ANNALS OF THE POLISH ASSOCIATION
OF AGRICULTURAL AND AGRIBUSINESS ECONOMISTS

ROCZNIKI NAUKOWE
STOWARZYSZENIA EKONOMISTÓW ROLNICTWA I AGROBIZNESU

Received: 28.12.2022
Acceptance: 21.02.2023
Published: 22.03.2023
JEL codes: L92, Q13, R41

Annals PAAAE • 2023 • Vol. XXV • No. (1)

DOI: 10.5604/01.3001.0016.2735

EDMUND LORENCOWICZ[1*], **JACEK UZIAK**[**]

[*]University of Life Sciences in Lublin, Poland
[**]College of Management and Enterprise, Wałbrzych, Poland

TRANSPORT EFFECTIVENESS OF GROCERY SHOPS DELIVERIES

Key words: road transport, groupage transport, food deliveries, transport effectiveness, transport usage

ABSTRACT. The paper presents the analysis of groupage transport supplying meat and meat products from wholesalers to grocery shops. The analysis uses transport efficiency indicators related to time management and is based on data collected for two cases, in two periods of 20 working days each. Based on the data collected by self-registration, loading lists, driver's records in a self-prepared schedule and supplementary interviews with the driver, the following indicators were calculated and discussed: daily load, daily distance, time of transport processes, technical and operational speeds, transport work, vehicle and time efficiencies, and vehicle performance. The most important factors affecting the efficiency were determined. It was found that the daily load varies and depends, not only on the route and the number of pick-up points, but also on the days of the week. It was revealed that in the working time structure, the time of driving with a load was on average from 31% to 44% of the overall time. Transport work varied, depending on the route, from 12.1 to 119.0 tkm, and vehicle performance, from 2.05 to 19.11 tkm/h. The time efficiency ratio ranged from 0.38 to 0.45, and the transport efficiency from 0.82 to 0.86. The possibility of optimizing the routes and improving the indicators are related to, among others, vehicles' technical accessories and warehouses equipment facilitating faster unloading and loading, as well as digitization of ordering and delivery settling processes.

1 Corresponding author: edmund.lorencowicz@up.lublin.pl

INTRODUCTION

Transport can be considered as the movement of goods and persons from place to place by various means by which such movement is accomplished. In organizational sense, it is the set of activities leading to those movements in time and space. Despite possibilities such as air or water, the road transport, and vehicle transport in particular, remains the most popular [Mendyk 2009]. However, an effective road transport depends on many factors; that includes type and weight of the load, type of the transport means, its organization (loading and unloading), as well as road planning and road conditions.

The most popular freight in shop deliveries is groupage transport; and it can be considered as a special type of shipping [Onstein et al. 2019]. Groupage consists of the collection of several small consignments and the formation of one large shipment thereof. Therefore, it is the kind of freight service that consists of goods that are grouped together but dispatched by or delivered to several different locations. Freight groupage is an effective method for achieving cost savings in the delivery of large product variety in low quantities, by consolidating multiple consignments into one large transport load. They are normally processed goods and finished goods that can be packed in an individual or collective packaging. They must have solid external form and at the same time they cannot be divided during shipment. The important thing is to be able to weigh and/or count the particular load.

In case of meat and meat product shipment from warehouses to shops, the shipping is normally done in typical Euro E2 container. These are standard plastic boxes for the meat industry. They are manufactured according to the DIN 55423 norm and meet the requirements of the EHI [Dellino, Hazle 1994].

Specific properties of meat and meat products require special refrigerated vehicles. the refrigerated vehicle is equipped with a freezer, which allows to significantly increase the range of available temperatures, hence the distance to which the cargo can be delivered and/or time of the shipment [Dellino, Hazle 1994]. However, using such vehicles creates some specific features, which include scattering of recipients of shipments, which causes complexity of transport organization and longer transport time due to additional operations that must be performed. Loading takes place in one place (storage, warehouse, logistics centre), and partial unloading of goods at individual recipients. The specific nature of deliveries of goods to stores necessitates the execution of such orders in a loop.

In distribution logistics, close cooperation between the supplier and the recipient is necessary, and the appropriate flow of information makes is required to determine the optimal routes [Woźniak et al. 2018].

