Determinants of Using Telematics Systems
in Road Transport Companies

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Abstract:

Purpose: *The aim of this study is to evaluate the scope of using telematics systems based on GPS/GPRS in the road transport as well as to identify determinants of applying telematics tools to increase the quality in the supply chain.*

Design/Methodology/Approach: *The contribution is based on a review of literature, preparing of a questionnaire-based survey directed to road transport companies and estimating logit models.*

Findings: *It is submitted that there is an observable trend of extending telematics in the road transport. The following variables increase the probability of using telematics systems for punctuality checking in supply chains such as the number of employed persons, importance of telematics for getting new orders, managers' viewpoints that telematics increases the quality of order processing and forecasting punctuality of loadings as well as speeds up decision-making processes.*

Practical Implications: *Application of IT solutions including telematics in road transport is growing continuously. However, the awareness of managers about possible areas of applying them is still unsatisfactory. The paper reveals the determinants of application telematics in supply chain, which can be used to motivate and train managers to extend its scope in practice.*

Originality/Value: *The study is based on primary data from road transport companies and related to the scope of application of telematics systems in operational management. A logit model is applied to evaluate the determinants of using IT systems in the road transport industry. It may be useful for practitioners and analytics of transport industry to broaden applications of IT solutions.*

Keywords: *IT solution, digital supply chain, road transport, logit model.*

JEL codes: *L2, L9, R41, C21.*

Paper type: *Research study.*

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1. Introduction

The increasing complexity and dispersion of supply chains, as well as greater customer requirements for fast and flexible delivery, both for production processes and directly to consumers, require implementation of improvements in the field of digital information processing tools and methods. The knowledge resulting from its processing allows better orientation of the chain towards changing customer expectations and increasing the quality of service. Another important reason for the digital integration of the supply chain is the ability to quickly identify sources of inefficiency in chain link relationships and to eliminate them (Wang *et al.*, 2016; Papadonikolaki, 2020).

Modern information technologies are gaining increasing importance in supply chain management, leading primarily to the organizational integration of all its components, and as a consequence to the transformation of network structures, business processes and management components. The subject literature and economic practice emphasise the special role of digital technologies such as social media, mobile technologies, large data sets and, finally, the widespread use of the so-called 'cloud computing' (Alfouzan, 2015, Legner *et al.,* 2017).

In road transport, telematics systems based on Global Positioning System (GPS) and General Packet Radio Service (GPRS) technologies have become a significant tool that allows planning, monitoring, coordinating and optimizing the operation of motor vehicles, with particular emphasis laid on ongoing delivery and distribution processes. Telematics and data processing technologies (Mikulski, 2007) play an increasingly important role in transport control and management systems that form the basis of competitive advantages in supply chains.

The aim of present study is to evaluate the scope of using telematics systems based on GPS/GPRS in road transport as well as to identify determinants of applying telematics tools to increase quality of the supply chain. The main tool of analysis is a questionnaire directed to randomly selected road transport companies located in Poland and operating on both domestic and international scenes and being a part of many supply chains all over Europe. It is worth noting that according to Statistics, Poland 5.7% of Polish GDP value is provided by road transport services. The position of Poland's road transport taking into account its transport work is one of the biggest in Europe and is still growing. Thus, Polish companies can be approximated as representative units across the European Union.

Typically, telematics systems are used for tracking the position of a vehicle while it is on road (Bhowmik and Halder, 2016). In our study, the scope of possible applications of telematics systems is much broader. It is worth noting that to our best knowledge such type of study was not reported anywhere. Thus, the novelty of the study lies in both a set of primary data and a logit model applied to evaluate determinants of using IT systems in the road transport industry.

The remainder of the paper is organized as follows: in the next section the role of telematics in supply chain is analysed. In Section 3, data characteristics is presented and some answers to relevant questions are provided. Section 4 is related to estimation and presentation of empirical logit models describing the probability of using telematics and Transport Management System (TMS) in road transport companies. In Section 5 we conclude.

2. Telematics in Supply Chains

According to Deshpande (2012) and Singh and Teng (2016), information technology is an important element in supply chain management. Garcia-Destrugue and Lambert (2003) claim that they affect its effectiveness and efficiency. White *et al*. (2005) indicate that modern information technologies and especially their integration between entities in the supply chain affect their better cooperation and more efficient coordination of material and information resources flows. Technologies using telematics solutions based on GPS and GPRS are particularly important in the supply chain that uses road transport. According to Giannopoulos (2009) telematics systems in road transport are primarily used for its planning, coordination and control in real time on the basis of applications using information systems that process information flowing from devices.

