PRODUCTION ENGINEERING ARCHIVES

The importance of telematic information and logistics indicators for the management of the quality of transport services

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Abstract
Transport companies, whose activities have a significant impact on the economy of the whole of Europe, constantly face new market challenges. The high demand for transport services, even in the time of the Covid-19 pandemic, and the introduction of new regulations by the European Union authorities mean that these enterprises have to increase their efforts on competitive foreign markets. Telematics systems play a crucial role in this battle as they enable the acquisition and processing of data characterizing processes in road transport. In this article, the author undertakes the issue of logistic indicators in theoretical frames, as well as their classification and characteristics as the main source of information about processes. This is followed by the analysis of data obtained from a transport company using a telematics system to manage transport processes in the context of ensuring the quality of services. The aim of the study is to demonstrate the significance of selected logistics indicators in terms of improving the quality of transport services. Statistical analysis is used to study the relationships and impact of individual measures in 2019-2020 as a forecasting tool. The result of the research is finding an appropriate link between the measures and using this knowledge as an opportunity to improve the quality of services.

1. Introduction

The market situation that has developed over the last few years, especially during the Covid-19 pandemic, has highlighted certain behaviours and tendencies of entities that are aimed at increasing competitiveness. The forced transformations in the scope of activities and processes caused both enterprises and entire industries to begin making their operations dependent on the acquired and shaped digital information incoming from the environment. This also applies to the transport industry, which, despite some turbulence, continues to be the most important area connecting individual market players into complex networks and logistics chains around the world.

These enterprises strive to maximize their profits by implementing modern technologies that enable the acquisition and processing of data into valuable logistics information. Increasing the profitability of selling services can be based on more

than just the continuous increase of the customer base and orders. It is necessary to consider the options that may allow to improve the quality of transport services by reducing the costs of executing orders for current clients or to increase the efficiency of these processes by eliminating errors and providing a flexible approach in planning. The benefits of telematics solutions in this area are important element to the management of information flow and its use as a pro-quality factor for the services provided. The wide range of telematics systems used allows for adjustment of all possible technical and information aspects to the requirements of clients and service providers through individual solutions targeted at companies. The level and quality of management decisions made by managers on the basis of available data in each organization determines their effectiveness (Reshetko et al., 2021).

2. Literature review

2.1. Road transport in pandemic

The impact of the coronavirus (Covid-19) pandemic on the entire world economy and thus on the freight transport sector has become the subject of many research and scientific studies. Therefore, given the uncertainty surrounding the pandemic at this moment, considering the views and suggestions of transport experts should be of paramount importance (Zhang et al., 2021).

With regard to road freight transport, some abnormal behaviour of professional drivers was noted during the first coronavirus wave in 2020. The closing of the borders of most EU Member States has caused significant difficulties and even blockings of passenger and freight transport. As a consequence, Western European countries recorded an increase in transport capacity, which was associated with a reduction in the number of truck returns to countries such as Poland and Romania in order to avoid the quarantine period (Loske, 2020).

The research presented in (Ho et al. 2021) showed a positive relationship between Covid-19 and road transport. China saw an increase in road freight turnover together with an increase in confirmed cases of the virus between December 2019 and August 2020. This phenomenon can be explained by a number of considered economic factors, such as:

–   stockpiling and/or improper material management by people, resulting from a sense of danger (Apergis and Apergis, 2020),
–   threat to the food industry and the energy market due to disruptions in supply and demand as well as falling oil prices (Liu et al., 2020; Narayan, 2020),
–   reducing investments and changing consumption patterns because of a sense of fear and insecurity (Yue eta al., 2020; Liu et al., 2020).

Also taken into account should be the rapid increase in the popularity of mobile payments, resulting from the increase in distribution carried out via Internet channels, which translated into an increase in flows in retail trade and thus an increase in road transport.

Since the impact of Covid-19 on all aspects of the economy is subject to constant research and updates, its far-reaching effects, which are associated with permanent changes in our environment, should be considered. For road transport, which is influenced by and adapts to economic conditions, it is necessary to take into account its environmental impact. The pandemic, in its tragic dimension, may also contribute to increasing the importance of responsible and sustainable transport, the aim of which is a reduction of CO_2 emissions and improving air quality (Budd and Ison, 2020).