Groupage transport of supplies to stores, like any other transport process, has certain disadvantages. These are mainly losses generated by factors such as: increased number of transhipment operations (loading and unloading), low utilization of the load capacity, detours and long lead times. In addition to these intrinsic disadvantages of groupage, there are also general factors typical for the road transportation like susceptible to weather changes, vulnerability to accidents, vehicle breakdowns and delays due traffic jams. These factors impact the duration of the transport process by affecting the individual activities included in the shipping cycle and thus reduce the efficiency of the process [Marchal et al. 2007, Lorencowicz 2019, Lorencowicz 2021].

The aim of the paper was to determine and analyse the fundamental indicators of the groupage transport effectiveness in stores deliveries.

DATA AND RESEARCH METHODS

The analysis performed using the method of self-registration [Żurek et al. 2006] in meat and meat products warehouse in two locations: case A – Lublin, Poland [Bielak 2021] and case B – Radom, Poland [Tuzimek 2022]. The data collection was done in two different periods: case A – 20 working days from 11 January to 20 February 2021 and case B – 20 working days from 14 August to 6 September 2022.

The data used included drivers' own records, entered in standardized forms (schedule of activities), VAT invoices, receipts and loading lists. Interviews with drivers, provided additional information.

The schedule was used to record partial mileages and travel times between loading and unloading points. The component times of the transport process were recorded, i.e., the loading and unloading times, time of handling and acceptance activities, parking, driving, engine operation, driver's work, breaks and unplanned stops. The drivers kept daily records, and then transferred to a spreadsheet that facilitated the detailed analysis.

During the tests, delivery vans with isothermal bodies of the following brands were used: case A: Renault Master 2.3 dci Frigo and case B: Fiat Ducato Maxi. Refrigeration installation allowed to achieve the appropriate temperature for the transported goods, i.e., 0-4 ^{o}C.

Deliveries were made on three extra-urban routes with lengths ranging from 155.4 km to 208.4 km (marked A1, A2 and B, respectively), and on one urban route with a length of 43.0 km (A3).

The goods were transported in standard plastic Euro E2 containers with dimensions of 600 × 400 × 200 mm and the mass of 2 kg. The daily load ranged from 530 to 1,387 kg, on average.

INDICATORS ANALYSED

The effectiveness indicators used were based on time and operation parameters. Analysis of the time structure of the transport processes (marked in the paper as T_{pt}), allows to identify those elements that affect the reduction of work efficiency (e.g., downtime) [Nurminen, Heinonen 2007, Lorencowicz et al. 2017, Hia et al. 2022].

The transport processes time (T_{pt}) analysed includes the time of all activities performed during the transport work. Its analysis enables the identification of components that have the greatest impact on the effectiveness of the shipment performed:

$$T_{pt} = T_z + T_r + T_{czd} + T_j + T_{pn} \tag{1}$$

where:
T_{pt} – time of transport processes [h],
T_z – loading time [h],
T_r – unloading time [h],
T_{czd} – handling and acceptance activities [h],
T_j – vehicle driving time [h],
T_{pn} – time of breaks and unscheduled stops [h].

An important operational indicator affecting transport times and productivity is the speed of the vehicle. Two types of speed have been defined: technical speed – V_t, and operational speed – V_e [Osman 2017]. The technical speed of the vehicle was calculated using the following expression:

$$V_t = \frac{L_d}{T_j} \tag{2}$$

where:
V_t – technical speed of the vehicle [km/h],
L_d – the daily distance [km],
T_j – vehicle driving time of the ($T_j = T_{jz} + T_{jr}$) with T_{jz} and T_{jr} driving time of the vehicle with the load and without the load, respectively [h].

The operational speed of the vehicle was calculated using time of transport processes, which included, apart from driving time, also time of the breaks, maintenance etc. Therefore, the operational speed is always lower than the technical speed:

$$V_e = \frac{L_d}{T_{pt}} \tag{3}$$

where:
V_e – operational speed of the vehicle [km/h],
L_d – the daily distance [km],
T_{pt} – the time of transport processes [h].

Transport work was defined as the product of the load weight and the distance travelled with the load [McKinnon 2015]. In the case of deliveries to stores, the weight of the cargo between individual delivery points (stores) decreases and the daily work (Q_d) is the sum of the discrete work between successive places of unloading – partial work (Q_i). The following expressions can be used to calculate daily and partial work:

$$Q_i = \frac{M_{ri} \times L_{pi}}{1000} \text{ [tkm]} \tag{4}$$

$$Q_d = \sum_{i=1}^{n} Q_i \tag{5}$$

where:
Q_i – partial transport work [tkm],
L_{pi} – distance between successive places of unloading [km],
M_{ri} – mass remaining on the vehicle [kg],
Q_d – daily transport work [tkm].

