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**MODELLING OF TRANSPORT PROCESSES IN THE CONTEXT  
OF NETWORK STRUCTURES**

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*Abstract*

The paper presents the problems of transport processes based on network structures. The concept of transport and the role it plays in the logistics system were defined. The problems of the transport process together and the components of the transport system were brought close to the reader. The concept of network structures and their advantages in relation to transport management were discussed. The support for transport processes occurs using a model of transport processes with the example of the company providing transport services for the food industry. The model proposes to include a transport coordinator in the transport process to eliminate disruptions to the process and to introduce initiatives that would contribute to the improvement in the process of transport of goods. The practical part analysed the efficiency and effectiveness of transport processes in Company A between 2016 and 2018 based on the historical data made available by the company. The study assessed the customers' satisfaction with the services provided by the company studied, the importance of the organisation's characteristics and the implementation of individual transport processes. Finally, the results of research and analysis were presented with suggestions for improvements.

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**Keywords:** Transport processes, transport networks, modelling.

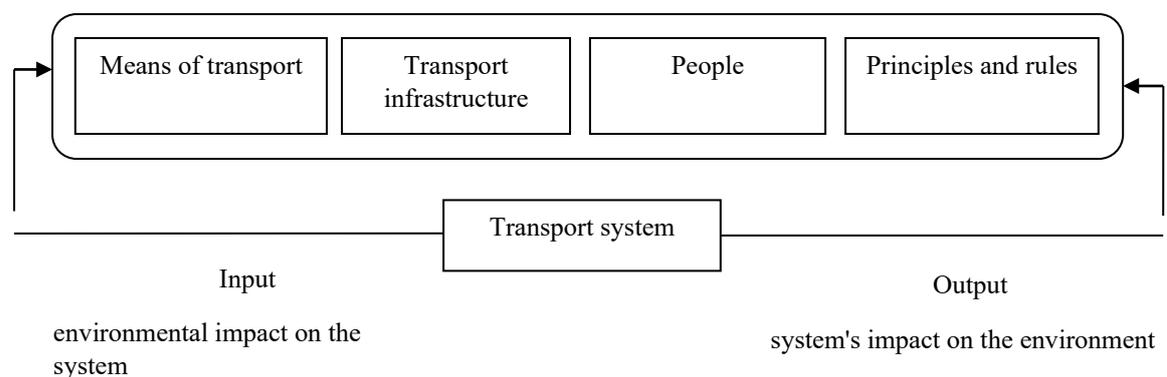


## 1. Introduction

A characteristic feature of the modern economy is globalization of the production and sales markets in which the growing amount of goods flows through transport networks (Szymczak, 2015). The implementation of transport processes is considered from the standpoint of the dynamically increasing complexity of the transport offer (Banaszyk & Gołemska, 2015). Modelling of modern network structures resulting from the evolution of structures characteristic for the industrial era brings effects in the form of transparent and detailed information on the condition of goods, their availability, conditions of real-time transport. Information processes enable data to be collected, analysed and amended in order to improve the efficiency of transport processes.

## 2. Organization of transport networks

In the classical approach, transport is an activity consisting in the movement of persons or goods in space, from the point of departure to the point of arrival, using appropriate resources, and the provision of related ancillary services (Kadłubek, 2018). Transport is present in the entire logistics system, starting from the process of supplying raw materials, materials and semi-finished products for production, to the distribution of finished products (Starostka-Patyk, 2014). The realization of the transport processes is possible with the interaction of a set of elements forming the transport system, consisting of means of transport, transport infrastructure, persons responsible for the functioning of the system, and principles and rules describing the operation of the system (Nowicka-Skowron, Nowakowska-Grunt, & Brzozowska, 2018). Elements of transport in the form of infrastructure, people, means of transport and rules resulting from legal regulations and requirements of counterparties form a transport system presented in Figure 1.



**Figure 01.** Transport system and its surroundings Source: Stajniak, Hajdul, Foltyński, & Krupa, (2008) 14-15.

The transport system, and, consequently, the transport process itself, cannot exist without all these components (Aranchiy, Pomaz, & Pomaz, 2016). At the same time, all these elements complement each other and interact with each other, especially in the context of optimization of the transport process.

