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Analysis of the use of logistics-telematics systems for cost reduction in a transport company

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Abstract: *Purpose*: The main purpose of this paper is to investigate the extent to which real-time monitoring of vehicles and the collection of operational data about them through telematic systems can contribute to the reduction of operating costs in a transport company. The study focuses on specific factors such as the driver's actions, which can affect the vehicle's technical condition and diesel consumption levels. *Methodology*: The research is based on an analysis of operational data obtained from the vehicles of a transport company engaged in international freight transportation. The data were primarily analyzed for an indicator related to total fuel (diesel) consumption while driving. Linear models were created using the least squares method, and the best-fitting models were selected to draw conclusions about the impact of telematic systems on the company's costs. *Results*: The study found that the introduction of a telematic system can have a positive impact on a transport company's operations and help reduce costs associated with the execution of transport orders. The analysis of the data showed that individual factors, such as driving time, average axle load, and average travel speed, can affect the total driving fuel consumption of all vehicles and contribute to the overall cost reduction. *Theoretical contribution*: This paper contributes to the understanding of the role of telematic systems in the optimization of fleet planning and management, which is a crucial aspect of the logistics of transporting goods. The research provides insights into the potential of real-time monitoring and data collection for improving the efficiency and cost-effectiveness of transport companies. *Practical implications*: The findings of this study can be useful for transport companies looking to improve their operations and reduce costs. The research highlights the importance of using telematic systems in the right way to carry out the transportation of goods and suggests that real-time monitoring and data analysis can be key to minimizing costs and maximizing profits.

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1. Introduction

With the demand for transportation services increasing annually, road transport companies, which are also a key element in, among other things, the logistics of transporting goods, must consider various factors that can affect the cost of operating the company and bring expected results such as rapid growth in the market. Among the group that has the greatest impact on this is the company's costs incurred during its operations. Optimized fleet planning involves knowledge in various fields to be able to properly steer the company's expenses and pursue the goal of making as much profit as possible and incurring as little financial loss as possible. One of these areas is fleet management. Mainly, it is a matter of using it in the right way to carry out the transportation of things overland. Controlling it in real time and collecting data about it to conduct in-depth analyses can be a key way to minimize costs (Topolska, K. & Topolski, M., 2016). A properly integrated telematic system can be useful as an auxiliary tool. Therefore, the current location of a specific vehicle and its status are known, which will allow you to appropriately plan the route limiting "empty runs", react appropriately to sudden changes (traffic jam, damage to the vehicle, etc.), monitor its technical conditions (early enough reaction will save not only costs but also time, which in this industry is very valuable), and monitor diesel fuel consumption (which particularly affects the main costs of the transport company) (Pasierbski, 2020).

Numerous authors have examined the issue of telematics. Telematic systems are employed in Poland as well as other countries for managing urban logistics movement. Those that satisfy the requirements of intelligent transportation systems are of particular importance. One study (Małecki & Iwan, 2014) examined similar systems employed in Polish cities. Additionally, this issue was discussed in the publications listed below (Litwin, 2003; Neumann, 2017, June; Wikipedia, 2023).

The Tri-City's Integrated Traffic Management System, or TRISTAR, is one of these systems. This system controls traffic in urban areas by utilizing a variety of systems, including road traffic control, video surveillance, measurement of meteorological parameters, monitoring and supervision of vehicle traffic and parking information, and information for passengers of public transport and traffic management of public transport vehicles (Biniasz, 2016; GDIK, 2019).

This system includes moving message boards that provide crucial information for drivers, boards that display the availability of free parking, and boards at bus stations. Collective transportation has been given precedence in this arrangement at intersection traffic signals (Małecki & Iwan, 2014).

Another illustration of such a solution can be found in the Szczecin systems. In addition to the Central System of Urban Transport Management (CUTMS), which includes, among other systems, fleet management, dynamic passenger information, video monitoring in vehicles, counting passenger streams, optimization of communication networks, location and monitoring of technical vehicles serving, there is a traffic management system (TMS) made up of a traffic management centre (ACET, 2019).

While CUTMS includes, among other things, passenger information boards at stops, internet information systems, mobile phones and multimedia information for passengers in vehicles, SZR includes variable content boards that enable the presentation of complex messages, road signs, and diagrams to road users, as well as variable content signs used to present road signs and short information (Małecki & Iwan, 2014).

