, the items pointed out during the focus group discussion were adopted, which was conducted with seven managers of road freight transport enterprises, including two managers of small enterprises, three managers of medium-sized enterprises, and two managers of large enterprises. For all measures approved for evaluation, a seven-point Likert scale was used, where 1 means "I completely disagree" and 7 means "I completely agree".

After determining all the necessary measures, a pilot study was carried out to verify the correctness of the assumed research procedure and to eliminate defects in the area of accepted items. As a result of the trial test results, two items were slightly modified. The final version of the measures adopted for the basic tests is presented in Appendix A, and their essential provenances are shown in Section 4.

Based on a comprehensive literature review, the possibilities of measurement of both ITS applications for vehicle support and general management support indicated a lack of references for road freight transport enterprises. For this reason, the items proposed by [28] and confirmed by the focus group in the discussion as crucial for the analyzed category were adapted. ITS applications dedicated to vehicle support in road freight transport enterprises were measured by using 4 items named ITSAVS1–ITSAVS3 (as the abbreviation for Intelligent Transportation System applications for vehicle support, numbered from 1 to 3) referred to enterprises' positive experience with the use of selected ITS applications, and ITSAVS4 (as the abbreviation for Intelligent Transportation System application for vehicle support, number 4) referred to the enterprises' increase in the scope of ITS applications dedicated to vehicle support. The measurement elements are formulated as follows: ITSAVS1—enterprise has a positive experience with the use of automotive navigation system application; ITSAVS2—enterprise has a positive experience with the use of vehicles with the automated driving application; ITSAVS3—enterprise has a positive experience with the use of the eco-driving application, vehicles Euro 6/VI application, alternative fuels application or electric vehicles application; ITSAVS4—the enterprise increases the scope of ITS applications dedicated to vehicle support in road freight transport enterprises.

Similarly, the measurement of ITS applications dedicated to general management in road freight transport enterprises was designed with 4 elements named ITSAGM1–ITSAGM3 (as the abbreviation for Intelligent Transportation System applications for general management, numbered from 1 to 3), which referred to enterprises' positive experience with the use of ten different ITS applications, and ITSAGM4 (as the abbreviation for Intelligent Transportation System applications for general management, number 4) referred to the enterprises' increase in the scope of ITS applications dedicated to general management in the enterprises. The items were also adopted from [28] and confirmed by the focus group in the discussion as crucial for the analyzed category. The measurements' elements are formulated as follows: ITSAGM1—enterprise has a positive experience with the use of demand control systems (cordon pricing, congestion pricing, electronic tooling, electronic tooling with GPS, pay as you drive) application; ITSAGM2—enterprise has a positive experience with the use of integrated parking guidance system application, Variable Message Signs (VMSs) application or expert system for the correlation and filtering of events (Automatic Incident Detection, or AID) application; ITSAGM3—enterprise has a positive experience with the use of integrated systems for a mobility management application, traffic data collections systems (section control, variable speed limit control, ramp metering, etc.) application, urban traffic control (UTC) application, video surveillance systems for the area and environment security application, control systems of urban and suburban traffic (section control, ramp metering, variable speed limit, activation of the emergency lane for congestion) application or systems for the management of fleets and logistics application; ITSAGM4—the enterprise increases the scope of ITS applications dedicated to general management in road freight transport enterprises.

A number of items for measuring logistics information have been mentioned by, inter alia, [8,32,33,63,64]. Three elements were selected from the set proposed by the authors for the research: LI1 (as the abbreviation for logistics information, number 1) referred to information flow and communication between employees and customers which accelerate the realization of logistics processes, LI2 (as the abbreviation for logistics information, number 2) referred to developed information technology solutions which allow completing the orders quickly and efficiently in the enterprise, and LI3 (as the abbreviation for logistics information, number 3) referred to integrated information technology system and procedures which support decisive processes management. This choice was prescribed by the focus of group discussion and a large majority of votes emphasizing the importance of these elements for road freight transport enterprises and the low significance of rejected elements.

Concerning the logistics location, items were selected based on indications presented in the literature on the subject, e.g., by [65–68]. Three measuring elements were adopted in the research procedure: LL1 (as the abbreviation for logistics location, number 1) referred to access to the enterprise's infrastructure as conveniently achievable, LL2 (as the abbreviation for logistics location, number 2) referred to access to the services offered by the enterprise as conveniently achievable, and LL3 (as the abbreviation for logistics location, number 3) referred to access to enterprise's employees, customers, and network opportunities as conveniently achievable. The items listed were approved by the selected focus group for road freight transport enterprises.

The logistics knowledge area was taken into consideration in the research and measured by using items proposed by, among others, [69–71]. Among the recommendations presented in the literature, three elements measuring logistics knowledge were selected, which were: LKI1 (as the abbreviation for logistics knowledge, number 1), which referred to knowledge about services offered by enterprises, processes developed, and their problems as easily available; LK2 (as the abbreviation for logistics knowledge, number 2) referred to knowledge about infrastructure and technology involved in services offered by the enterprise as easily available, as well as LK3 (as the abbreviation for logistics knowledge, number 3), which referred to knowledge about enterprise's customers, their requirements, and dilemmas as also easily available. The discussion of the focus group finally made it possible to select the above-mentioned items as optimal for enterprises in the surveyed industry.

Crucial for the research logistics customer service was determined in categories of possible measures by, i.e., [65,72,73]. The four dominant issues that were selected to measure this area were LCS1 (as the abbreviation for logistics customer service, number 1), which referred to the enterprise's engagement in considering the customers' requirements towards logistics service; LCS2 (as the abbreviation for logistics customer service, number 2), which referred to the enterprise's implemented policy of logistics customer service; LCS3 (as the abbreviation for logistics customer service, number 3), which referred to the enterprise's improvement of the standards of logistics customer service; and LCS4 (as the abbreviation for logistics customer service, number 4), which referred to the enterprise's increase in the level of transaction elements of logistics customer service, such as energy efficiency of transport means, environmental protection, delivery time, punctuality, reliability, flexibility and completeness of deliveries, communication, the competence of service personnel. All these items have also been recognized by the focus group as fundamental for the road freight transport enterprises' activities.