Due to the recent increase in the importance of road freight transport, it is necessary to consider options that will increase the efficiency of the processes taking place in this area. One of them is the use of telematics systems to obtain information that enables the improvement of the quality of services provided by transport companies.

2.2. Telematics information

The transport sector is currently experiencing increased development in the area of digitization and computerization. The entire TFL industry plays a key role in economic systems around the world. By ensuring a smooth flow of resources and ready-made goods, it creates appropriate conditions for the economic development of individual entities and entire countries. The process of digitization of transport concerns the use of digital technologies that enable the support of existing regulations as well as the management of logistics processes (The, 2021; Ziyadin et al., 2020). Thanks to the great development potential and implementation possibilities, digitization covers many levels of enterprises and institutions. This significantly influences the flow of information and thus may contribute to the increase of competitive advantage in the market (Gunasekaran, Subramanian, Papadopoulos, 2017) and improve the chances for providing sustainable transport in all areas: environmental, physical, economic and social (Sarkis et al., 2020). The technological progress we are dealing with today enables efficient and smooth mobility activities, also between different branches of transport industry, ensuring a high level of integration in the global transport system (Harris et al., 2015).

The importance of integrating information technology in the transport industry (Sałek, 2017) allows for a fast and flexible connection that supports enterprises in managing operations and control by ensuring end-to-end, real-time visibility of each stage of the supply chain (E2E). This goes beyond the scope of the main organization and covers all partners in the chain (customers, shippers, suppliers, logistics operators, customs agencies). Such an undertaking requires choosing a coordinator of the entire freight ecosystem, who will be able to manage all resources and processes between the chain entities and within the company. The need to coordinate activities across the entire supply chain increased the importance of using the concept of dedicated digital platforms (Somapa et al., 2018).

The high growth potential for such digital solutions is the result of the growing demand among entities in the TFL industry, but at the same time it is their main problem. Due to the variety of functionalities of the available systems, entrepreneurs have a big problem with choosing the solution that is optimal (for themselves). At the initial stage, it is necessary to carefully plan the implementation of the telematics system, taking into account all financial and technical aspects according to own requirements. The use of such a solution for a fleet of vehicles positively influences, above all, the quality of the services offered, thus improving customer relations and the overall efficiency of information flow and internal processes translating into lower costs (Neumann, 2017). The use of telematic systems is justified in all cases which require paying attention to the safety of transport, transport efficiency and cost reduction. This mainly applies to public services, security agencies, transport and forwarding, courier and communication companies. The possibilities of application are very wide due to the versatility of integrated subsystems that have been in use for many years. This mainly applies to satellite commu-

nication and GPS positioning, as well as GSM terrestrial systems, which enable efficient communication and monitoring of current processes (Badzińska and Cichorek, 2015). Data acquisition and processing is carried out using dedicated software that has built-in tools for route optimization, digital maps, communication, visualization and location tracking (Sałek and Kliś, 2012; Said et al., 2016; Kamiński, 2019). The data that is obtained, saved and analysed by the telematics system constitute the basic source of information for further activities, which consist of defining logistic indicators as a method of evaluating the transport system or the entire supply chain in its many aspects.

2.3. Quality of transport services

A key aspect of the operations of transport companies is the provision of high-quality services that directly translate into their market success. There are many criteria influencing the quality of transport, e.g. price, speed of delivery, safety and timeliness. However, ultimately it is the customer who decides which carrier to hire or with whom to cooperate within their own business activities. Carriers must pay special attention to the quality of the services they provide due to their economic importance, which relates to increasing sales and profit, gaining the loyalty of new customers, and building value and a positive image of the company (Martin and Dolinayová, 2015).

Quality management is focused on multi-dimensional activities that require prior optimization of transport processes (Sirina et al. 2021). Taking into account a number of activities related to optimization, achieving a positive effect is possible through defining the right methods of service logistics and transport management, relying on the information obtained by TMS (Transportation Management System) systems. These are tools that allow for comprehensive management of the activities of a transport or forwarding company. Their task is to monitor the fleet and send drivers the information about possible points of interest they might pass on a given route. This technology enables more efficient management and organization of drivers' work schedules and facilitates earlier cost calculation of the process. In addition, TMS systems enable data management in areas such as: warehouse management, accounting, finance and service (Woźniak and Stryjski, 2018).