The following publications also discuss telematics in transportation (Hossain et al., 2010; Van Der Laan, Heino, & De Waard, 1997; Quddus, Ochieng, Zhao, & Noland, 2003; Smart Cities and Communities, 2012; Zelinka, Svitek, Votruba, Jirovsky, & Novak, 2013; Svítek, Zelinka, Jirovský, & Jeřábek, 2012). Referring to the above assumptions, the authors analysed the operational data obtained by means of a telematic system from the vehicles of a transport company engaged in international freight transportation.

2. Materials and methods

The data (factors) were analysed mainly for an indicator related to total fuel (diesel) consumption while driving. Based on these data, linear models were created using the least squares method, and the best-fitting models were selected. These measures made it possible to conclude that the introduction of a telematic system has an impact on the costs of a transportation company. There was also a cost analysis of the introduction of ecodriving based on the telematic system, from which specific operational data were extracted as a basis for evaluating the driving style of each driver employed by the company.

3. Analysis of the impact of using transics systems to reduce transportation costs

The overall impact of using transics systems to reduce transportation costs can vary. This depends on the degree of use and implementation of the systems. The surveyed transport company, which provides operating data on fleet vehicles, is engaged in the international transportation of general cargo carried on tarpaulin trailers and perishable goods on refrigerated trailers. The company uses logistics-telematic systems such as TX-CONNECT, TX-FLEX, TX-ECO, and TX-CONNECT MP, which are on-board devices in each vehicle, TX-SKY. These systems allow the collection and storage of detailed information on vehicles. The vehicle operating data are in the form of monthly reports for each month starting in January 2022 and ending in December 2022. At the time of the study, the transport company had 55 units of vehicles (truck tractors) of various brands meeting the Euro 6 standard and equipped with an additional braking system called a long-acting brake (retarder):

- DAF LowDeck 15 pcs;
- DAF Standard 8 pcs;
- Mercedes LowDeck 9 pcs;
- Volvo Standard 7 pcs;
- Volvo LowDeck 16 pcs.

LowDeck tractor units are a type of tractor unit with a low-suspension design. This solution was developed to perform transport with trailers with a lower floor height from the ground. This type of vehicle has a smaller drive (295/60R22.5 or 315/60R22.5) and steer tires, a lower fifth wheel (trailer support) height and a different drive bridge ratio compared to tractors with standard suspension. The disadvantages of the design are smaller fuel tank capacities and greater susceptibility to damage from uneven road surfaces and road elements, i.e., curbs and traffic circle islands (Grupadbk, 2023). An example of a tractor-trailer model is shown in Figure 1.

Figure 1: DAF XF106 LowDeck

Source: (Getruck, 2023)

The relevant data collected and archived by the transics system for each of the 55 vehicles from the entire year by month are described as follows:

- y – total fuel consumption while driving (l),
- x_1 – distance travelled (km),
- x_2 – driving time (s),
- x_3 – average axle load (t),
- x_4 – average speed of motor rotation (rpm),
- x_5 – average travel speed (km/h),
- x_6 – duration of use of cruise control (s),
- x_7 – number of braking events (quantity),
- x_8 – duration of use of retarder (s),
- z_1 – DAF typ: standard (1),
- z_2 – DAF typ: LowDeck (1),
- z_3 – Volvo typ: Standard (1),
- z_4 – Volvo typ: LowDeck (1),
- z_5 – Mercedes-Benz typ: LowDeck (1).

The system records all vehicle data related to driving when its speed exceeds 2 km/h; otherwise, the data fall into a different category (a group of data related to vehicle engine running).