In addition, three control variables were included in the research procedure: area of the enterprise's activity, size of the enterprise, and enterprise's activity age. It was assumed that area of enterprise's activity is a dummy variable, where 1 indicates national activity and 0 indicates international activity. For the size of the enterprise's measurement, the natural logarithm was used concerning the number of enterprise employees. Similarly, for the age of the enterprise's measurement, the natural logarithm was used regarding the number of years of the enterprise's activity.

In the selected research procedure, various methods were used in several stages. In the first stage, to establish the reliability and validity of the constructs, confirmatory factor analysis was realized. Subsequently, discriminant validity assessment, common method variance assessment, and hierarchical multiple regression analysis were undertaken.

4. Results

In Section 4, the results of the research are presented. In Section 4.1, the assessment of the measurement model is introduced. Next, in Section 4.2, the common method of variance assessment is displayed. In the last section, Section 4.3, the results of hierarchical multiple regression and further analysis are indicated.

4.1. Assessment of Measurement Model

In order to estimate the reliability and validity of the constructs, a confirmatory factor analysis (CFA) was carried out in accordance with the guidelines presented, among others, by [74–76]. Taking into account the proposed model, an acceptable fit of the data was obtained (Table 2), with X^2 (173) = 192.75, RMESA = 0.025, NFI = 0.93, CFI = 0.98, SRMR = 0.046. According to the data presented in Table 2, the values of Cronbach's alpha and composite reliabilities reached a level higher than suggested by 0.70, among others, by [76]. For all the elements of the measurement model, the factor loadings were higher than 0.7, assuming they were significant if $p < 0.01$. Moreover, [76] indicated that the suggested value of average variance extracted should be above 0.5, and the obtained results of AVE for all the constructs met this condition and, according to Table 2, were in the range 0.622–0.797. Therefore, the correct convergent validity was obtained.

Table 2. Measurement model.

Element	Loading	T-Value *	Average Variance Extracted (AVE)	Composite Reliability (C.R.)	Cronbach's Alpha
FITS applications dedicated to vehicle support in road freight transport enterprises					
ITSAVS1	0.91	14.43	0.792	0.928	0.927
ITSAVS2	0.87	13.34			
ITSAVS3	0.92	14.57			
ITSAVS4	0.80	11.76			
ITS applications dedicated to general management in road freight transport enterprises					
ITSAGM1	0.82	11.57	0.665	0.877	0.878
ITSAGM2	0.78	10.95			
ITSAGM3	0.81	11.27			
ITSAGM4	0.80	11.20			
Logistics information					
LI1	0.88	13.50	0.797	0.911	0.912
LI2	0.87	13.31			
LI3	0.87	13.27			
Logistics location					
LL1	0.85	12.25	0.726	0.877	0.879
LL2	0.86	12.35			
LL3	0.81	11.60			
Logistics knowledge					
LK1	0.79	10.26	0.622	0.821	0.821
LK2	0.75	9.69			
LK3	0.79	10.28			
Logistics customer service					
LCS1	0.70	9.28	0.646	0.869	0.867
LCS2	0.84	11.87			
LCS3	0.87	12.65			
LCS4	0.74	10.03			

* Elements' loadings are significant at the $p < 0.01$ level.

Proceeding to discriminant validity assessment, following the indications of the subject literature [76], the square roots of average variance extracted for all the constructs were analyzed in comparison to the correlations between the principal construct with the other constructs. A summary of this data is presented in Table 3, indicating sufficient discriminant validity. Square roots of variance extracted are presented in bold on the diagonal of a matrix. Due to the classic composition of the data in the matrix, the diagonal inter-construct correlations are indicated below. Above the diagonal, the results of the correlations were modified in reference to the common method variance (MV) marker test.

Table 3. Correlations.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	MV
ITS applications dedicated to vehicle support in road freight transport enterprises (C1)	**0.890**	0.550 *	0.277 *	0.107	0.226 *	0.440 *	0.046	0.205 *	−0.027	−0.060
ITS applications dedicated to general management in road freight transport enterprises (C2)	0.555 *	**0.814**	0.227 *	0.133	0.213 *	0.411 *	−0.071	0.055	−0.041	0.000
Logistics information (C3)	0.283 *	0.235 *	**0.891**	0.229 *	0.277 *	0.147	−0.131	−0.213 *	−0.219 *	−0.113
Logistics location (C4)	0.117	0.141	0.236 *	**0.852**	0.353 *	0.111	0.060	0.070	−0.073	0.047
Logistics knowledge (C5)	0.233 *	0.220 *	0.285 *	0.360 *	**0.788**	0.179 *	0.078	0.056	−0.150	−0.045
Logistics customer service (C6)	0.045 *	0.416 *	0.155	0.120	0.186*	**0.804**	−0.019	0.090	−0.023	−0.011
Area of enterprise’s activity (C7)	0.056	−0.060	−0.120	0.069	0.087	−0.009	**n.a.**	0.111	0.095	0.154
Size of enterprise (C8)	0.212 *	0.065	−0.200 *	0.070	0.066	0.107	0.121	**n.a.**	0.390	0.131
Age of enterprise’s activity (C9)	−0.018	−0.031	−0.207 *	−0.062	−0.140	−0.014	0.104	0.396	**n.a.**	0.052
Method variable (MV)	−0.040	0.010	−0.102	0.056	−0.035	−0.001	0.161	0140	0.061	**0.882**

* $p < 0.05$ (two-tailed); n.a.—not applicable.

4.2. Common Method Variance Assessment

Considering the literature guidelines [77] regarding the correct use of common method variance, the procedure of proceeding steps was applied. In the initial step, Harman's single factor test was used, which resulted in the data that indicated that no one factor regarded a range higher than 30% of the covariance. Then, following the recommendations of [78], the absence of extremely high correlations was found. In the next step, following the guidelines of [79], the method variance marker test was realized in order to estimate the latent common method bias. A three-item variable was used to assess the respondents' beneficial affection to be accepted as a method variance marker due to [80]. By the adaptation of the lowest correlation of positive range between the method variable marker and the rest of the variables, the results (Table 3) indicated that none of the considered correlations were non-significant after modification. The consequence of this result was the ascertainment that the obtained data was not excessively affected by common method variance. Afterwards, using the method variable marker, the confirmatory factor analysis marker test was determined, and five models were constituted, with the results being presented in Table 4. There were no considerable discrepancies between the basic model and method C model. According to [81], obtained results indicated that common method bias was not critically involved in the data regulation.