Vehicle performance [Guan et al. 2003] was defined as the ratio the daily shipment work (Q_d) and time of transport processes (T_{pt}):

$$W_p = \frac{Q_d}{T_{pt}} \text{ [tkm]} \tag{6}$$

The effectiveness of the use of transport was measured by two indicators: time (E_t) and shipment (E_p) efficiency indices [Mendyk 2009].

The time efficiency index (E_t) is defined as the ratio of the driving time of the vehicle with the load (T_{jz}), to the time of transport processes (T_{pt}), according to the expression:

$$E_t = \frac{T_{jz}}{T_{pt}} \text{ [tkm]} \tag{7}$$

Whereas the shipment efficiency index (E_p), is the ratio between the distance travelled with the load to the total distance travelled in a given time [Rokicki 2014]:

$$E_p = \frac{L_z}{L} \text{ [tkm]} \tag{8}$$

where:
L_z – distance with load [km],
L – route length [km].

LOADS AND ROUTES CHARACTERISTICS

Loads carried by the drivers during the tests were meat and meat processed products. The goods were handed over for loading in Euro E2 plastic containers. For 20 working days, driver in case A delivered a total of 29,561.1 kg and driver in case B 20,951.1 kg. The average daily load on individual routes was: 1,386.7 kg (A1), 1,615.3 kg (A2), 1,050 kg (B) and 530.1 kg (A3). The variation coefficients were respectively: 31.3%, 62.7%, 31.7% and 14.1% (Figure 1).

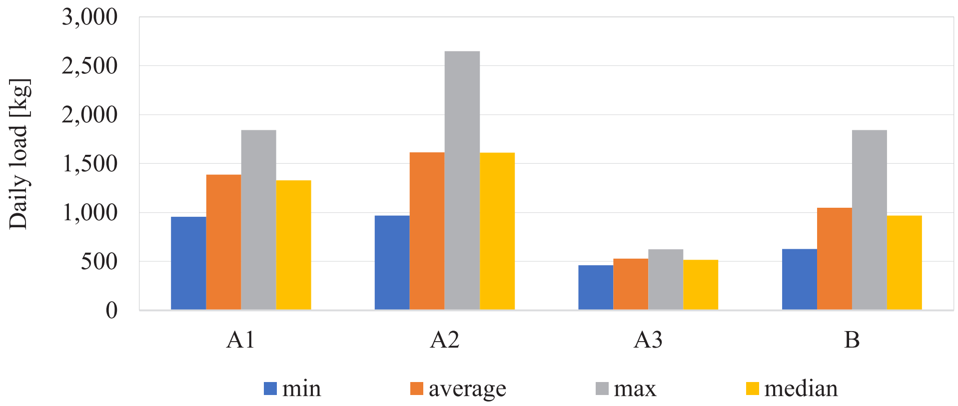

Figure 1. Daily load
Source: own study

The weekly weight distribution of the load was not uniform, with a noticeable increase in from Monday to Friday. Values above the daily average were recorded on Thursday and Friday (Figure 2 – the graph shows load for case B as an example). This was due to several factors, including: increased demand for goods, more delivery points on the route, promotional prices offered by wholesalers.

Drivers in the serviced areas drove on national, regional and municipal roads. The analysed routes were of various lengths, on average: A1 – 155.4 km; A2 – 208.4 km; B – 162.8 km and A3 – 43.0 km. In addition, daily mileage on routes also varied from the average because some customers ordered goods every second or third day (Figure 3). In total, during the period under review, the total distances travelled were case A – 3,194 km and case B – 3,255 km.

The number of delivery points on the route ranged from 5 to 12, and the distances between points varied from a maximum of 41 km to less than 1 km (minimum 200 m). The highest daily mileage was 226 km (A2). On that day, the driver had 12 customers on