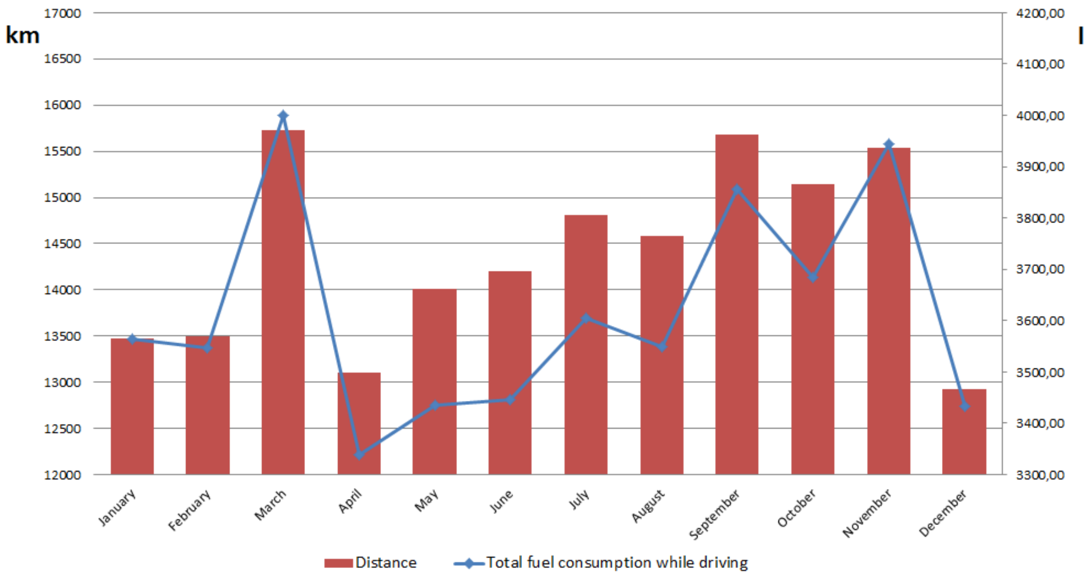
The purpose of the research will be to evaluate the archived data from 2022, analyse the costs associated with the introduction of a telematic system to a transport company, and evaluate the costs and possible savings associated with the implementation of the ecodriving linked to the telematic system.

The main factor that will be examined in terms of total costs related to diesel consumption has been marked with a "y" for a reason. This approach will help determine how the introduction of a telematics system affects a company's cost level in terms of fuel consumption and how it can affect decisions related to the company's future investments.

The obtained data allow us to analyse the total driving fuel consumption of a fleet of vehicles in a transport company from an operational and economic point of view. It will be helpful to develop graphs based on the obtained data. Linear models created using the classical method of least squares will also be useful for analysis and evaluation. This method involves the determination of a regression line, i.e., a trend line for the collected data; in other words, a straight line is determined whose sum of squares of estimation errors (the difference between the estimated regression line and the actual result) will be the lowest. It is also used to estimate linear and nonlinear dependence (Naukowiec, 2023). This method will show whether individual factors (x_1,(...), x_8) affect the total driving fuel consumption of all vehicles and to what extent they affect its final value each month and throughout the year. Those models will be considered to have the largest coefficient of determination R-square (which will describe as much variability (variance) of total driving fuel consumption as possible), assuming that the influence of a random factor is less than 5% and that the p value of the factors (the probability that the value of a given factor occurs randomly) is less than 5%, have no collinearity problems and that there is no heteroskedasticity of the variance of the random component.

Through all these procedures, the thesis that the introduction of a telematic system has a positive impact on the operation of a transport company and reduces the costs associated with the execution of transport orders will be tested.

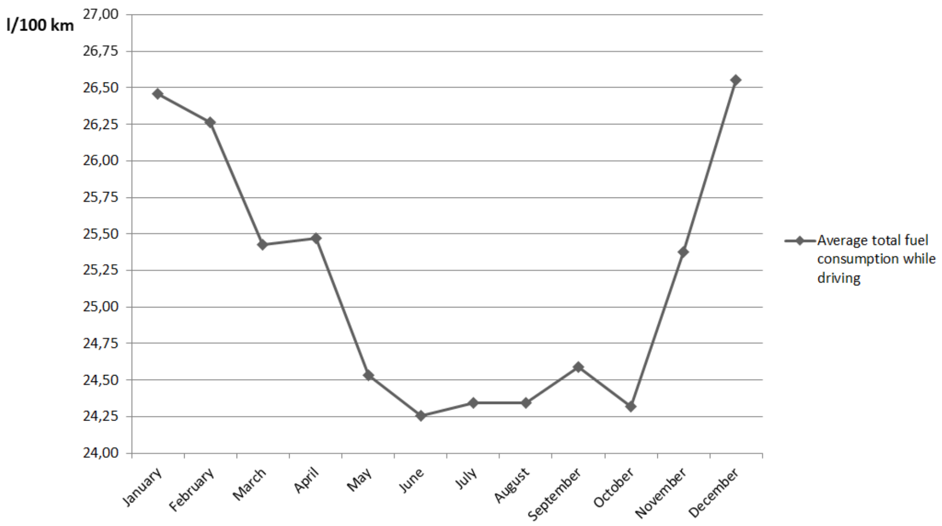
Figure 1: Average values for total fuel consumption while driving and distances travelled by transport company vehicles in 2022