Transport network management involves the disintegration of a traditional organization, which is replaced by smaller or larger organizations, composed of independent employees or entities (Kawa, 2017). These units are characterized by a high degree of decision-making autonomy, speed and independence of decisions, which results in a higher quality of the product and more efficient management. The advantages of the network structure include: (Światowiec-Szczepańska & Kawa, 2018)

- the possibility of achieving high efficiency of transport processes by eliminating unnecessary operations, increasing transport flexibility, introducing new and faster methods of information exchange in order to increase competitiveness and facilitate learning,
- the 'network of links' between the entities is conducive to the exchange of resources,
- easy control of work and delegating employee's duties,
- possibility of achieving the synergy effect<sup>1</sup>,
- high degree of autonomy of the counterparties in the system, which encourages initiatives
- presence of a multilateral cooperation effect

Transport companies strive for a networked organization of structures in order to ensure more efficient and effective management of transport processes (Światowiec-Szczepańska & Kawa, 2016). Network management requires a change in the principles, activities and methods used so far (Lis & Ptak, 2018). Changes in personnel are necessary since people with new skills are needed. The appointment of transport coordinators accelerates and empowers decision-making, and to some extent decentralizes management functions while improving the flow of information. Network structures offer opportunities for immediate response to changes or disturbances in the transport process and adjustment of transport services to the customer's requirements and flexible responding to changing needs.

### **3. Modelling of transport processes in Company A**

The basic approach that is used in the programming of the company's development is modelling (Yıldız & Alpkan, 2015). It is aimed at finding innovative economic, organisational and technical solutions (Tokgöz, Bulkan, Zaim, Delen, & Torlak, 2018).

Modelling itself is a creative process whose aim is to modify ongoing processes so as to take into account the factors of changes developed earlier in future processes (Jelonek & Stępnia, 2016). The transport process consists of a series of consecutive operations which result in the products being delivered to a specific place, to a specific recipient, and at the right time (Petryczka, Budzik, Szczepańska, & 2017). Modelling of transport processes opens up more opportunities for the analysis and planning of changes in these processes (Cao, Navare, & Jin, 2018).

Modelling of transport processes enables more effective management of this process, which includes the implementation of activities in the field of transport planning, organization and supervision

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<sup>1</sup> Sułkowski Ł. Sikorski Cz.(2014), *Metody zarządzania kulturą organizacyjną*, Wydawnictwo Difin, Warsaw, p. 170

Organizational activities are directly related to the organization of the transport process, e.g. planning of loading and unloading, possible storage, organisation of routes for transport, etc. The executive operations concern directly the transport of goods using appropriate means of transport.

Furthermore, commercial activities include those performed within the framework of commercial services for the transport process, i.e. for shippers and recipients of transported cargo (Gołemska, Bentyn, & Gołembski, 2016).

In the food industry, which is the area of operations of Company A, performance of transport processes plays a very important role because it has a significant impact on the health quality of the transported goods. Therefore, the implementation of this process must comply with the applicable legal regulations, including in particular the requirements of the HCCP system used in all European Union countries, and sanitary requirements relating in particular to the means of transport used to transport vegetables and fruits, as well as the preparation of these loads for transport. The transport processes performed by Company A include organizational, executive and commercial activities. Organizational activities include preparation of transport documents and planning of the transport route. The following executive activities are performed:

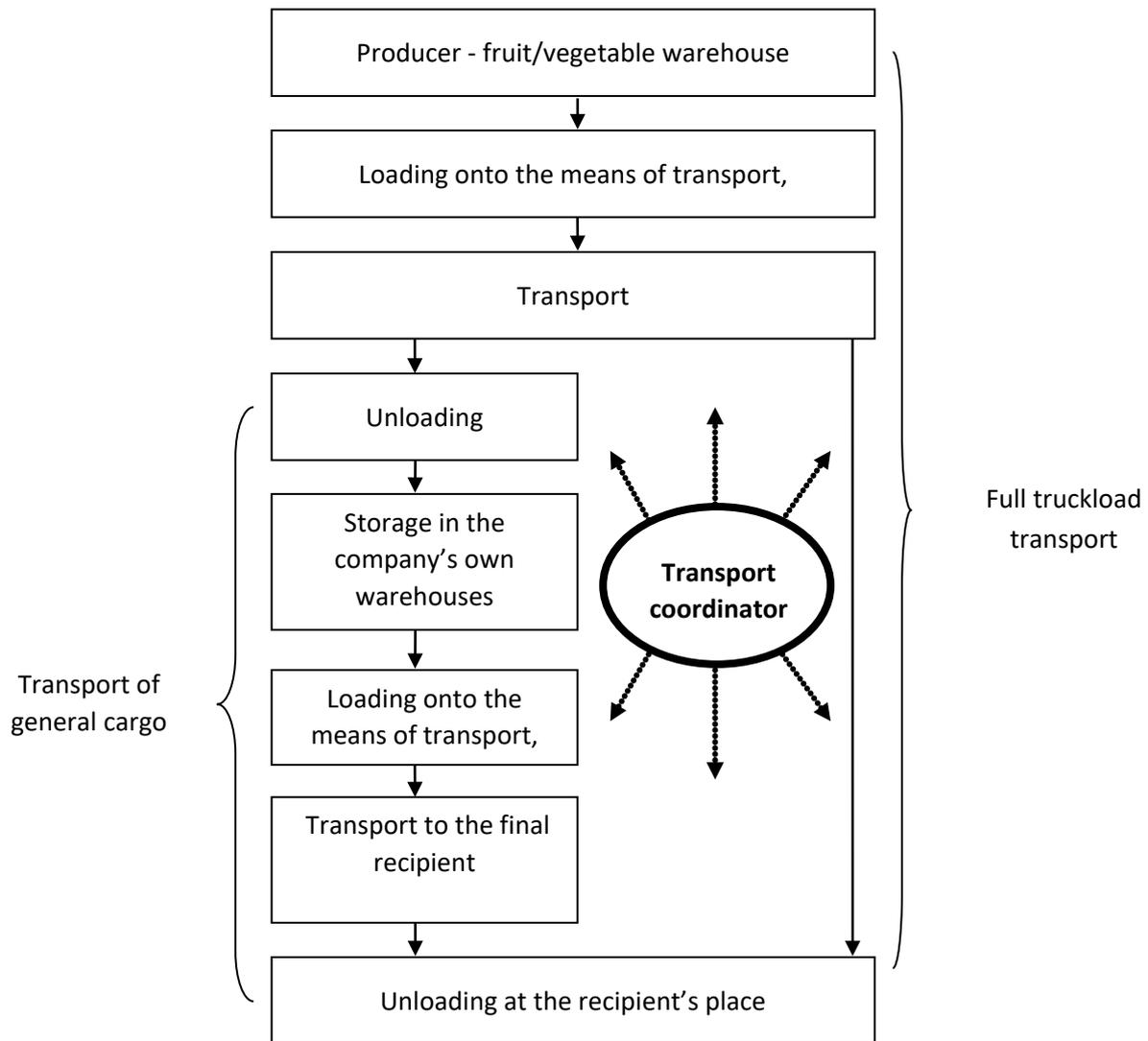
- loading of fruit and vegetables at the producer's premises,
- transport of cargo to the company's warehouses and cold storage chambers,
- unloading of transported cargo,
- storage,
- loading on means of transport,
- transportation,
- unloading at the recipient's place.

The enumerated activities can be divided into main and auxiliary activities. The main activities that are always performed by the company as part of its transport processes include:

- loading of fruit and vegetables at the producer's premises,
- transportation,
- unloading at the recipient's place.

Additional activities are performed if the amounts of cargo delivered by producers are insignificant. Then they are transported to warehouses and cold storage chambers of company A, adequately packaged and then transported to recipients within the combined transport.