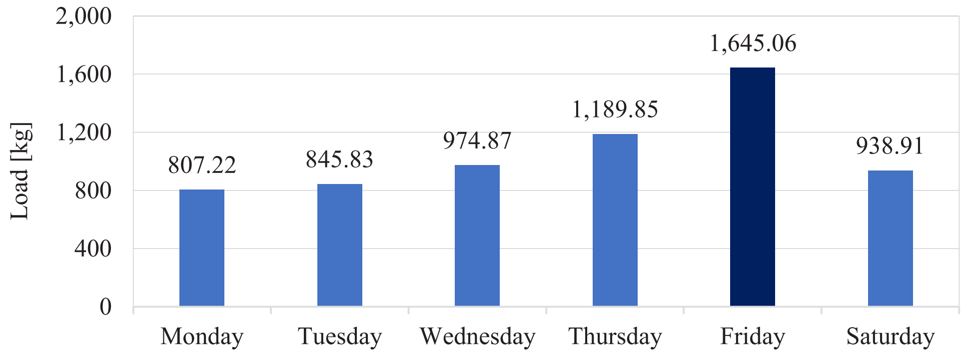

Figure 2. Average daily load (route B)
Source: own study

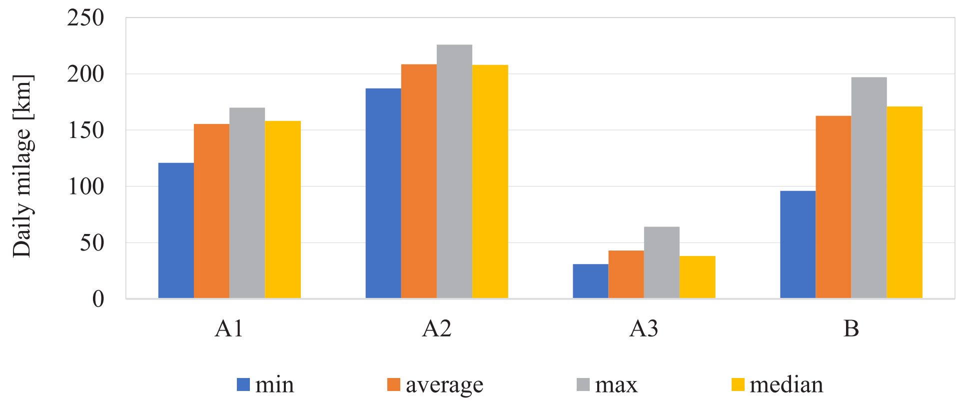

Figure 3. Daily mileage
Source: own study

the route and the total load on the vehicle was as much as 1,615.3 kg. The shortest daily distance was only 31 km (urban route – A3). The coefficient of variation of the daily distance varied depending on the route from 8.5% (A2) to even 39.4% (A3).

Routes variation also affects the speed achieved (Figure 4). In the case of technical speed, they varied between 18.8 km/h (A3) to 63.5 km/h (B). These velocities were not changing a lot with the coefficient of variation ranged from 6.1% (B) to 13.1% (A1). Operating speeds ranged from 7.2 km/h (A3) to 34.5 km/h (B), with variations from 6.3% (A1) to 18.4% (A3).

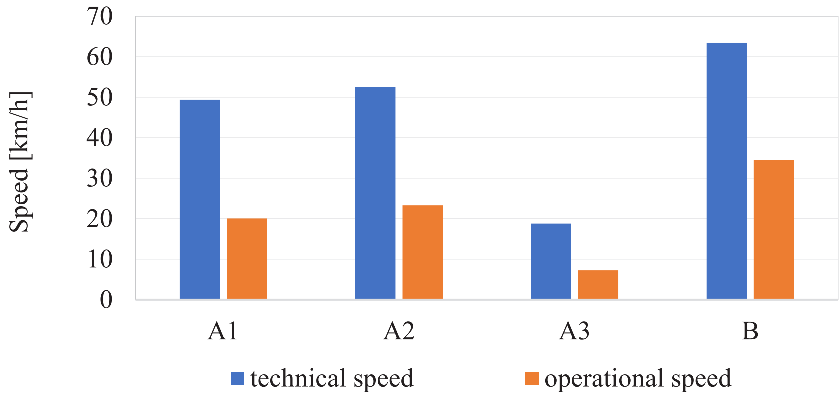

Figure 4. Average technical and operational speeds on the analysed routes
Source: own study

TRANSPORT WORK

The average daily transport work (Q_d) during the tests fluctuated between 12.1 tkm/h (A3) to 146.2 tkm/h (A2) (Figure 5). The coefficient of variation of this parameter was from 37.5% (A3) to 66.3% (A2). In the extreme case, the maximum value of transport performance was 210.3 tkm (A2) and the minimum value was 8.5 tkm (A3). Such a large value of the coefficient was caused by the differences between the extra-urban and urban routes and the load on a particular day of the week (number of unloading points).