Table 4. Model comparison tests.

Model	**Chi-Square (X^2)**	**Goodness of Fit Values (df)**	**Model Comparison Tests (NFI)**
Confirmatory Factor Analysis (CFA)	259.28	230	0.93
Basic Model	262.18	241	0.93
Method-C	261.94	240	0.93
Method-U	241.49	220	0.93
Method-R	330.95	252	0.91
X^2 model comparison testes			
Δ Models	ΔX^2	Δdf	X^2 (critical value at 0.05)
Basic Model/Method-C	0.21	1	3.82
Method-C/Method-U	19.43	19	30.39
Method-C/Method-R	68.00 *	12	21.66

* significant value at 0.05.

4.3. Results of Hierarchical Multiple Regression and Further Analysis

The models shown in Table 4 in the next step of the research procedure following the indications of, inter alia, [82], were tested in reference to hierarchical multiple regression analysis, the results of which are presented in Table 5. The first Kolmogorov–Smirnov test was realized, which resulted in data which confirmed the residuals' normality. Then, the test of White and the test of Breush–Pagan were accomplished, and obtained results indicated the residuals' homoscedasticity. The implication of the variance inflation factor excluded multicollinearity to have a negative influence on the regression data. Moreover, the Ramsey Reset test was realized, and obtained data proved that excluded variable bias was not excessively influencing the hypotheses averaging.

According to the hypothesis testing results presented in Table 6, most of the relationships included in the model were confirmed: six hypotheses were confirmed as significant at 0.05 level, while two path coefficients were not considerable enough to support the relationships.

Due to the data presented in Table 5, in Model B, the coefficients of ITS applications dedicated to vehicle support in road freight transport enterprises ($\beta = 0.258$, $p < 0.01$) and ITS applications dedicated to general management in road freight transport enterprises ($\beta = 0.244$, $p < 0.01$) signified that both groups of ITS applications have a positive impact on logistics customer service. The results contributed to the confirmation of the H1 and H2 hypotheses. Moreover, this impedance is held by $\Delta R^2 = 0.215$, which suggests that ITS applications dedicated to both vehicle support and general management in road freight transport enterprises clarify 21.5% of the variance in logistics customer service. Moreover, the effect size estimation also supported the above results, as ITS applications are dedicated to vehicle support in road freight transport enterprises (f^2 = 0.220) and ITS applications are dedicated to general management in road freight transport enterprises' (f^2 = 0.201) implicitly influenced logistics customer service.

Table 5. Results of hierarchical multiple regression.

Dependent Variable	**Logistics Customer Service**					
Model	**A**	**B**	**C**	**D**	**E**	**F**
Controls						
Intercept	4.956 **	2.504 **	2.202 **	2.246 **	2.601 **	2.338 **
Area of enterprise's activity	−0.046	−0.035	−0.055	−0.047	0.023	−0.082
Size of enterprise	0.107	0.026	0.019	0.006	−0.018	0.013
Age of enterprise's activity	−0.100	−0.018	−0.001	−0.011	−0.041	−0.035
Effects						
ITS applications dedicated to vehicle support in road freight transport enterprises (ITSV)		0.258 **	0.252 **	0.231 **	0.259 **	0.306 **
ITS applications dedicated to general management in road freight transport enterprises (ITSM)		0.244 **	0.221 **	0.220 **	0.183 **	0.208 *
Moderators						
Logistics information (LOGI)			−0.002	−0.004	−0.025	−0.039
Logistics location (LOGL)			0.027	0.010	0.017	0.010
Logistics knowledge (LOGK)			0.041	0.085	0.079	0.080
Moderating effects						
ITSV * LOGI				−0.147 **		
ITSM * LOGI				0.031		
ITSV * LOGL					−0.117 **	
ITSM * LOGL					−0.086 *	
ITSV * LOGK						0.026
ITSM * LOGK						−0.211 **
R^2	0.015	0.231	0.236	0.303	0.366	0.288
F	0.780	10.150 **	6.283 **	6.612 **	9.240 **	6.560 **
ΔR^2		0.215	0.004	0.055	0.121	0.041
ΔF		23.581 **	0.320	6.252 **	16.177 **	5.715 **
VIFmax	1.186	1.535	1.646	1.660	1.710	1.907
K-S test	0.054 (p = 0.07)	0.040 (p = 0.020)	0.025 (p = 0.020)	0.050 (p = 0.020)	0.041 (p = 0.20)	0.051 (p = 0.20)
Breusch–Pagan test	0.00 (p = 0.85)	1.00 (p = 0.20)	0.33 (p = 0.50)	0.05 (p = 0.70)	0.10 (p = 0.63)	0.68 (p = 0.40)
White test	4.15 (p = 0.73)	18.08 (p = 0.43)	37.26 (p = 0.70)	52.32 (p = 0.55)	48.60 (p = 0.75)	53.00 (p = 0.64)
Ramsey Reset test	0.17 (p = 0.80)	0.01 (p = 0.87)	0.77 (p = 0.34)	0.01 (p = 1.00)	0.46 (p = 0.60)	0.34 (p = 0.77)

* significant value at 0.05; ** significant value at 0.01.

Table 6. Results of hypotheses testing.