Fulfilling customer needs is of paramount importance in the overall management of the transport process (Nowakowska-Grunt, Mazur, 2016). It is related to all activities undertaken in order to improve the efficiency and effectiveness of the organization of the transport process and continuous improvement for better control of its implementation. Undertaking such activities results in such positive effects as the option of continuous monitoring, analysis, design and optimization of the process as well as efficient management of its course in accordance with the assumptions and requirements of customers (Łukasik et al., 2017).

Building a competitive advantage in the TFL industry is associated with a multi-faceted approach to the issues of managing the activities of market enterprises. These conditions often lie outside the area of the organization, and result from legal regulations and the environment in which the entity operates. Transport and logistics infrastructure is of paramount importance in this aspect. In his work, S. Park (Park, 2020) refers to the assumptions of building a comparative advantage of production companies in terms of the quality of infrastructure and logistics services. The research presented in the article emphasizes the importance of transport quality for the supply chains of manufacturing companies which, by reducing transport costs, have the opportunity to compete on foreign markets. The essence of these studies lies in the emphasis on the importance of the area of logistics services and transport for the growth of exports and increasing the competitiveness of entire industries related to the TSL sector.

2.4. Logistic indicators and meters as a source of information

Logistics and transportation companies measure performance based on various indicators. Despite many ambiguities resulting from the decisions made regarding key indicators, the management staff of the logistics industry is constantly striving for more effective studies and a better understanding of them (Kucukaltan et al., 2016).

It is very important for logistic entities to determine the relevance of given performance indicators for their competitiveness (X. Liu et al. 2010; Muangmee et al. 2021, Dzhuguryan et al. 2020). Any information can be an element of the indicator structure. Information about customers and their purchasing decisions, GPS position or information about fuel consumption, all them can potentially be a source of competitive advantage having been transformed into organizational knowledge (Trajkov and Biljan, 2012). Policymakers can therefore use the possibilities of analysing key indicators to assess their suitability (Muntean et al., 2014; Rezaei et al., 2018).

Increasing the efficiency of logistics processes while maintaining the principles of sustainable development is reflected in the solutions of the Logistics 4.0 concept (Kauf, 2016; Werner-Lewandowska and Kosacka-Olejnik, 2019). Achieving these assumptions through intelligent management: trucks, parking areas and shipments, transport, air pollution monitoring and reduction of CO_2 emissions, can be contained in three perspectives. They have been presented in the paper by (Torbacki and Kijewska 2019), Industry 4.0 (Ślusarczyk and Pypłacz, 2020; Ingaldi and Ulewicz, 2020), Logistics 4.0 and sustainable development as areas of obtaining and using performance indicators. Ensuring an appropriate level of measurement for indicators may contribute to obtaining correct analysis of processes taking place in the enterprise. However, it is not easy, especially when the focus is on improving the efficiency of entire supply chains, where the number of indicators, their diversity and the variety of applications in business practice is the main problem. This is due to the diversity of entities operating in supply chains (Dzhuguryan and Deja 2021). The ratio analysis should first be defined by the area (purchasing, storage, production, transport, distribution) and should begin with the selection of indicators that are to be identified (Cudziło and Kolińska 2014). The area outlined for

the purposes of this paper relates directly to telematics data obtained as part of the management and organization of the transport process.

3. Own research

3.1. Subject of research - transport company case study

The company is an experienced carrier providing cargo delivery services by means of road transport. It specializes in services related to the supply of air and container transport, using trucks. The company's activities consist of the transport of cargo "hubs" commissioned by airlines between smaller airports and larger reloading airports, where they continue their journey by air transport. These processes are handled in both

directions. The means of transport used in the execution of shipments are fully adapted to the transport of air cargo. More than 75% of the "Mega" semi-trailers enable the transport of loads of a height of up to three meters. In addition, these semi-trailers are equipped with a number of practical and modern solutions, e.g. rollers in the floor, electronic locks, ADR, navigation and cooling devices. An additional activity of the company is container transport, which is carried out across all Europe. It should be emphasized that the option of obtaining telematic data was possible thanks to the use of modern solutions in all transport devices of the company. Equipping the fleet with on-board computers allows for monitoring the location of vehicles and effective real-time exchange of operational data.