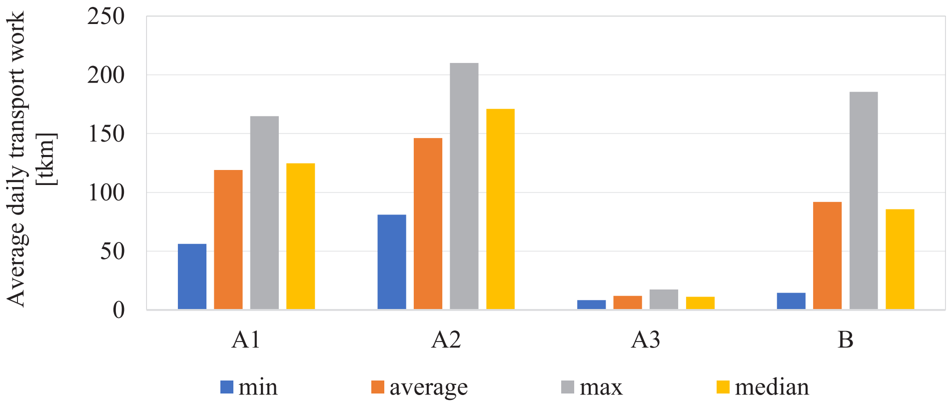

Figure 5. Average daily transport work
Source: own study

The daily time of transport processes varied from 340 to 521 minutes. The structure of the daily time (Figure 6) indicates a significant share of auxiliary times during the transport process, both on extra-urban routes (A1, A2, B1, B2) and urban routes (A3). That is clearly reducing the efficiency of transport. The most significant component reducing the efficiency, were the times of loading and unloading. Followed by time of handling and acceptance activities, consisting of settling documents and checking the goods, both in the warehouse and unloading points. The laden travel time accounted for 31% (A3) to 44% (A2 and B) of the total transport time. This is a typical time structure for deliveries to stores or courier services [Wajrak 2020].

Figure 6 presents transport processes time structure for case B as an example, similar results were obtained for case A.

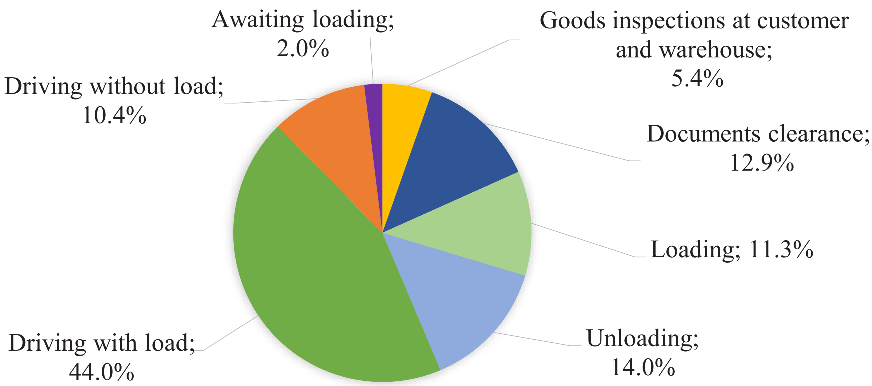

Figure 6. Working time structure (route B)
Source: own study

PERFORMANCE AND EFFICIENCY INDICATORS

The average vehicle performance (W_p), depending on the route and orders, ranged from 2.05 tkm/h (A3) to 19.1 tkm/h (B) (Figure 7). The minimum performance value was recorded for A3 – 1.59 tkm/h and the maximum for B – 31.4 tkm/h. The coefficient of variation was high and varied from 31.6% (A3) to 46.6% (A2).

The daily time efficiency index (E_t) varied between 0.38 (A3) and 0.45 (A2) (Figure 8). The maximum time efficiency index value was 0.52 (B) and the minimum – 0.27 (B). The maximum index values were caused by large distances between customers. The minimum value of 0.27, was caused by a special situation related to the delivery. On that day, driving with a load took the driver 1 hour 9 minutes, and transport processes 4 hours 16 minutes. Such a big difference was caused by the error in loading for one of the customers.