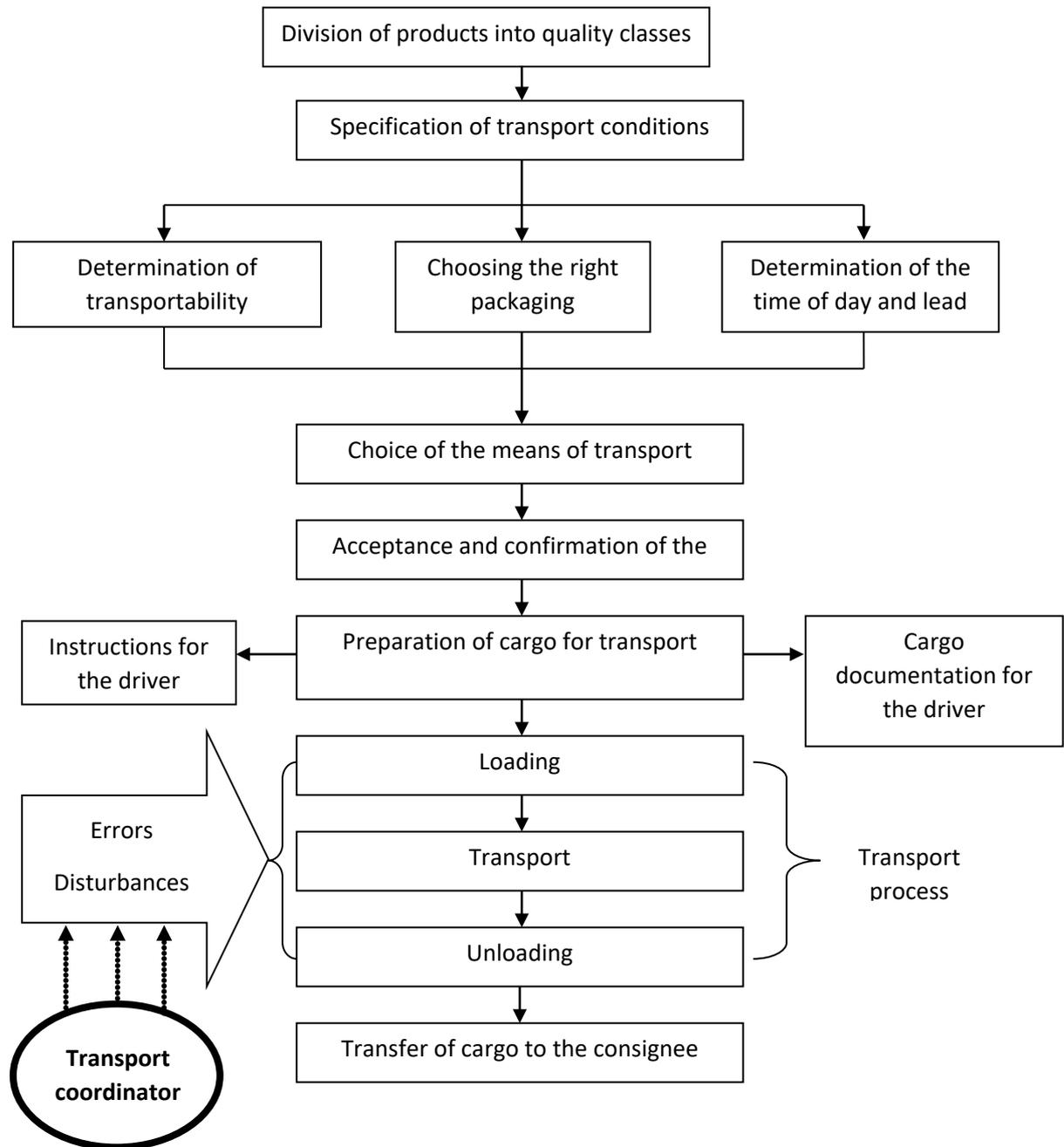
Commercial activities performed within the framework of transport processes in Company A include financial settlements with customers. The model of the transport process is illustrated in Fig. 2.



**Figure 02.** Model of the transport process in Company A Source: author's own elaboration based on the information made available by company A.