Table 1. Quantitative indicators of the logistics subsystem evaluation - transport

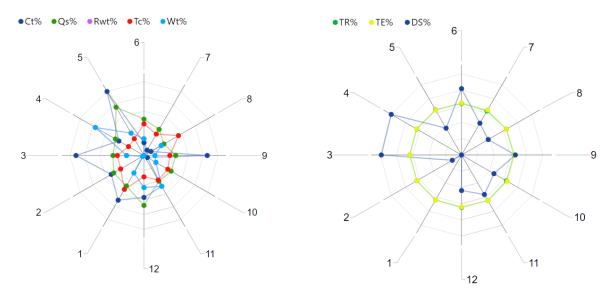| No.	Definition of the indicator	Calculation formula	Unit
Quantitative indicators			
1	Simple quantitative meters		
	Q_s – number of shipments		Pcs.
	R_{wt} – actual working time of means of transport		Hour
	C_t – transported goods		Tons
2	Transport costs per shipment	$T_c = \dfrac{\text{transport cost}}{\text{number of shipments}}$	EUR / pcs.
3	Use of working time	$W_t = \dfrac{\text{working time used}}{\text{available working time}} \times 100$	%
Quality parameters			
4	Transport reliability	$T_R = \dfrac{\text{number of transport operations carried out on time}}{\text{total number of shipments}} \times 100$	%
5	Transport flexibility	$T_E = \dfrac{\text{number of transport requirements met}}{\text{total number of transport requirements}} \times 100$	%
6	The share of damage during transport	$D_S = \dfrac{\text{number of transport units damaged}}{\text{total number of transport units transported}} \times 100$	%

Source: (Franceschini, Rafele, 2000)

Fig. 1. Dynamics of quantitative and qualitative indicators in 2019-2020

3.2. Methodology

Research conducted on the basis of the data obtained from the telematics system focused on determining the main quantitative and qualitative indicators. The data was obtained in 2019 and 2020 and detailed for each month. Table 1 presents the division and the main calculation formulas for quantitative and qualitative indicators evaluating transport as a logistics subsystem. With the data on individual aspects of the company's operations gathered by telematic systems, and the indicators that evaluate the selected logistics subsystem, it is possible to perform a full statistical analysis defining a wide

respective of the company's operations. The study covered quantitative indicators and meters (Q_s, R_{wt}, C_t, T_c, W_t) and qualitative indicators (T_R, T_E, D_S) in the period 2019-2020. The analysis (Fig. 1) shows that the quantitative ones are characterized by the greatest dynamics variability. In the case of qualitative indicators, only D_S shows significant increases and decreases in the dynamics of changes taking place in 2020 compared to 2019. In the annual summary and division into months (Fig. 2), the greatest differences can be observed in April and March (D_S index increase by 24-25%).
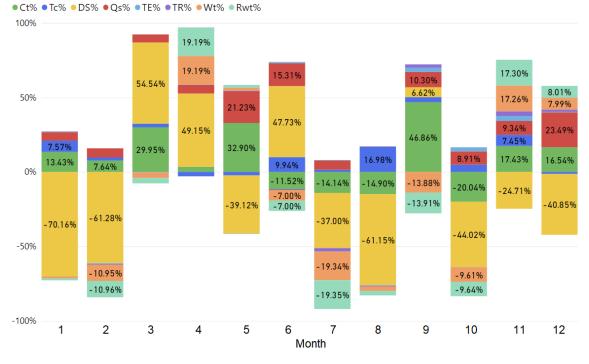

Fig. 2. Share of the dynamics of changes in indicators in the subsequent months of 2019-2020

May and September - in these months observed were increases of 12-15% in the quantitative indicators (C_t). In comparison of the quantitative meters with the dynamics of the quantitative coefficient T_c (Fig. 3), the trend of the meters is relatively stable and growing, while for the dynamics of the quantitative coefficient T_c, the trend is decreasing and the volatility itself is very different from it. On the other hand, in the juxtaposition

of quantitative indicators with qualitative indicators (W_t, Fig. 4) the volatility of dynamics is inversely proportional to changes (2019-2020 for the DS indicator also in their trends: W_t - increasing, D_S. - decreasing). The remaining changes in qualitative indicators remain around 2%. Therefore, it can be concluded that damage during transport (D_S) is the qualitative indicator with the highest variability.
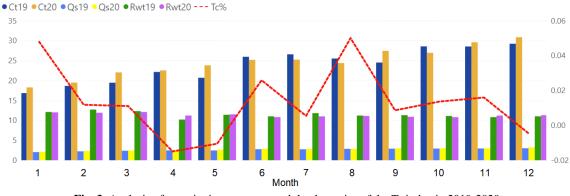