Source: authors' study

Figure 2 shows that this company's 2022 vehicles significantly drive fewer kilometres in the months of January, February, April and December. The low performance in January-February may be due to the so-called "dead season" in transportation. Transportation companies report shortages at transport exchanges and a shortage of professional drivers with the right licenses who want to start working (Luksmann, 2023). Due to the long holiday period in December (free working days), the average number of kilometres travelled is lower. Despite periodic restrictions related to summer traffic bans for vehicles of more than 12 tons on weekends (starting Friday from 6 pm to 10 pm, Saturday from 8 am to 2 pm and Sunday from 8 am to 10 pm) (Magemarlog, 2023), the average distance travelled increased steadily, and in the autumn season, when restrictions on the movement of these vehicles ceased to apply, it increased by an estimated 900 km until the end of this season. The graph of the data confirms that the total fuel consumption during driving depends on the number of kilometres travelled. As the distance travelled increases, the total driving fuel consumption also increases but to varying degrees. Therefore, it is also worth examining the average total driving fuel consumption per 100 km.

Figure 2: Average driving fuel consumption of all transport company vehicles in 2022



Source: Authors' study

Figure 3 shows how the spring-summer season affects diesel consumption. This value is definitely lower than that in the autumn-winter season. The average total driving fuel consumption of all vehicles throughout the year is 25,16 l/100 km, and the amplitude over a twelve-month period is 2,3 l/100 km.