Hypotheses	**Results**
Hypothesis 1 (H1). *The use of ITS applications dedicated to vehicle support in road freight transport enterprises: improving the energy efficiency of transport and reducing the negative impact of transport on the natural environment (4 applications), reducing transport time but increasing connectivity and comfort (2 applications), lead to higher levels of logistics customer service.*	Supported
Hypothesis 2 (H2). *The use of ITS applications dedicated to general management in road freight transport enterprises: controlling the transport management processes (6 applications), increasing accessibility and comfort of transport (3 applications), improving cohesiveness and control in transport management processes (1 application), lead to higher levels of logistics customer service.*	Supported
Hypothesis 3a (H3a). *Logistics information positively moderates the positive effect of the use of ITS applications dedicated to vehicle support in road freight transport enterprises: improving the energy efficiency of transport and reducing the negative impact of transport on the natural environment (4 applications), reducing transport time but increasing connectivity and comfort (2 applications), on logistics customer service.*	Supported

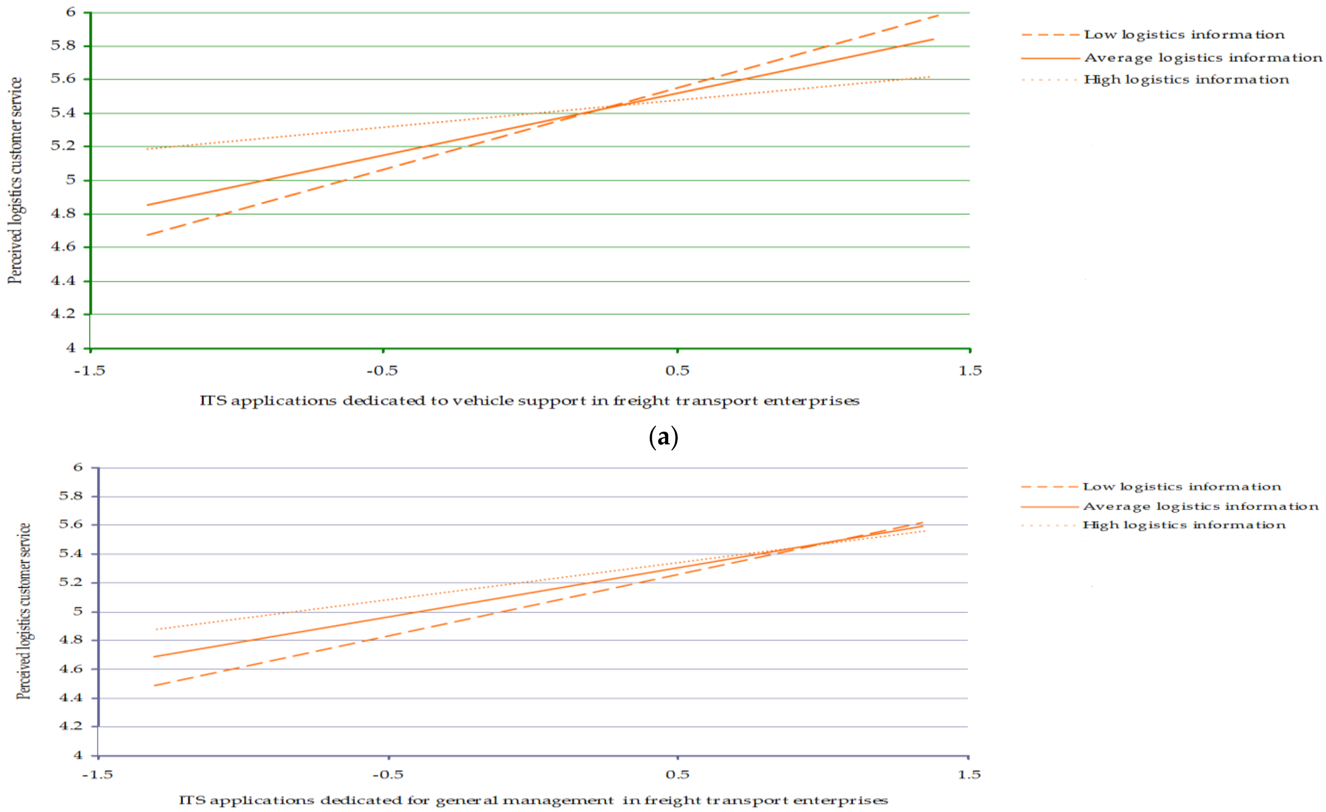
Table 6. *Cont.*

Hypotheses	Results
Hypothesis 3b (H3b). *Logistics information positively moderates the positive effect of the use of ITS applications dedicated to general management in road freight transport enterprises: controlling the transport management processes (6 applications), increasing accessibility and comfort of transport (3 applications), improving cohesiveness and control in transport management processes (1 application), on logistics customer service.*	Rejected
Hypothesis 4a (H4a). *Logistics location positively moderates the positive effect of the use of ITS applications dedicated to vehicle support in road freight transport enterprises: improving the energy efficiency of transport and reducing the negative impact of transport on the natural environment (4 applications), reducing transport time but increasing connectivity and comfort (2 applications), on logistics customer service.*	Supported
Hypothesis 4b (H4b). *Logistics location positively moderates the positive effect of the use of ITS applications dedicated to general management in road freight transport enterprises: controlling the transport management processes (6 applications), increasing accessibility and comfort of transport (3 applications), improving cohesiveness and control in transport management processes (1 application), on logistics customer service.*	Supported
Hypothesis 5a (H5a). *Logistics knowledge positively moderates the positive effect of the use of ITS applications dedicated to vehicle support in road freight transport enterprises: improving the energy efficiency of transport and reducing the negative impact of transport on the natural environment (4 applications), reducing transport time but increasing connectivity and comfort (2 applications), on logistics customer service.*	Rejected
Hypothesis 5b (H5b). *Logistics knowledge positively moderates the positive effect of the use of ITS applications dedicated to general management in road freight transport enterprises: controlling the transport management processes (6 applications), increasing accessibility and comfort of transport (3 applications), improving cohesiveness and control in transport management processes (1 application), on logistics customer service.*	Supported

With reference to the moderating effect of logistics resources, the logistics information and logistics location were recognized as moderating a positive effect of ITS applications dedicated to vehicle support in road freight transport enterprises on logistics customer service. The considerable values of coefficients for relationships were, in Model D, between ITS applications dedicated to vehicle support in road freight transport enterprises and logistics information ($\beta = -0.147$, $p < 0.01$) and, in Model E, between ITS applications dedicated to vehicle support in road freight transport enterprises and logistics location ($\beta = -0.117$, $p < 0.01$). The obtained results were a confirmation of hypotheses H3a and H4a. The next relationship analyzed in the research procedure within Model F was between ITS applications dedicated to vehicle support in road freight transport enterprises and logistics knowledge. Due to the obtained results, this dependency was not significant ($\beta = 0.026$, n.s.) and provided information about hypothesis H5a as not confirmed. Moreover, the effect size estimation supported the above results. Limited effect ($f^2 = 0.066$) was recognized in reference to logistics information which moderated the interrelation between ITS applications dedicated to vehicle support in road freight transport enterprises and logistics customer service. Logistics location data affirmed the average moderating effect ($f^2 = 0.164$) while, for logistics knowledge, the moderating effect ($f^2 = 0.003$) was almost unaccented.