Fig. 3. Analysis of quantitative measures and the dynamics of the T_c index in 2019-2020

4. Results and discussion

The last months of economic consequences following the outbreak of the pandemic in Poland are March and April, which is confirmed by the values in Figure 2. 2020 brought an observable increase in the number of shipments, which may be confirmed, for example, by an increased use of the fleet. Nevertheless, the actual working time of the means of transport and the transported load show a decrease in dynamics, which seems to contradict the above-presented thesis.
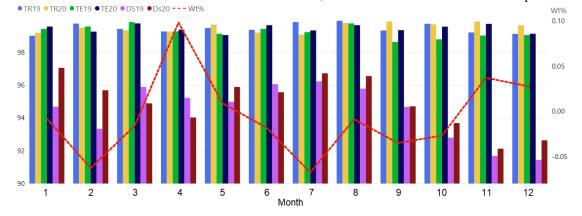

Fig. 4. Analysis of qualitative measures and the dynamics of the W_t index in 2019-2020

It can be concluded that the variability of D_S may depend on, for example, limited supervision over the efficiency of the fleet - lack of staff caused by the pandemic. In order to check the influence of quantitative meters and indicators on the qualitative ones, performed was a regression analysis.

Table 2. Regression analysis for measures and quantitative indicators o qualitative indicators in 2019

Regression Statistics	TR19	TE19	DS19
Multiples of R.	0.841	0.791	0.481
R square	0.708	0.626	0.231
Matching R square	0.465	0.315	-0.410
Standard error	0.216	0.303	1.999
Observations	12.000	12.000	12.000
VARIATION ANALYSIS	*p-value*		
Intersection	1.14E-05	3.35E-05	0.677
Qs19	3.02E-01	1.67E-01	0.988
Rwt19	2.51E-02	3.38E-01	0.973
Ct19	2.48E-01	9.49E-01	0.499
Tc19	3.22E-01	8.57E-02	0.661
Wt19	2.52E-02	3.38E-01	0.974

Table 3. Regression analysis for measures and quantitative indicators in 2019 on qualitative indicators in 2020

Regression Statistics	TR20	TE20	DS20
Multiples of R.	0.762	0.925	0.661
R square	0.580	0.855	0.437
Matching R square	0.231	0.734	-0.033
Standard error	0.255	0.121	1.615
Observations	12.000	12.000	12.000
VARIATION ANALYSIS	*p-value*		
Intersection	0.000	0.000	0.979
Qs19	0.246	0.013	0.786
Rwt19	0.352	0.079	0.521
Ct19	0.230	0.735	0.970
Tc19	0.960	0.001	0.904
Wt19	0.352	0.079	0.521

Table 2 takes into account the interdependencies of the data in 2019, while Table 3 takes into account the interdependence of the data from 2019 to 2020. The linear models for 2019 indicators are as follows:

$$Y_{TR19} = 104.1 - 1.2X_{Qs19} + 438.6X_{Rwt19} + 0.1X_{Ct19} - 19.3X_{Tc19} - 57X_{Wt19} \tag{1}$$

$$Y_{TE19} = 121.14 - 2.39X_{Qs19} - 215.96X_{Rwt19} + 0.01X_{Ct19} - 51.41X_{Tc19} + 28.06X_{Wt19} \tag{2}$$

$$Y_{DS19} = -31.79 - 0.16X_{Qs19} + 47.97X_{Rwt19} + 0.4X_{Ct19} + 76.1X_{Tc19} - 6.15X_{Wt19} \tag{3}$$

The data shows that there is a high and positive correlation between the quantitative indicators in relation to T_R and T_E. On the other hand, there is a clear relationship between DS (low correlation). Statistical significance is burdened with a 2.5% error in the relationship $Y_{TR19} \leftrightarrow X_{Rwt19}$ Y and for $Y_{TE19} \leftrightarrow X_{Tc19}$ the estimation error is 6.5%. However, for DS, there is no statistical significance in relation to the quantitative indicators.