Telematics is increasingly an element of complex integrated systems in terms of defined tasks implemented for transport. In this arrangement, they are sets or subsets of basic systems that provide complementary services necessary for the needs of users. Nowacki (2006) classifies and groups tasks of telematics systems in areas of activity such as, for instance, road monitoring infrastructure, traffic management and control, information services for travellers and road users, rolling stock and cargo management, electronic toll collection systems, accident and road rescue services and operating on-board systems in vehicles. Telematics also provides road transport with the opportunity to use technology and methods of remote access to vehicles or loads via a wireless ICT (*Information and Communications Technology*) network.

As one of the executive tools of logistics, it is used not only to support management processes, but also to improve efficiency and competitiveness on the transport market. It allows to improve transport safety, support traffic control, create and develop databases in enterprises, organizations or institutions (Farmer *et al*., 2010; Wahlstrom *et al*., 2014; Yan *et al*., 2016). By using telematics elements (ICT networks, traffic control systems, electronic vehicle and cargo location systems, electronic exchange of documents), it is possible to optimize vehicle transit routes (Cattaruzza *et al*., 2017), which significantly contributes to the reduction of freight transport time (Schuessler and Axhausen, 2009). Telematics technologies used to track vehicles and loads are of particular importance in the transport of hazardous goods and goods that are liable to high rates of excise duty (Minni, 2013). The development of telematics systems and the dissemination of their use in transport contributes to increasing the mobility of freight transport, enriching the service offer

of carriers, increasing their competitiveness, applying intermodal solutions in transport and thus to the economic activation of regions (Harris *et al.*, 2015).

In both Polish and English-language publications, it is difficult to find empirical studies describing the level of use of telematics systems in supply chains. A significant part of the publication focuses on the digitization of supply chains. Pflaum *et al.* (2020) point to the models, methods and tools that are necessary to digitize the supply chain, and analyse the technological and legal barriers to their implementation. Kolar *et al.* (2020) when analysing the Czech railway market, pose a research question about the digital chain implementation system in the context of the legal framework related to international regulations. Michel *et al.* (2017) based on a survey conducted by the Material Handling Institute (http.mhi.org) states that 80 percent of respondents believe that the digital supply chain will be the dominant business model in the next five years. The use of technologies such as predictive analysis, better visibility (transparency) of goods flows, as well as the use of robots in maintaining warehouses and distribution centres will play a fundamental role in managing the digital supply chain.

Xue *et al.* (2013) describe the digital supply chain (DSC) as inter-organizational systems (IOS) that companies implement to digitize transaction processes and collaborate with their supply chain partners (*i.e.,* suppliers and customers). Currently, companies such as Amazon, Alibaba, Lufthansa, BMW, DHL DB, or Schenker are making investments in digitization. Some of the digitized processes and tools that these companies invest in include digital mobility laboratories, electronic transport, electronic payments, robotics for handling goods, supply drones and new applications for analysing their own assets. Saenz and Cotrill (2019) raise doubts that digitization is dominated by big market players and does not have to be as widespread due to the large number of small and micro enterprises. The use of telematics in transport is the subject of an article by Minea and Surugiu (2013) presenting research performed on transport in supply chains as the most time-consuming and cost-intensive factor and the possibility of real-time analysis of events occurring in distribution processes.

3. Data Characteristics

The empirical research was projected as survey directed to road transport companies located in Poland. The survey[3] was conducted by an external research company using the CATI method. In order to obtain correct and complete survey results, the study population was defined. The surveyed units were defined in terms of material, *i.e.* enterprises performing road and territorial transport, *i.e.* representing enterprises

whose economic activity is registered in Poland. The study was conducted on a sample of companies derived from the database of members of the Association of International Road Carriers in Poland (ZMPD) and from the databases of regional associations of road carriers. Approximately 3,800 carriers performing work within the country and abroad belong to the ZMPD association, which gives grounds to state that selected entities represent the general population well. As a result, by combining the databases, the sample from which the companies were drawn was 4,500 enterprises. Finally, 3,750 enterprises came from the ZMPD database and 750 from the provincial associations' databases. Characteristics of the population and the sample are presented in Table 1.