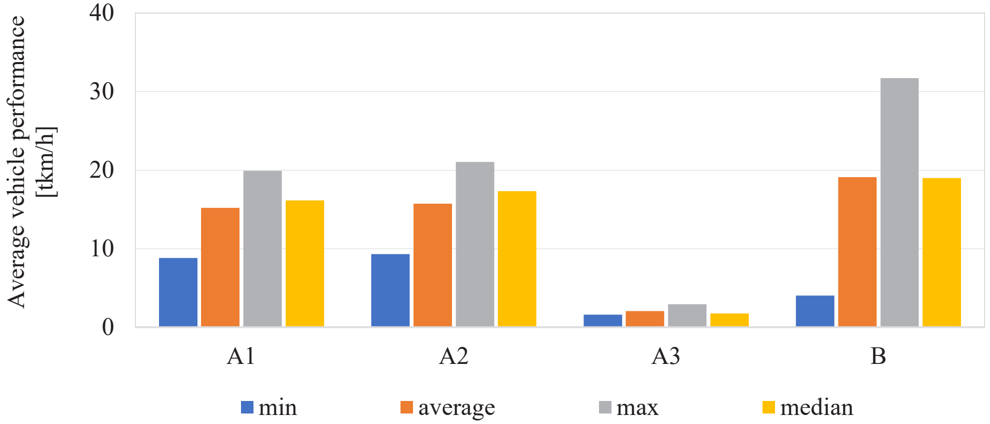

Figure 7. Average vehicle performance
Source: own study

The average shipment efficiency index (E_p) ranged from 0.82 (B) to 0.85 (A1 and A3) (Figure 8). On all the analysed routes, the driver was laden for more than 80% of the total route distance. Small fluctuations of the coefficient of variation (from 4.2% – A3 to 10.2% – A2) can be explained by the fact that the route often ended at the same customer, so the driver always had the same distance to the warehouse. The minimum value shipment efficiency index was recorded on the Monday route in case B. The value of 0.59 resulted from the fact that the last customer on that day was located 40 km from the wholesaler and the rest of the route was empty.

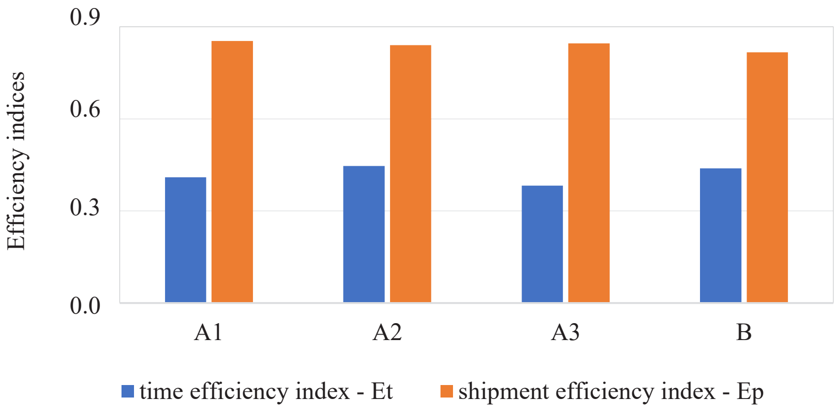

Figure 8. Comparison between time efficiency (Et) and shipment efficiency (Ep)
Source: own study

Table 1. Summary of the analysed parameters and indices

Parameter or index	Symbol	Unit	Average value	Median	Standard deviation	Average variation coefficient [%]
Daily load	M_d	kg	530.1-1615.3	516.7-1,613.1	64.9-608.7	14.1-62.7
Daily distance	l_d	km	43.0-208.4	38.0-208.0	12.2-29.7	8.5-39.4
Technical speed	V_t	km/h	18.8-63.5	17.8-63.4	1.5-5.1	6.1-13.1
Operational speed	V_e	km/h	7.2-34.5	7.7-35.0	1.1-4.4	6.3-18.4
Daily transport work	Q_d	tkm	12.1-119.0	11.2-124.7	3.2-53.7	37.4-66.3
Vehicle performance	W_p	tkm/h	2.05-19.11	1.76-19.00	0.50-7.91	31.6-46.6
Time efficiency	E_t	-	0.38-0.45	0.39-0.46	0.04-0.07	10.6-16.2
Shipment efficiency	E_p	-	0.82-0.85	0.83-0.86	0.03-0.08	4.2-10.2

Source: own study

The analysis of all collected data (Table 1) indicates a high variability of two parameters: daily transport work (Q_d) and vehicle performance (W_p). Coefficients of variation range from around 32% to over 62%. Also, the daily load was very diverse, and the coefficient of variation ranged from about 14% to about 63%, depending on the route. In other cases, the calculated values are characterized by lower variability.