The linear models for quantitative indicators in 2019 onto qualitative indicators in 2020 are as follows:

$$Y_{TR20} = 97.68 + 1.65X_{Qs19} + 175.74X_{Rwt19} - 0.09X_{Ct19} - 1.11X_{Tc19} - 22.85X_{Wt19} \tag{4}$$

$$Y_{TE20} = 123.3 - 2.14X_{Qs19} - 175.17X_{Rwt19} + 0.01X_{Ct19} - 56.39X_{Tc19} + 22.74X_{Wt19} \tag{5}$$

$$Y_{DS20} = 1.62 + 2.3X_{Qs19} - 752.93X_{Rwt19} + 0.02X_{Ct19} + 16.72X_{Tc19} + 97.79X_{Wt19} \tag{6}$$

The data shows moderate and high relations. There is a very large dependence in the T_R20 relation and the statistical significance of the variables is burdened with an error of 0.1%, 1.3% and 8%, respectively for:

$$Y_{TE20} \leftrightarrow X_{Tc19}; \ X_{Qs19}; \ X_{Rwt19}; \ X_{Wt19}.$$

In the case of the dependence for the T_R20 indicator, two variables C_t19 and Q_s19 confirm the statistical significance at the level of 2.3 and 2.5%. As in the previous model, the D_S indicator shows too big an error to be considered statistically significant.

The above calculations confirm the earlier thesis that the high variability of the qualitative index of damage to goods is not dependent on quantitative factors, none of the models showed a quantitative variable confirming its statistical relationship with the qualitative variable. It can be noticed that stronger relations (high values of the coefficient of determination) exist between the data in 2019 for 2020 and not in the year 2019 alone. The analysis of the conducted research shows that, taking into account the quality level of transport flexibility in 2021, the costs of transporting parcels and the number of parcels in 2020 should be monitored. However, in the case of T_R reliability, its quality in 2021 may depend on the amount of transported cargo in tonnes and the number of shipments in 2020.

5. Summary and conclusion

In a market economy, it is the customers who can choose the service, and the basic criterion is the company's ability to meet their requirements. It is similar with the quality of transport services, where organizations providing transport are aware of the need to be competitive on the market. They adapt their activities through a strategic approach to managing internal and external processes to better position themselves on the market. One of the many possible strategies is striving for providing the highest quality. Its implementation is conditioned by the definition and continuous improvement of the quality of services, business processes and management systems. A high degree of competitiveness is characteristic of the transport sector and the quality management of the transport process actually comes down to the management of individual quality factors.

The conducted analysis showed that increases of statistically significant quantitative indicators in the previous year may generate an increase in the corresponding qualitative indicator in the current year. This means that the use of dynamics, correlation and regression analysis for selected logistic indicators can be used as a forecasting tool for future actions to improve the quality of processes and services provided. This knowledge can have a significant impact on the development and competitiveness of transport companies, especially in such an unstable environment. A significant amount of acquired and processed telematics data requires currently adapted IT tools and statistical methods that will allow to use this information as an added value for a transport company.

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远程信息处理和物流指标对运输服务质量管理的重要性

關鍵詞
信息管理
运输
服务质量
远程信息处理

摘要
其活动对整个欧洲的经济产生重大影响的运输公司不断面临新的市场挑战。即使在 Covid-19 大流行期间，对运输服务的高需求，以及欧盟当局出台的新法规，也意味着这些企业必须加大对竞争性外国市场的努力。远程信息处理系统在这场战斗中发挥着至关重要的作用，因为它们能够采集和处理道路运输中的数据特征化过程。在本文中，作者在理论框架中承担了逻辑指标的问题，以及它们作为过程信息的主要来源的分类和特征。然后分析从运输公司获得的数据，使用远程信息处理系统在确保服务质量的情况下管理运输流程。该研究的目的是证明所选物流指标在提高运输服务质量方面的重要性。统计分析用于研究 2019-2020 年各个措施的关系和影响，作为预测工具。研究的结果是在这些措施之间找到适当的联系，并利用这些知识作为提高服务质量的机会。