Table 1. Characteristics of a population and a sample

Status	Numbers
Number of companies in the population	4,500
A random sample	500
Interviews from the original sample drawn but not carried out (refusal or missed call)	48
Number of respondents from the population remaining to be drawn at random	91
Number of interviews completed	500
Average interview time	20.23 min

The number of 500 respondents was dictated by the assumption as to the maximum level of estimation error not exceeding 5% for independent answers. In the study, the maximum estimation error, assuming standard normal distribution, was

$d = \sqrt{\frac{z_{0,95}^2}{4 \cdot 500}} = \sqrt{\frac{1.96^2}{4 \cdot 500}} = 0.034$, taking the confidence ratio $1 - \alpha = 0.95$. The allowable error of estimate d is 0,034, that is 3.34%, and is less than 5%, so that, with high probability, the results of the study can be applied to the general population.

Selection of transport companies located in Poland is related with important position of transport industry on the European market. The volume of transport work in the years 2012-2017 of leading countries in Europe is presented in Table 2. In 2017 volume of transport work carried out by Polish companies exceeded level of Germany, which was the leader among hauliers all over the Europe.

Table 2. The volume of transport work carried out by national and international road transport of a vehicle with GVW> 3.5 T covered by cabotage

Billion tkm						
Country/Year	2012	2013	2014	2015	2016	2017
Germany	307.0	305.7	310.1	314.8	315.8	313.1
Spain	199.2	192.6	195.8	209.4	217.0	231.1
France	172.4	171.5	165.2	153.6	155.8	167.7
Italy	124.0	127.2	117.8	116.8	112.6	119.7

Poland	222.3	247.6	250.9	260.7	290.7	335.2
United Kingdom	158.5	147.2	143.2	158.9	155.0	153.9

Source: *Based on Statistical Pocketbook 2019. EU Transports and figures. https://op.europa.eu/en/publication-detail/-/publication/f0f3e1b7-ee2b-11e9-a32c-01aa75ed71a1 (access: 2020.03.23).*

The structure of the companies surveyed is presented in Table 3.

Table 3. *The structure of the sample examined according to selected criteria*

1. Form of business activity conducted	[%]	2. Number of the employed	[%]
Entry in the business activity register	40.4	Up to 49 employees	63.8
Limited liability company	36.2	Over 50 to 249	31.2
Joint-stock company	2.8	250 employees and more	5.0
Other (limited partnerships, other)	20.6		
3. Business experience	[%]	4. Number of transport units	[%]
Over 10 years	60.6	From 1 to 9	49.4
Over 5 years to 10 years	22.8	From 10 to 19	25.0
Over 3 years to 5 years	12.4	20 to 49	6.0
Up to 3 years	4.2	50 to 100	6.0
		Over 100	3.8
5. The range of services	[%]	6. The leading direction of the service portfolio	[%]
International transport	66.2	Poland - other EU countries	57.8
The area of the whole country	23.4	Poland	33.0
Region (several neighbouring provinces)	7.1	Poland - Eastern European countries	4.8
Local (One Province)	3.3	Inside the EU - outside Poland	4.4

Having analysed the data presented in Table 3, it can be stated that the sample of 500 companies selected for the survey reflects the structure of transport companies performing domestic and international transport in accordance with the data presented in the report prepared by Polish state agency called BOTM *https://gitd.gov.pl/fileadmin/user_upload/BTMZEZWOLENIA_ZAGRANICZNE/ Dane_ statystyczne_dotyczace_transportu_miedzynarodowego_w_2019_r..pdf*.

Furthermore, the analysis of the research sample indicated that for 246 enterprises (49.2% of the sample) it was a homogeneous activity in which road transport accounted for over 80% of their revenues. In 50.8% of cases, the activity was not homogeneous, which meant that the sources of revenue were diversified. Transport activity in 91% of cases was universal transport activity and only 9% of enterprises carried out specialized transport. In 85% of cases, the companies had a license for domestic and international transport, and only in 15% of them transports were carried out due to the so-called 'own needs'. Figure 1 illustrates the structure of answers about the extent of the employment of telematics systems in the transport industry and which tasks they perform.
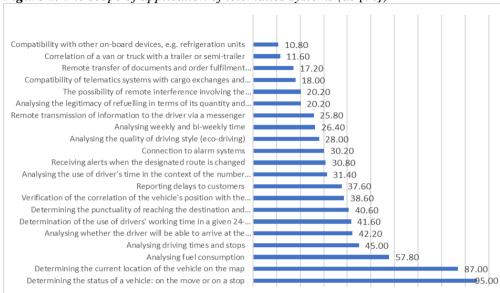
Figure 1. *The scope of application of telematics systems (as [%])*