SUMMARY AND CONCLUSIONS

Based on the conducted research, the following conclusions can be drawn.

1. The analysis of the working time structure confirms that in the case of transporting goods to grocery stores, the driving time of the vehicle is less than other components of the total time of transport processes. In the cases considered, the driving time was on average from 38 to 45% of the total time.
2. The city route (A3), due to the lowest results for indicators as transport work (Q_d), time efficiency index (E_p) and shipment efficiency index (E_t), seems to be the least profitable for the company. However, ensuring deliveries to stores in the city and contracts with their owners who also have stores outside the city, plus the need to retain customers means that such routes should not be removed from the shipper's offer.

3. Values of variation coefficient for transport work (Q_d) and vehicle performance (W_p) indicate a potential high disproportion of loads, route lengths and transport processes. Efforts should be made to reduce auxiliary times in transport processes. During the research, it happened that the driver had to look for the goods for the customer on several pallets when unloading, which he received from the warehouse, which lengthened the unloading time. To reduce loading and unloading times, the received daily load should be clearly arranged.
4. Activities regarding the optimization of routes and loadings are difficult in the transport of deliveries to grocery stores. The customers fragmentation, the variability of orders and routes affect the need for direct, operational organization of transport. Further, optimization should include technical solutions for vehicles facilitating faster unloading and loading, technical solutions of warehouses, digitization of ordering and delivery settling processes.

BIBLIOGRAPHY

Bielak Michał. 2022. *Analiza efektywności wybranego transportu drobnicowego* (Assesment of selected groupage transport efficiency). Engineering diploma thesis made under supervision of E. Lorencowicz (typescript). University of Life Sciences in Lublin: Poland.

Dellino Clive V.J., G. Hazle. 1994. Cooling and temperature controlled storage and distribution systems. [In] *Food Industry and the Environment*, ed. J.M. Dalzell, 259-282. Boston: Springer. DOI: 10.1007/978-1-4615-2097-9_7.

Guan Tut San, Robert Mason, Stephen M. Disney. 2003. MOVE: modified overall vehicle effectiveness. [In] The 8th International Symposium of Logistics, 641-649. Seville, Spain, July 6-8, 2003.

Hia Selamat Walmanto, Moses Laksono Singgih, Raja Oloan Saut Gurning. 2022. Performance metric development to measure overall vehicle effectiveness in mining transportation. *Applied Sciences* 12 (23): 12341. DOI: 10.3390/app122312341.

Lorencowicz Edmund. 2019. Ocena efektywności transportu ciężarowego dalekobieżnego – studium przypadku. [In] *Inżynieria zarządzania. Cyfryzacja produkcji. Aktualności badawcze 1* (Evaluation of the effectiveness of long-distance truck transport – a case study. [In] Management engineering. Digitization of production. Research news 1), ed. Knosala Ryszard, 273-286. Warszawa: PWE.

Lorencowicz Edmund. 2021. Ocena efektywności wybranych procesów transportu drobnicowego. [In] *Inżynieria zarządzania. Cyfryzacja produkcji. Aktualności badawcze 3,* (Evaluation of the effectiveness of selected groupage transport processes. [In] Management engineering. Digitization of production. Research news 3), ed. Ryszard Knosala, 601-611. Warszawa: PWE.

Lorencowicz Edmund, Rafał Jarmuł, Milan Koszel, Artur Przywara. 2017. Analiza wykorzystania czasu pracy kierowców (Analysis of time use by drivers). *Problemy Transportu i Logistyki* 2 (38): 27-38.

Marchal Jean, Cathy Verbeke, Alain Verbeke. 2007. *Bases of a growth of intermodal transport in Belgium: The search of "Missing Links"*. Final report. Brussels: Federal Science Policy, 2007 (SP1766).

McKinnon Alan. 2015. *Performance measurement in freight transport – its contribution to the design, implementation and monitoring of public policy*. International Transport Forum. Kuehne Logistics University, Hamburg, Germany, https://www.itf-oecd.org/sites/default/files/docs/mckinnon.pdf , access 20.12.2022.

Mendyk Edward. 2009. *Ekonomika transportu* (Transport economics). Poznań: WSL.

Nurminen Tuomo, Jaakko Heinonen. 2007. Characteristic and time consumption of timber trucking in Finland. *Silva Fennica* 41 (3): 471-487.