Divergence in reference to the above results was recognized in the area of logistics location and logistics knowledge which had a conditioning impact on the effect of ITS applications dedicated to general management in road freight transport enterprises on logistics customer service. The considerable values of coefficients were in Model E for a relationship between ITS applications dedicated to general management in road freight transport enterprises and logistics location ($\beta = -0.086$, $p < 0.05$) and in Model F between ITS applications dedicated to general management in road freight transport enterprises and logistics knowledge ($\beta = -0.211$, $p < 0.01$). The obtained results were confirmed for hypotheses H4b and H5b. Nevertheless, the coefficient for the relationship between logistics information and ITS applications dedicated to general management in road freight transport enterprises in Model D was not significant ($\beta = 0.031$, n.s.) and provided information about hypothesis H3b as not confirmed. Logistics location ($f^2 = 0.135$) and logistics knowledge ($f^2 = 0.060$) had a small moderating effect on the interrelation between ITS applications dedicated to general management in road freight transport enterprises and logistics customer service, whereas logistics information had a very poor moderating influence ($f^2 = 0.009$).

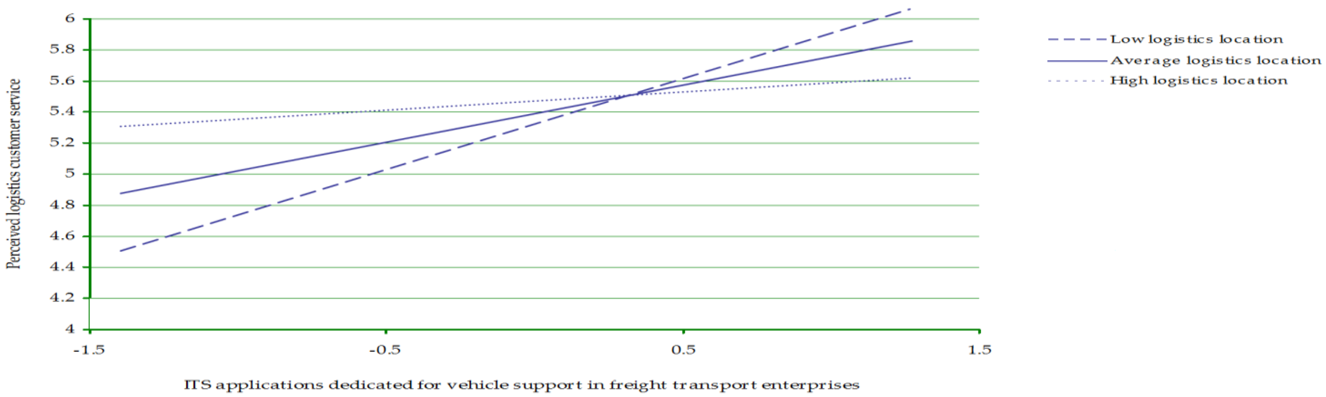
All of the obtained moderating effects are also presented in Figures 3–5, respectively featuring the effects of ITS applications dedicated to both vehicle support and general management in road freight transport enterprises on logistics customer service for the values of logistics information, logistics location, and logistics knowledge.



(**a**)

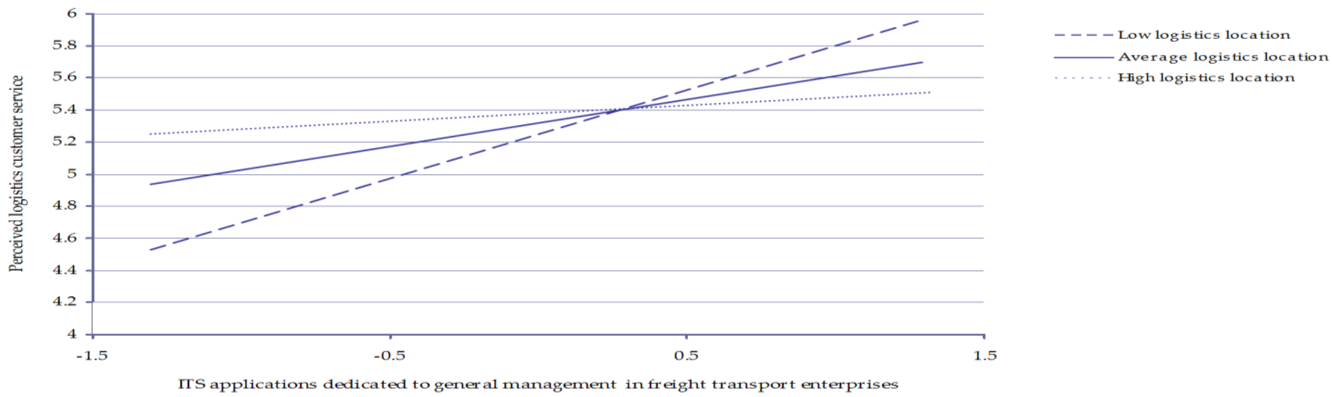
(**b**)

Figure 3. Moderating effect of logistics information for: (**a**) ITS applications dedicated to vehicle support in road freight transport enterprises, (**b**) ITS applications dedicated to general management in road freight transport enterprises.