	[%]
Compatibility with other on-board devices, e.g. refrigeration units	10.80
Correlation of a van or truck with a trailer or semi-trailer	11.60
Remote transfer of documents and order fulfilment...	17.20
Compatibility of telematics systems with cargo exchanges and...	18.00
The possibility of remote interference involving the...	20.20
Analysing the legitimacy of refuelling in terms of its quantity and...	20.20
Remote transmission of information to the driver via a messenger	25.80
Analysing weekly and bi-weekly time	26.40
Analysing the quality of driving style (eco-driving)	28.00
Connection to alarm systems	30.20
Receiving alerts when the designated route is changed	30.80
Analysing the use of driver's time in the context of the number...	31.40
Reporting delays to customers	37.60
Verification of the correlation of the vehicle's position with the...	38.60
Determining the punctuality of reaching the destination and...	40.60
Determination of the use of drivers' working time in a given 24-...	41.60
Analysing whether the driver will be able to arrive at the...	42.20
Analysing driving times and stops	45.00
Analysing fuel consumption	57.80
Determining the current location of the vehicle on the map	87.00
Determining the status of a vehicle: on the move or on a stop	95.00

When analysing the opportunities that the use of telematics systems and integrated TMS (*Transport Management System*) systems create, including telematics, based on this study, it can be concluded that for entrepreneurs the most important elements are the knowledge of the current status of the vehicle - whether it is on the move or on a stop - 95% of respondents consider this to be the most important factor; the ability to determine of the vehicle on the map - 87% of respondents consider it important, as well as the amount of fuel consumption per 100 km - 57.8% of the answers provided. Other variables are less important for carriers. Information about the timely implementation of transport tasks, *i.e.* the level related to the supply chain and the possibility of digital analysis of planning and implementation is relevant to only 42.2% of respondents.

Table 4. *Frequency of using telematics devices depending on the areas of application*

Legend: 1 - never; 4 - in half of the cases; 7- always		1	2	3	4	5	6	7
Specification		Share of answers [%]						
Control of timely delivery of orders		13.8	8.0	10.6	12.4	8.6	11.0	35.6
Checking the number of kilometres driven by the vehicle in accordance with the planned route		13.0	8.4	11.8	17.8	10.8	12.2	26.0
Adaptation of return loads after unloading to available vehicles		22.4	8.8	10.6	16.6	8.0	11.8	21.8

Ensure effective use of working time by drivers		17.0	8.2	11.2	18.4	8.4	13.8	23.0
Analysis of the legitimacy of stops during the delivery of the order		19.8	9.0	10.4	21.0	6.2	12.0	21.6
Ensuring safety in the implementation of transport		11.6	5.6	9.6	12.2	12.2	14.4	34.4

Source: *Own calculations.*

Analysis of the data resulting from the survey and of those presented in Table 4 extends the scope of information contained in Figure 1. Due to the adoption of a seven-point Likert scale, the table presents seven variants of the answer. We note that only 46.6% of respondents (grades 6-7) always or almost always control the timely delivery of orders, which is a key element in the implementation of tasks in supply chains. This confirms the supposition of a low level of supply chain service.

A similar level of response applies to ensuring safety in the implementation of transport. Despite the fact that this is one of the key factors determining the quality of services and certainty of their implementation and, as a consequence, trust in the company, only 48.8% of respondents always analyse transport processes in this context (level 6 and level 7 on the scale). Relatively rare telematics devices are used in other fields of exploitation. This applies to answering questions about the legitimacy of drivers' analysis of stops, the use of their working time, matching return loads and, finally, checking the kilometres travelled. In all these cases, the frequency of telematics use does not exceed 40.0% of the respondents' positive responses (level 6 and level 7).