Table 1: Performance data of all vehicles - average of all months of 2022

Vehicle	y	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	z_1	z_2	z_3	z_4	z_5
1	3 361,14	13 636	632 103	8,8	986	76,93	428 734	5 260	29 219	1	0	0	0	0
2	2 388,53	10 034	504 756	8,0	963	71,51	310 798	6 149	18 879	1	0	0	0	0
3	3 427,61	13 892	649 956	8,7	981	75,88	406 930	5 497	20 304	1	0	0	0	0
4	2 568,13	10 429	514 773	7,2	981	72,99	281 161	6 453	23 666	1	0	0	0	0
5	3 849,95	15 523	714 477	6,9	987	77,49	503 144	5 139	22 292	1	0	0	0	0
6	2 832,33	11 714	564 536	6,5	976	74,50	339 526	4 398	26 462	1	0	0	0	0
7	4 280,48	18 875	829 717	4,1	1 039	81,90	587 619	5 812	19 821	0	1	0	0	0
8	4 208,35	18 863	828 583	7,4	1 001	81,94	380 770	7 117	12 902	0	1	0	0	0
9	4 709,18	20 055	881 137	4,1	1 008	81,94	501 804	7 723	13 860	0	1	0	0	0
10	4 159,28	19 141	882 834	5,3	978	78,05	479 811	4 333	18 694	0	1	0	0	0
11	4 289,33	19 194	834 587	7,8	1 017	82,77	621 207	5 266	15 661	0	1	0	0	0
12	5 317,41	22 913	1 031 704	3,9	982	79,93	708 924	5 933	20 840	0	1	0	0	0
13	4 695,09	20 324	897 915	8,0	1 020	81,55	618 972	5 241	21 461	0	1	0	0	0
14	4 791,62	20 854	922 689	8,0	1 014	81,37	664 333	5 263	18 787	0	1	0	0	0
15	4 431,22	20 341	885 673	6,6	1 015	82,67	612 498	5 210	17 888	0	1	0	0	0
16	4 250,13	19 091	836 730	8,1	1 029	82,14	553 056	3 690	28 521	0	1	0	0	0
17	4 499,88	19 686	872 233	7,6	1 017	81,10	626 686	4 676	26 459	0	1	0	0	0
18	4 601,68	20 135	880 520	7,1	1 024	82,31	520 298	6 743	12 509	0	1	0	0	0
19	4 572,44	19 534	866 654	5,9	1 010	81,10	540 218	6 478	21 392	0	1	0	0	0
20	4 156,78	18 421	803 228	7,5	1 008	82,49	563 506	3 232	19 140	0	1	0	0	0
21	4 356,55	19 226	833 330	5,1	1 029	83,07	588 368	4 615	21 304	0	1	0	0	0
22	3 890,27	13 100	625 263	7,4	1 068	75,34	414 347	5 054	36 628	0	0	0	1	0
23	2 866,10	11 245	543 683	7,0	1 082	74,19	282 729	3 991	28 322	0	0	0	1	0
24	3 309,61	11 678	562 290	7,9	1 097	74,78	34 602	4 039	31 944	0	0	0	1	0
25	3 242,42	11 279	541 801	7,6	1 115	74,99	364 057	3 778	34 895	0	0	0	1	0
26	3 348,88	12 411	597 513	6,9	1 087	74,39	207 116	4 948	52 456	0	0	0	1	0
27	3 305,48	13 131	603 947	7,4	1 124	77,49	334 450	5 168	18 060	0	0	0	0	1
28	3 402,42	13 356	621 223	4,2	1 108	75,87	353 493	5 094	29 824	0	0	0	0	1
29	1 775,57	6 640	347 155	6,7	1 002	67,53	116 203	3 446	11 080	0	0	0	1	0
30	2 970,49	10 744	516 692	6,3	1 084	74,71	269 728	3 812	6 963	0	0	0	1	0
31	2 982,34	11 535	566 239	6,2	1 057	73,37	307 832	5 041	26 582	0	0	0	1	0
32	2 852,47	10 790	546 276	6,8	1 068	71,00	334 896	6 368	29 500	0	0	0	0	1
33	2 944,62	10 778	530 629	5,5	1 091	72,39	275 547	4 174	31 090	0	0	0	0	1
34	3 439,43	12 243	587 897	7,1	1 100	74,93	80 110	4 940	15 228	0	0		0	1
35	3 216,30	11 745	572 152	5,8	1 062	73,75	353 695	5 388	23 732	0	0	0	0	1
36	3 327,35	11 808	569 248	6,5	1 085	74,48	340 656	4 373	30 326	0	0	0	0	1
37	3 227,23	11 666	575 388	6,9	1 101	72,93	251 078	5 223	29 835	0	0	1	0	0
38	3 222,93	11 852	569 199	6,4	1 101	74,73	396 477	6 473	23 670	0	0	1	0	0
39	3 264,28	13 539	623 942	7,7	1 088	77,74	355 995	5 587	18 086	0	0	0	0	1
40	2 824,34	10 951	532 689	8,1	970	73,71	216 146	8 207	12 218	1	0	0	0	0
41	3 825,22	14 894	697 821	8,7	995	76,33	464 235	5 791	24 601	1	0	0	0	0
42	4 063,65	14 428	677 901	7,5	1 101	75,58	404 260	4 610	25 494	0	0	1	0	0
43	5 038,89	18 158	838 086	7,5	1 121	77,09	511 743	6 642	23 036	0	0	1	0	0
44	2 968,72	11 355	557 144	6,7	1 080	73,44	253 432	7 885	19 536	0	0	1	0	0
45	3 812,48	14 082	675 737	6,5	1 085	74,29	353 319	5 841	31 126	0	0	0	1	0
46	3 765,68	13 422	654 378	6,5	1 095	73,76	22 701	4 287	12 564	0	0	0	1	0
47	3 024,18	11 393	550 159	6,1	777	74,17	222 640	3 282	5 841	0	0	0	1	0
48	3 825,31	15 054	682 072	6,1	1 099	79,23	150 512	4 077	40 315	0	0	0	0	0
49	4 461,34	17 365	776 144	8,0	1 137	80,03	519 552	4 238	11 579	0	0	0	0	1
50	2 807,54	10 218	498 992	7,2	832	73,68	184 234	4 234	18 903	0	0	1	0	0
51	2 529,32	10 218	503 770	8,2	1 049	73,12	221 223	4 716	28 045	0	0	1	0	0
52	3 668,14	13 411	626 558	8,0	1 125	76,59	190 373	4 579	29 319	0	0	0	1	0
53	3 842,57	13 112	617 036	7,7	1 088	76,29	240 623	5 603	21 742	0	0	0	1	0
54	2 950,81	10 932	533 356	7,2	1 069	73,69	350 381	4 616	17 345	0	0	0	1	0
55	3 164,26	11 140	539 171	7,3	1 089	74,26	290 993	4 896	38 205	0	0	0	1	0