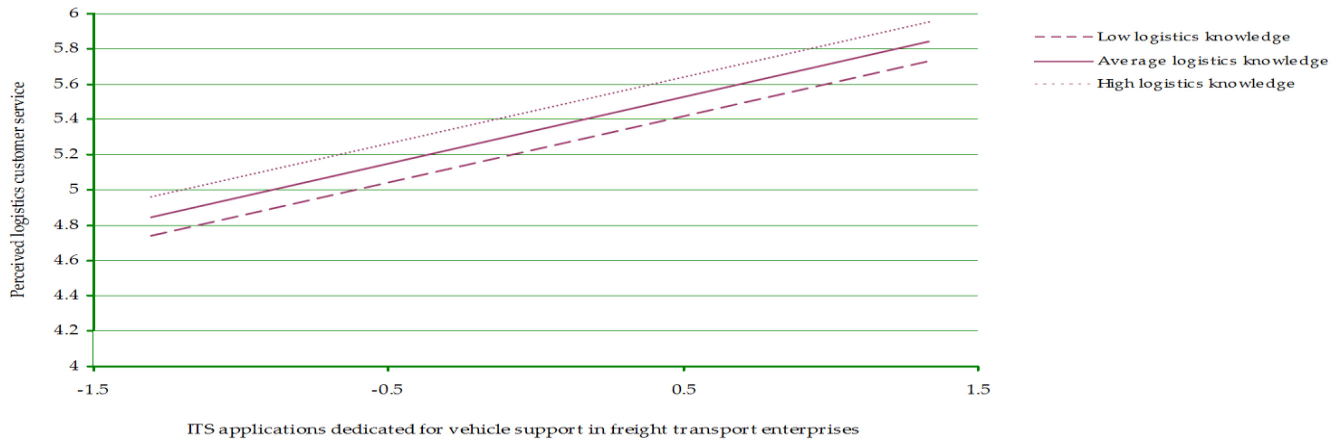
(**a**)

Figure 4. *Cont.*

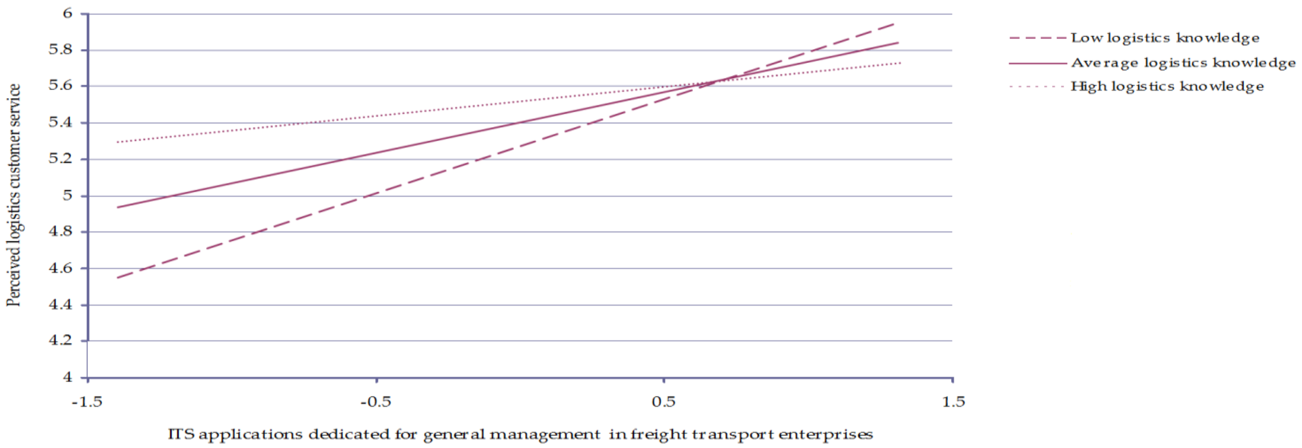


(**b**)

Figure 4. Moderating effect of logistics location for: (**a**) ITS applications dedicated to vehicle support in road freight transport enterprises, (**b**) ITS applications dedicated to general management in road freight transport enterprises.



(**a**)



(**b**)

Figure 5. Moderating effect of logistics knowledge for: (**a**) ITS applications dedicated to vehicle support in road freight transport enterprises, (**b**) ITS applications dedicated to general management in road freight transport enterprises.

5. Discussion

The main results of the conducted research, presented in the previous chapter of the paper, allow for taking subsequent considerations leading to the formulation of the conclusions.

The most important result based on the indicated estimations concerns the confirmation of strong support for the claim that both ITS applications dedicated to vehicle support and general management in road freight transport enterprises have a positive effect on logistics customer service. Although, for advanced issues of logistics customer service, references to ITS applications are very rare in the literature on the subject, by considering them as one of the information technology solutions [83], one can nevertheless find literature entries consistent with the obtained research results. Similar conclusions were presented in the works on information technologies, among others, by [8,39,40].

It has also been confirmed that both ITS applications dedicated to vehicle support and general management in road freight transport enterprises form valuable means that can contribute to the gaining of access to important information in the area of logistics customer service. Another observable area of logistics customer service, which is developing thanks to the use of ITS applications dedicated to vehicle support and general management in road freight transport enterprises, is building and maintaining relationships with customers. The authors of [49,50] presented similar results of their research on the activities of giants such as Alibaba and IBM.

Another important observation applies to both ITS applications dedicated to vehicle support and general management in road freight transport enterprises which should be arranged next to logistics resources by supporting logistics customer service more widely. Particular attention should be paid in the area of ITS applications dedicated to vehicle support in road freight transport enterprises and the inferior position of logistics location as well as the high status of logistics information as logistics resources significant in improving logistics customer service. At the same time, it was proved in the course of the research that ITS applications dedicated to general management in road freight transport enterprises can better develop logistics customer service when the logistics location of the enterprise is not highly ranked, as well as when logistics knowledge is quite level in the enterprise.

In a comprehensive view of the research results, ITS applications dedicated to vehicle support in road freight transport enterprises are comparable to ITS applications dedicated to general management in terms of alleviating logistics customer service. At the same time, ITS applications dedicated to vehicle support and general management in road freight transport enterprises may be engaged to a varying degree in enterprises with different logistics resources. For example, ITS applications dedicated to vehicle support in road freight transport enterprises are more effective in enterprises with a lower position of logistics information; however, ITS applications dedicated to general management in road freight transport enterprises are more effective in enterprises with a lower position of logistics location and logistics knowledge. Nevertheless, ITS applications dedicated to vehicle support in road freight transport enterprises are similarly relevant to ITS applications dedicated to general management in road freight transport enterprises for simplifying logistics customer service if the enterprise is of a high position of logistics information, logistics location, or logistics knowledge.