4. Determinants of Using Telematics and Transport Management System - Empirical Results

To evaluate determinants of using telematics and/or transport management systems by road transport companies, the logit models have been estimated. Logit model is a useful construction which when used for microdata allows estimating the impact of determinants that support one of two variants of the defined variable. In the reported case, the usefulness of telematics systems and Transport Management System in supply chains is analysed. That is why the first question corresponding to that case was:

Do you use telematics systems for checking punctuality of vehicle loadings in the supply chain?
Thus, the endogenous variable takes the form:

$$Y_i = \begin{cases} 1, when\,the\,firm\,uses\,telematics \\ \quad\quad 0, otherwise \end{cases}. \tag{1}$$

The linear model takes the following form:

$$Y_i = \alpha_0 + \sum_{k=1}^{K} \alpha_k X_{ki} + \varepsilon_i .$$

(2)

As the endogenous variable has only two variants and exogenous variables are both numerical and binary, it is necessary to transform the model to obtain consistent estimates. One of the useful transformations is logit transformation (Cameron and Trivedi, 2008, pp. 469). Let p denote probability of a given variant of the defined variable Y conditionally on given values of exogenous variables. Then we transform probability from the interval (0;1) into logit values from the interval $(-\infty, +\infty)$ using:

$$L = \ln \frac{p}{1-p}$$

(3)

The transformed model is then as follows:

$$L_i = \alpha_0 + \sum_{k=1}^{K} \alpha_k X_{ki} + \varepsilon_i .$$

(4)

To find a value of probability p the following transformation is taken:

$$p = \frac{1}{1+\exp\left[-\left(\alpha_0 + \sum_{k=1}^{K} \alpha_k X_{ki}\right)\right]}$$

(5)

Parameters of model 4 are estimated using the maximum likelihood method for microdata, *i.e.* individual data taken from the questionnaire. As already stated, 500 individual answers were analysed and used for model building. The following exogenous variables were considered:

X1 period that firm is present on the market (in years)
X2 number of vehicles
X3 number of employed persons
X4 binary variable (is telematics system required by customers?)
X5 binary variable (is reporting vehicle position required by customers?)
X6 binary variable (is telematics system important for getting new orders?)
X7 binary variable (does telematics support transport processes?)
X8 binary variable (does telematics support operational management of the
    company?)
X9 binary variable (do you use a Transport Management System - TMS?)
X10 binary variable (is the telematics system integrated with TMS?)
X11 binary variables (what is the value added of telematics systems in
    transportation?)

a. better quality of order processing
b. forecasting punctuality of loadings
c. higher security of deliveries
d. flexibility of reaction in sudden unforeseen situations
e. better adjustment to the needs of customers

X12 binary variable (does telematics fasten decision-making process?).

The result of final estimations is presented in Table 5.

Table 5. *Determinants of using telematics systems by road transport companies in the supply chain*

Variable	Coeff	Std. err.	z	Slope
Const	−7.939	0.737	−10.75	
X3	0.004	0.001	2.848	0.0009
X6	0.542	0.099	5.453	0.1064
X11a	0.252	0.124	2.033	0.0495
X11b	0.267	0.114	2.320	0.0523
X12	0.387	0.128	3.025	0.0760

Model diagnostics			
McFadden R2	0.4599	Likelihood ratio test (chi2) [p value]	310.647 [0.000]
Loglikelihood	−182.361	AIC	376.723
S.C.	402.010	Correct prediction ratio	82.8 [%]

It can be stated that the results of estimation are both satisfactory and reasonable. The following variables increase the probability of using telematics system for punctuality checking in supply chains: number of employed persons, importance of telematics for getting new orders, managers' viewpoints that telematics increases quality of order processing and forecasting punctuality of loadings. Moreover, it accelerates the decision-making process. The highest impact is related to variable X6. This means that growing importance of telematics for getting new orders increases the probability of using telematics systems by 0.1064. McFadden R2 (McFadden, 1974) coefficient equals 0.4599 and correct prediction ratio equals 82.8% which means that the model properly identified cases of 0s and 1s in the sample. As the sample was randomly taken, the informative value of the model is quite high.

Another model supporting findings presented above has been estimated. We asked the question whether Transport Management System (TMS) is used by transport companies located in Poland. Then the endogenous variable is a binary variable that corresponds to two variants of answers to the following question:

Do you use Transport Management System (TMS)?
where yes = 1 and no = 0.