The characteristic feature of the transport processes performed by Company A is their multi-stage character, the mutual interactions between the processes of transport and storage of vegetables and fruits transported by the company, and the adjustment of the means of transport to the size of the order. It is therefore necessary to introduce a transport coordinator to ensure that the transport process runs smoothly. At the same time, this approach is supposed to enable quick and independent decisions to be made while improving the information flow and allowing the coordinator to respond flexibly to the clients' requirements and needs (Bentyn, 2015).

The organization of the processes of transport of vegetables and fruits offered by the company A involves several stages, as shown in Figure 3.



**Figure 03.** Model of activities determining the organization of transport processes in the company A.  
 Source: author's own elaboration based on the information made available by company A.

The most important stages include: division of products according to quality classes, choice of appropriate packaging, storage, determination of the time of day and time of transport, loading, transport, unloading, and invoicing and settlement with consignees. The transport coordinator is supposed to ensure that the transport process runs smoothly by responding with corrective measures to errors, disturbances, and unexpected changes. However, the coordinator can also start initiatives at different stages, affecting the transport process in order to improve its functioning

#### 4. Analysis of the efficiency and effectiveness of transport process management in the company studied

An important aspect of transport process management in Company A is periodical measurement of the efficiency and effectiveness of the process based on the information collected by the logistics department in the company (Nowicka-Skowron, 2000). To that end, annual data on the number of means of transport available, their annual mileage, number of deliveries, and revenues and costs related to the performance of transport processes are compiled. These data allow for the evaluation of transport processes (Chudzicki, 2016). The presented data concern the period of the last three years of the company's activity, based on which the value of the most important indices of efficiency of transport processes were calculated. Table 1 characterizes the methodological assumptions of the analysis performed.

**Table 01.** Assumptions for the assessment of efficiency and effectiveness of transport processes conducted by company A

Assessment metric	Method of calculation	Unit
Reliability of transport processes	Ratio of the number of deliveries on time and all deliveries completed throughout the year	%
Number of damaged goods during transport	Ratio of the number of damaged transport units to total number of transport units transported	%
Transport flexibility	Ratio of the number of transport requirements met to total number of transport requirements in a year	%
Costs of completed transport processes per km	Ratio of transport costs to the number of kilometres travelled	PLN/km
Costs of completed transport processes per delivery	Ratio of transport costs to the number of completed deliveries	PLN/pcs
Degree of utilisation of means of transport	Ratio of the volume of actual cargo transported to the volume of cargo that could be transported	%
Utilization of working time	Ratio of used to available working time	%
Failure rate of means of transport	Ratio between the number of failures detected and the number of transport operations completed	%
Number of kilometres per means of transport	Ratio of total kilometres travelled to transport units transported	km
Delivery readiness	Ratio of the number of immediately completed deliveries to the total annual number of deliveries completed	%

Source: author's own elaboration based on the information made available by company A

The data made available for calculations of the metrics of efficiency and effectiveness of transport performed by Company A are presented in Table 2.

**Table 02.** Input data for the assessment of efficiency and effectiveness of transport processes performed in Company A in 2016-2018

Metric	Value		
	2016	2017	2018
Number of deliveries completed on time	1,198	1,248	1,304
Number of all deliveries completed	1,557	1,620	1,636
Number of damaged transport units	54	50	36
Total number of transport units transported	1,985	2,024	2,269
Number of special transport requirements	16	19	18
Number of special transport requirements fulfilled	12	14	16

Transport costs [thousand PLN]	756.26	789.23	802.14
Number of kilometres travelled [thousand km]	450	463	499
Utilized working time [h]	11,200	11,450	11,680
Available working time [h]	11,520	11,660	11,800
Actual load transported [t]	32,580	34,550	36,850
Load possible to be transported [t]	40,000	42,000	42,000
Number of employees responsible for the performance of transport processes	10	12	16
Number of means of transport	8	10	12
Number of hours of operation of means of transport [h]	9,950	10,750	11,200
Possible number of working hours of means of transport [h]	11,500	12,800	14,200
Number of failures of means of transport	48	67	96
Number of orders executed immediately	900	942	987

Source: author's own elaboration based on the information made available by company A.