Furthermore, logistics information seemed to be an imperative moderator of the effect of ITS applications dedicated to vehicle support in road freight transport enterprises on logistics customer service, but it did not influence the interrelation between ITS applications dedicated to general management in road freight transport enterprises and logistics customer service. The findings seem to be achievable regarding two aspects of lower logistics information of the enterprises: the feasibility of accelerated implementation of the strategy as well as the diminished communication required between functional employees. Within the first attitude, the effect of ITS applications dedicated to general management in road freight transport enterprises on logistics customer service is intensified due to accelerated strategic implementation. Within the second attitude, the effect of ITS applications dedicated to general management in road freight transport enterprises on logistics customer service is reduced due to the interference of the efficient exertion of the logistics resources involved in the usage of ITS applications dedicated to general management in road freight transport enterprises. While considering the trade-off between these attitudes, the effect of ITS applications dedicated to the general management in road freight transport enterprises presents no meaningful dissimilarities between enterprises of higher and lower logistics information.

Another signal interference concerns the level of logistics knowledge which moderates the interrelation between ITS applications dedicated to general management in road freight transport enterprises and logistics customer service; however, it does not modify the effect of ITS applications dedicated to vehicle support in road freight transport enterprises on logistics customer service. Due to the strategic decision to employ ITS applications dedicated to vehicle support in road freight transport enterprises to achieve the improvement of the logistics customer service area, it should be referred to the logistics knowledge of managers of the enterprises. Respectively, the spectrum and number of ITS applications needed in the enterprise are under the responsibility of many specialists in the organization and their professional knowledge about different aspects of vehicle support preferences indicated by the employees and the customers.

The conducted research seems to make a specific contribution to the recognized state of knowledge presented in the literature. First of all, the most important area from the perspective of the research undertaken and their results is logistics customer service. Research on this logistics aspect in road freight transport enterprises is still not advanced, especially in Poland [10,84]. Particularly, while numerous studies have proposed a fundamental analysis of the logistics customer service area indicated in the literature review section, the approach of empirical data confirmation within conceptual models is not a considerable practice. Moreover, with regard to the international literature in the area of logistics customer service, relatively few works are presented by the Polish framework, especially according to empirical research results.

Moreover, the study objectives seem to become contributory to enhancing the literature on ITS applications dedicated to road freight transport enterprises. The interrelations between ITS applications and logistics customer service are a relatively rare resemblance, especially in the road freight transport companies, and the results presented are often contradictory to each other. The research of the paper determines up-to-date evidence in the logistics customer service circumstances. Moreover, the research also explores the effect of logistics resources in the context of recognizing the explanation of the discrepancies. At the same time, an approach that is different from the subject of the comprehensive procedure, most often implemented in the cited literature, was used; namely, the focus was on an inquiry involved in different groups of ITS applications and their influence on logistics customer service under divergent circumstances.

The results of the research seem to provide useful interference for road freight transport enterprises that search for support indicators in choosing possibilities of developing logistics customer service. One of the significant suggestions for road freight transport enterprises is the use of ITS applications as compensation for logistics customer service. Many road freight transport companies look for an opportunity to introduce new standards of logistics customer service, while the findings of the paper recommend ITS applications as strategic service abilities, referring to the energy efficiency of transport means, environmental protection, delivery time, punctuality, reliability, flexibility and completeness of deliveries, communication, and the competence of service personnel. The results of the research are notably significant for Polish road freight transport companies which have a deficiency in modifying their offer to the requirements of an immensely competitive market. The proposal of advanced logistics customer service enhanced by novel technological solutions that are relatively easily available seems to be an adequate response.

Another implication refers to the endorsement for road freight transport enterprises towards the conscientious estimation of which ITS applications should be designated to be applied and exploited in consideration of logistics resources. Predominantly, both ITS applications dedicated to vehicle support and general management in road freight transport enterprises are effective in the alleviation of logistics customer service; nevertheless, one group of ITS applications may be more capable according to the enterprise's logistics resources for the enterprise's customers' requirements than the other. For the enterprises with a lower level of logistics knowledge, ITS applications dedicated to general management in road freight transport should be chosen to support logistics customer service. Divergence importance is suggested for the enterprises with a lower level of logistics information, which should consider ITS applications dedicated to vehicle support in road freight transport enterprises for developing logistics customer service.

The further recommendation, which may be a relevant indication for the road freight transport enterprises, is related to how they may determine ITS applications when logistics resources are modified according to the improvement of logistics customer service. The results of the research suggest that ITS applications dedicated to general management in road freight transport are invulnerable to logistics information and that ITS applications dedicated to vehicle support in road freight transport are not. Contrariety is noticed for ITS applications dedicated to vehicle support in road freight transport enterprises as invulnerable to logistics knowledge; however, ITS applications dedicated to general management in road freight transport are not. It may imply that, if a road freight transport enterprise modifies the logistics resources and broaden logistics information, the ITS applications dedicated to general management should contribute to preserving the effectiveness, and ITS applications dedicated to vehicle support in road freight transport enterprises will be less effective. Correspondingly, if a road freight transport enterprise changes the logistics resources to become more advanced in logistics knowledge, the ITS applications dedicated to vehicle support in road freight transport enterprises should contribute to preserving the effectiveness, and ITS applications dedicated to general management will be less effective. Logistics location seems to be solely inconsistent with ITS applications referred to as logistics customer service support. If a road freight transport enterprise changes the logistics resources associated with logistics location, both ITS applications dedicated to vehicle support and general management in road freight transport enterprises may be less effective.

6. Conclusions

The development of Intelligent Transportation Systems understood as applications of information and communication technologies is increasingly reflected in the framework of smart mobility as a component of the smart city concept. There are many indications for the development and application of modern technologies as an alternative to the road freight transport sector in the form of a strategy aimed at decarbonizing transport, optimizing processes, saving resources, and the efficient use of transport means and infrastructure through the implementation of intelligent mobility systems. As part of smart mobility, one of the priorities is to increase the efficiency of the transport system through the optimal use of digital technologies. In terms of modern technologies, three main factors are to serve these goals:

- greener energy (thanks to the use of new fuels and propulsion systems);
- higher efficiency of vehicles (thanks to new engines, materials, and design);
- better use of networks and their safer and more reliable operation (thanks to information and communication systems).