Onstein Alexander T.C., Lóránt A. Tavasszy, Dick A. Van Damme. 2019. Factors determining distribution structure decisions in logistics: a literature review and research agenda. *Transport Reviews* 39 (2): 243-260. DOI: 10.1080/01441647.2018.1459929.

Osman Janusz. 2017. *Wskaźniki efektywności transportu* (Factors of transport effectivness). http://members.upcpoczta.pl/j.osman8/logistyka/organizacja/pliki_pdf/Wskazniki_efektywnosci_transportu.pdf, access: 25.03.2021.

Rokicki Tomasz. 2014. *Organizacja i ekonomika transportu* (Organisation and economics of transport). Warszawa: SGGW

Tuzimek Karol. 2022. *Ocena efektywności transportu drobnicowego dostaw towarów do sklepów na wybranym przypadku* (Assesment of the efficiency of groupage transport of goods deliveries to stores in selected case). Engineering diploma thesis made under supervision of E. Lorencowicz (typescript). University of Life Sciences in Lublin, Poland.

Wajrak Marcin. 2020. *Charakterystyka rynku i analiza efektywności pracy kuriera w Polsce* (Characteristic of the market and analysis of courier's work efficiency in Poland). Master's thesis made under supervision of E. Lorencowicz (typescript). University of Life Sciences in Lublin, Poland.

Woźniak Waldemar, Roman Stryjski, Janusz Mielniczuk, Tomasz Wojnarowski. 2018. Analiza wybranych metod optymalizacyjnych w transporcie drogowym (Analysis of selected optimization methods in road transport). *Prace Naukowe Politechniki Warszawskiej. Transport* 120: 447-458.

Żurek Jan, Olaf Ciszak, Robert Cieślak, Marcin Suszyński. 2006. Metody badania czasu pracy w procesach montażu (Methods for worktime investigation in assembly processes). *Technologia i Automatyzacja Montażu* 3: 43-46.

***

EFEKTYWNOŚĆ TRANSPORTU DOSTAW DO SKLEPÓW SPOŻYWCZYCH

Słowa kluczowe: transport samochodowy, transport drobnicowy, transport żywności, dostawy żywności, efektywność transportu, wykorzystanie środków transportowych

ABSTRAKT. Celem opracowania jest analiza wybranych wskaźników charakteryzujących efektywność transportu drobnicowego, obsługującego dostawy mięsa i wędlin z hurtowni do sklepów spożywczych. Dane zgromadzone w dwóch obiektach, w okresie 20 dni roboczych, dotyczyły wskaźników efektywności transportu związanych z zarządzaniem czasem. Dane zgromadzono za pomocą metody autorejestracji, informacji z list załadunkowych oraz wywiadów uzupełniających z kierowcą. Na ich podstawie obliczono i omówiono takie wskaźniki, jak: dzienna masa ładunku, odległość dzienna, czas procesu transportowego, prędkości techniczne i eksploatacyjne, praca przewozowa, wydajność pojazdu oraz efektywność czasowa i efektywność przewozowa. Stwierdzono, że dzienna masa była zmienna i zależała nie tylko od przebiegu trasy i liczby punktów odbioru, ale także od dni tygodnia. W strukturze czasu transportowego czas jazdy z ładunkiem stanowił średnio od 31 do 44%. Praca przewozowa, w zależności od trasy, wynosiła od 12,1 do 119,0 tkm, a wydajność od 2,05 do 19,11 tkm/h. Wskaźnik efektywności czasowej wahał się do 0,38 do 0,45, a efektywności przewozowej od 0,82 do 0,86. Możliwości optymalizacji tras i poprawy wskaźników związane są m.in. z rozwiązaniami technicznymi pojazdów i obsługiwanych magazynów, ułatwiającymi szybszy rozładunek i załadunek oraz z cyfryzacją procesów zamawiania i rozliczania dostaw.

AUTHORS

EDMUND LORENCOWICZ, DR HAB. PROF.
ORCID: 0000-0002-4190-0422
University of Life Sciences in Lublin, Poland
Department of Machinery Exploitation and Management of Production Processes
e-mail: edmund.lorencowicz@up.lublin.pl

JACEK UZIAK, PHD
ORCID: 0000-0001-7844-3694
College of Management and Enterprise, Poland
e-mail: uziak@poczta.wwszip.pl

Proposed citation of the article:
Lorencowicz Edmund, Jacek Uziak. 2023. Transport effectiveness of orders deliveries to grocery shops. *Annals PAAAE* XXV (1): 166-179.