Based on the data presented in Table 2, the value of the most important metrics of efficiency and effectiveness of transport processes was calculated. The results of the calculations are shown in Table 3.

**Table 03.** Values of metrics for the assessment of efficiency and effectiveness of transport processes performed in company A in 2016-2018

Assessment measure	Value of metric		
	2016	2017	2018
Reliability of transport processes [%]	76.9	77.0	79.7
Number of goods damaged during transport [%]	2.7	2.5	1.6
Transport flexibility [%]	75.0	73.7	89.0
Costs of completed transport processes per km [zł]	1.68	1.70	1.61
Costs of completed transport processes per delivery [zł]	485.72	487.18	480.31
Degree of utilisation of means of transport [%]	81.5	82.2	87.7
Utilization of working time [%]	97.2	98.2	98.9
Failure rate of means of transport [%]	3.1	4.1	5.8
Number of kilometres per means of transport [km]	56,250	46,300	41,583
Delivery readiness [%]	57.8	58.1	60.3

Source: author's own elaboration based on the information made available by company A.

Analysis of the data presented in Table 3 reveals that in the last three years, the reliability of transport processes performed by company A was improved. In the entire period, the number of deliveries performed by company A increased by 79, i.e. by 5%, whereas the number of deliveries performed on time rose by 106, i.e. by 8%. In general, over the three analysed years, their reliability index increased by 2.8%. The number of goods damaged during transport decreased in this period. The value of this index in 2016 was 2.7%, whereas at the end of 2018 it was only 1.6%. These results show that the efficiency of the transport processes performed by Company A has improved. This is also confirmed by the fact that in the analysed period, flexibility of completed transport processes increased by 14%, the degree of utilization of means of transport increased by 6.2%, the degree of utilization of working time increased by 2.7%, and the company's delivery readiness increased by 2.5%. On the other hand, the costs of completed transport processes were reduced. It is worth noting that the number of kilometres per means of transport decreased over the three years analysed. However, failure rate of means of transport used by the company increased significantly by as much as 78%. In order to improve efficiency and effectiveness of transport processes, company A should take care to reduce this failure rate.

Apart from the ratio analysis, it is important to determine the level of satisfaction among the clients of Company A with the deliveries performed by the company. A survey was conducted in the last quarter of 2018 among 80 recipients of vegetables and fruits transported by Company A. The results of the survey are presented in Table 4.

**Table 04.** Customer satisfaction with the transport processes performed by company A

Importance of the characteristic					Characteristic	Customer satisfaction				
1	2	3	4	5		1	2	3	4	5
0	4	16	23	37	Comprehensiveness of services	0	0	5	33	42
1	2	10	17	50	Flexibility of services	0	0	9	22	49
0	0	0	8	72	Timeliness of deliveries	0	0	7	15	58
0	0	5	40	35	Reliability of deliveries	0	0	15	25	22
5	7	40	18	10	Communicativeness of employees	0	4	10	14	52
0	2	8	32	38	Level of expertise of employees	0	0	17	36	27
0	0	6	12	62	Prices of services provided	0	0	9	12	59
0	6	30	36	8	Accepting complaints	0	5	5	29	41
0	0	0	29	51	Accepting returns	0	0	10	38	32

Source: elaboration based on the author's study

The survey allowed for identification of the characteristics of deliveries provided by company A which are the most important for the recipients of vegetables and fruits transported by the company. Table 5 shows the importance of the characteristics in the company according to the assessment of its customers.

**Table 05.** Mean importance of characteristics of organisation and performance of transport processes by company A

Characteristic	Importance of the characteristic
Comprehensiveness of services	4.16
Flexibility of services	4.41
Timeliness of services	4.9
Reliability of services	4.38
Communication with employees	3.26
Level of expertise of personnel	4.33
Prices of services provided	4.7
Accepting complaints	3.58
Accepting returns	4.64

Source: elaboration based on the survey.

The distribution of the data presented in Table 5 reveals that for the recipients of Company A, the most important characteristics include timeliness (4.90), prices (4.70) of transport processes, and accepting returns (4.64). Table 6 presents the mean degree of customer satisfaction with the organization and performance of transport processes provided by the company analysed.