The implementation of ITS applications can be recognized as a component of road freight transport management, capable of providing energy-efficient means of transport, environmental protection, delivery time, punctuality, reliability, flexibility, and completeness of deliveries for smart mobility in a sustainable outlook of the regions. The empirical research results present the efficacy of the selected ITS applications from the perspective of smart city assumptions, referred to as smart mobility development.

The presented study has explored the effects of both ITS applications dedicated to vehicle support and general management in road freight transport enterprises on the logistics customer service area. The identification and analysis of the conformation between ITS applications and logistics resources in improving logistics customer service in road freight transport enterprises were introduced. Logistics information, location, and knowledge were scrutinized in terms of the comprehension of logistics resources as customer service determinants. Compensation of the research conducted among representatives of 164 road freight transport enterprises signifies that both ITS applications dedicated to vehicle support and general management have a conclusive impact on logistics customer service; however, ITS applications should be exploited in consideration of an enterprise's logistics resources. The results conjointly maintain the traditional allegation with genesis in resource-based view theory that the leverage value of ITS applications on logistics customer service is the consequence of the ability of successful integration with other resources and capabilities within the enterprise's aptitude. The introduced conceptual model may incline management support in the context of the response assessment of ITS applications targeting the logistics customer service area and its resources' background significance.

Regardless, the study comprises several limitations which may be considered as potential directions for future research. The paper presents the analysis of the interrelation between both ITS applications dedicated to vehicle support and general management in road freight transport enterprises, logistics resources, and logistics customer service. Firstly, only three of the chosen types of logistics resources were taken into consideration in the research procedure, therefore the possible effects of logistics information, logistics location, and logistics knowledge were estimated. However, the impact of ITS applications dedicated to vehicle support and general management in road freight transport enterprises on logistics customer service may be dependent on other logistics resources. Future inquiry objectives may include the influence of these determinants and the effect of ITS applications on logistics customer service.

Another important limitation of the study refers to the scope of ITS applications, which considered only selected applications dedicated to vehicle support and general management in road freight transport enterprises. They aimed within a group of six applications critical for the area of vehicle support: improving the energy efficiency of transport and reducing the negative impact of transport on the natural environment (four applications), reducing transport time but increasing connectivity and comfort (two applications), as well as within a group of ten different applications chosen as crucial for general management support: controlling the transport management processes (six applications), increasing accessibility and comfort of transport (three applications), and improving the cohesiveness and control in transport management processes (one application). A number of different offered applications may extend the range presented in the study in regard to the areas of vehicle support and general management, but also to other significant areas assisted by ITS applications, such as the infrastructure of the road freight transport support, their policy management assistance, electromobility assistance, reducing exhaust emissions support, electric drives use, or energy use minimizing by road freight transport enterprises. Forthcoming inquiries could explore the possibilities of the differentiation of ITS applications and analyze their influence on logistics customer service.

Moreover, the paper introduces only a predicament approach to establish the ambiguous effect of ITS applications on logistics customer service. Subsequent studies may investigate other probable evidence, such as the non-linear interrelation between ITS applications and logistics customer service in circumstances of road freight transport enterprises' activities.

A further proposal for the research direction is an adverse research procedure design to the one presented in the paper, therefore, contrary to survey-based and cross-sectional research, following the conception of test casualty through the panel data examination or other methods. They may include more restraint determinants that can influence logistics customer service as well as explore the interdependent effects of ITS applications and those determinants on logistics customer service in road freight transport companies.

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Appendix A

Table A1. Measurement elements.

ITS Applications Dedicated to Vehicle Support in Road Freight Transport Enterprises	
ITSAVS1	Enterprise has a positive experience with the use of automotive navigation system application.
ITSAVS2	Enterprise has a positive experience with the use of vehicles with the automated driving application.
ITSAVS3	Enterprise has a positive experience with the use of: eco-driving application, vehicles Euro 6/VI application, alternative fuels application, or electric vehicles application.
ITSAVS4	The enterprise increases the scope of ITS applications dedicated to vehicle support in road freight transport enterprises.
ITS applications dedicated to general management in road freight transport enterprises	
ITSAGM1	Enterprise has a positive experience with the use of demand control systems (cordon pricing, congestion pricing, electronic tooling, electronic tooling with GPS, pay as you drive) application.
ITSAGM2	Enterprise has a positive experience with the use of: integrated parking guidance system application, Variable Message Signs (VMSs) application or expert system for the correlation and filtering of events (Automatic Incident Detection, AID) application.
ITSAGM3	Enterprise has a positive experience with the use of: integrated systems for a mobility management application, traffic data collections systems (section control, variable speed limit control, ramp metering, etc.) application, urban traffic control (UTC) application, video surveillance systems for the area and environment security application, control systems of urban and suburban traffic (section control, ramp metering, variable speed limit, activation of the emergency lane for congestion) application or systems for the management of fleets and logistics application.
ITSAGM4	The enterprise increases the scope of ITS applications dedicated to general management in road freight transport enterprises.
Logistics information	
LI1	Information flow and communication between employees and customers accelerate the realization of logistics processes.
LI2	The enterprise has developed information technology solutions that allow to complete the orders quickly and efficiently.
LI3	The enterprise has integrated information technology system and procedures which support decisive processes management.
Logistics location	
LL1	Access to the enterprise's infrastructure is conveniently achievable.
LL2	Access to the services offered by enterprise is conveniently achievable.
LL3	Access to enterprise's employees, customers, and network opportunities is conveniently achievable.
Logistics knowledge	
LK1	Knowledge about services offered by the enterprise, processes developed, and their problems are easily available.
LK2	Knowledge about infrastructure and technology involved in services offered by the enterprise is easily available.
LK3	Knowledge about the enterprise's customers, their requirements and dilemmas is easily available.
Logistics customer service	
LCS1	The enterprise is engaged in considering the customers' requirements towards logistics service.
LCS2	The enterprise has implemented a policy of logistics customer service.
LCS3	The enterprise improves the standards of logistics customer service.
LCS4	The enterprise increase the level of transaction elements of logistics customer service, such as: energy efficiency of transport means, environmental protection, delivery time, punctuality, reliability, flexibility and completeness of deliveries, communication, competence of service personnel.

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