In comparison to the previous model, one additional exogenous variable has been added, *i.e.*

X13: a binary variable; do you use telematics system for:

      a. determining current localization of vehicle

      b. determining whether truck was present on loading on time

      c. determining of driver's time of work during 24 hours

      d. sending messages to driver using TMS

      e. integration of the system with other devices present in the vehicle

The estimation results are presented in Table 6.

Table 6. *Determinants of using TMS*

Variable	Coeff	Std. err.	z	Slope
Const	−5.613	1.167	−4.808	
X2	0.018	0.012	1.564	0.0040
X5	0.063	0.114	0.549	0.0135
X10	6.144	0.561	10.946	0.8805
X13b	2.297	1.104	2.079	0.5121
X13c	1.006	0.579	1.736	0.1997
X13d	0.863	0.583	1.480	0.1701

Model diagnostics			
McFadden R2	0.7740	Likelihood ratio test (chi2) [p value]	536.481 [0.000]
Loglikelihood	−67.513	AIC	170.594
S.C.	200.096	Correct prediction ratio	95.6 [%]

The following variables increase the probability of using transport management system by road transport companies: number of vehicles, reporting vehicle position requirement, integrity of telematics with TMS, determining current localization of vehicle, determining of driver's time of work during 24 hours and sending messages to drivers using TMS. The highest impact is related with variable X10 for which a slope coefficient is equal to 0.8805. This means that the integrity of TMS and the telematics system are the strongest determinants of probability of using TMS. McFadden R2 coefficient equals 0.7740 and the correct prediction ratio equals 95.6%. That means that the model properly identified cases of 0s and 1s in the sample.

These two simple logit models imply that there exist common factors which determine the probability of using telematics systems and/or transport management systems as tools supporting operational management in road transport industry. In both cases the size of the company was important (represented either by the number of employees or number of vehicles). This means that larger companies are more likely to use IT systems including telematics in everyday management. However, managers in bigger companies are more aware of the fact that IT systems help

improve organization not only within the company but also within a supply chain. Furthermore, they help smooth any shocks in time of turbulences and consequently reduce risk of being out-of-time-window. Contemporary logistic systems coordinating flows of articles, information and funds within a given supply chain (Bowersox, Closs and Cooper, 2012; Kadłubek, 2018) take into consideration the empirically identified factors to integrate functions, processes and organizations.

5. Conclusions

The aim of the study was to assess the scope and degree of using telematics systems based on GPS/GPRS technology, which are used by Polish road transport companies carrying out goods transport, which are the main processes of supply chains. The analysis was based on the surveys carried out on a sample of 500 companies headquartered in Poland. Data analysis showed that 92% of all transport means in the companies surveyed were equipped with telematics devices cooperating with TMS IT systems, which proves the very high popularity of the systems used. Despite the widespread availability of systems and a significant share of transport in the European market, the scope and level of use of data obtained from telematics systems is still very diverse and very low in case of key elements for the functioning of supply chains.

The results presented in this article clearly show that the factors as knowledge about the vehicle status, its current location, fuel consumption and the time remaining to be used by the driver in a given day are particularly significant for entrepreneurs. The punctuality of reaching the destination, the size of time delays, the effectiveness of the use of driver's working time and matching of return cargo sites are regarded as much less important.

This is so due to the lack of reporting of such data to clients or the low level of awareness among managers about the impact of these factors on the quality of services rendered. The unsatisfactory extent of the use of telematics solutions may be caused by the need for additional employment of a person who will conduct data analysis and inform the management boards of the companies in order to undertake corrective actions. Furthermore, the lack of standardization in the telematics systems used may also be an important element, making it difficult to present a comparable result format.

Two logit models have been estimated to determine the factors which increase the probability of using telematics and transport management systems in road transport companies. They imply that factors such as, for instance, the importance of telematics for getting new orders, managers' viewpoints that telematics increases quality of order processing and forecasting punctuality of loadings as well as speeds up decision-making processes, increase the probability of using telematics systems. For using TMS, the following determinants were important: reporting vehicle position requirement, integrity of telematics with TMS, determining current

localization of vehicle, determining of driver's time of work during 24 hours and sending messages to driver using TMS. In both cases the company's size was important (represented either by the number of employees or number of vehicles). This means that larger companies are more likely to use IT systems, including telematics, in operational management.

The results of the analysis carried out can and should be compared based on a similar sample in another European country with a similar transport potential. This would allow defining more precisely the scope of telematics solutions used as well as lead to the identification of barriers in their application.

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