**Table 06.** Mean degree of customer satisfaction with characteristics of organization and performance of transport processes by company A

Characteristic	Degree of customer satisfaction
Comprehensiveness of services	4.46
Flexibility of services	4.5
Timeliness of services	4.64
Reliability of services	3.19
Communication with employees	4.43
Level of expertise of personnel	4.13
Prices of services provided	4.63
Accepting complaints	4.33
Accepting returns	4.28

Source: elaboration based on the survey.

Analysis of the mean level of satisfaction of the recipients of fruit and vegetables transported by Company A shows that they gave the highest marks to the timeliness of transport processes (4.64), the price of services provided (4.63) and the flexibility of services in the company (4.50). The Customer Satisfaction Index (CSI) as presented in Table 7 was determined based on the mean importance of the characteristics and the average degree of customer satisfaction with the organization and implementation of transport processes by Company A. Table 8 presents the criteria for assessing the CSI index.

**Table 07.** Relative weights of characteristics of organization and performance of transport processes by company A

Relative weights	Characteristic	Weighted average
0.11	Comprehensiveness of services	0.48
0.12	Flexibility of services	0.52
0.13	Timeliness of deliveries	0.59
0.11	Reliability of deliveries	0.36
0.09	Communication with employees	0.38
0.11	Level of expertise of employees	0.39
0.12	Prices of services provided	0.42
0.09	Accepting complaints	0.33
0.12	Accepting returns	0.42
		<b>CSI = 3.90</b> <b>CSI [%] = 78%</b>

Source: elaboration based on the survey.

**Table 08.** Criteria used to assess the CSI index

Criteria for CSI values [%]	Assessment
0% – 40%	Very bad
40% – 60%	Bad
60% – 75%	Medium
75% – 90%	Good
90% – 100%	Very good

Source: Wolniak & Skotnicka, (2008). p. 80

The indicator reached the level of 78%. Although some minor problems with reaching full customer satisfaction were found, the overall result of customer satisfaction is good.

## 5. Findings

The analysis of the value of the metrics of efficiency and effectiveness of transport processes performed by Company A in 2016 - 2018 leads to the conclusion that the reliability of transport processes improved and the number of goods damaged during transport decreased. This demonstrates that the efficiency of the transport processes performed by Company A improved. This is also confirmed by the fact that in the analysed period, flexibility of completed transport processes rose, the degree of utilization of means of transport increased by 6.2%, the degree of utilization of working time improved by 2.7%, and the company's delivery readiness increased by 2.5%. On the other hand, the costs of completed transport processes were reduced. It is worth noting that the number of kilometres per means of transport decreased over the three years analysed. Nevertheless, failure rate of the means of transport used by the company increased significantly, by as much as 78%, as a result of the intensity of their utilization and insufficiently frequent technical inspections.

The assessment of the importance of the characteristics of the organization and realization of transport processes in the company analysed revealed that for the recipients of company A, the most important is timeliness (4.90) and price (4.70) of transport processes, and accepting returns (4.64). Furthermore, the evaluation of the mean level of customer satisfaction with the deliveries showed that the recipients gave the highest marks to the timeliness of transport processes (4.64), the price of services provided (4.63) and the flexibility of the services delivered by the company surveyed (4.50).

## 6. Conclusion and Discussions

With regard to the analyses conducted in the study, it can be concluded that the introduction of a transport coordinator, as proposed in the transport process implementation model, would improve the transport process due to the capability of:

- Early error detection
- Immediate and independent decision-making
- Introduction of process improvement initiatives such as the purchase of new means of transport

The function of a transport coordinator is consistent with the company's striving for establishing the network organization of the structures in order to ensure more efficient and effective management of transport processes.

In order to reduce the failure rate of the vehicles in the audited company, it is proposed to:

- perform more frequent technical inspections of vehicles equipped with refrigeration systems, most frequently used by the company to transport vegetables and soft fruits,
- the purchase of new means of transport equipped with specialized equipment to enable the transport of soft fruit and vegetables over long distances during the summer when temperatures are high,
- implementation of changes in the planning of transport routes in order to minimize their length.

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