By analysing Figures 2 and 3, it can be concluded that the season of the year has a strong influence on the distances travelled and fuel consumption at this company. This is a hint to those who manage the company's processes, i.e., the organization of transportation and the management of the company's financial resources. With this analysis, the company's capital can be managed more effectively. During the summer period, you can make more investments because this period for the company is the most profitable, and during the winter period, you look for solutions or new customers to avoid the negative impact of the "dead season". Considering that the fuel consumption of driving is higher during this period, the rates per kilometre should also be proportionally higher.

Using the data in Table 1, a linear model was estimated:

$$y = -337{,}093 + 0{,}275x_1 - 613{,}875z_2 + 292{,}279z_3 + 348{,}960z_4 + 159{,}825z_5 \quad (1)$$

Each factor included in the model has the following interpretation:

- An increase in vehicle miles travelled by 1 km results in an increase in total driving fuel consumption of 0,275 l, ceteris paribus.
- In the case of the DAF automobile type LowDeck, the total fuel consumption while driving decreases by 613,875 l ceteris paribus.
- for Volvo autos type: Standard, total fuel consumption while driving increases by 292,279 l ceteris paribus.
- For the Volvo automobile type, LowDeck, total fuel consumption while driving increases by 348,960 l, ceteris paribus.
- For the Mercedes-Benz automobile type, LowDeck, total fuel consumption while driving increases by 159,825 l ceteris paribus.

The model's R-square coefficient of determination is approximately 0,973 (the model created describes 97,3% of the variation (variance) in total fuel consumption during driving). White's test for heteroskedasticity showed that the least squares method was correctly used to create the model. This test verifies that the variance of the residuals in the model is constant. This finding verifies whether the random component is homoskedastic or whether it is responsible for heteroskedasticity (Wikipedia, 2023). If heteroskedasticity occurs, the resulting estimators (statistics used to estimate population parameters) are consistent but not loaded and inefficient. Loaded estimators of the variance of the random component may occur in this case. This leads to errors in statistical inference (McCulloch, 1985). An evaluation of the collinearity of the explanatory variables entered into the model indicates that there are no collinearity problems. The average observed total fuel consumption while driving differed from these model values by 0,03596 (3,6%), assuming a maximum allowable difference of 5%. It can be concluded that the impact of the random factor is not large.

Significance levels of the model factors:

- $x_1 = 1{,}61e^{-31}$;
- $z_2 = 5{,}47e^{-9}$;
- $z_3 = 5{,}09e^{-5}$;
- $z_4 = 1{,}13e^{-7}$;
- $z_5 = 0{,}0149$.

Other factors (x_2, x_3, x_4, x_5, x_6, x_7, x_8, z_1) were not used in the model, as they had no significant effect on this data sample (p>5%) in the created linear model.

The model meets all the specified conditions and has the highest coefficient of determination R2. According to the model created, the extent to which the fuel consumption per 1 km for fleet vehicles increases can be determined if other factors remain unchanged. It also shows how vehicle models and types affect total fuel consumption when driving in the year under study. On this basis, transport managers can more easily estimate the minimum rate at which transport orders achieve the desired profit since they can estimate fuel costs. The results also suggest which car models are the most efficient in terms of fuel consumption levels. The model clearly shows that by choosing DAF LowDeck autos, the total fuel consumption was lower than that of other brands. For example, if the company had used 5 DAF LowDeck vehicles instead of Volvo LowDeck vehicles to carry out transport orders, it would have had to purchase 3 069,38 l less diesel fuel on average per month. At the current wholesale price of diesel fuel (5,10 PLN/l net) (Hawa, 2023), 15,653,84 PLN net is saved. When Mercedes-Benz cars of the LowDeck type are used, consumption increases, but not as much as when Volvo cars of the Standard and LowDeck types are used. When investing in new vehicles for the fleet of a transport company, it is worth considering the model created.

Since DAF LowDeck vehicles affect the reduction of total driving fuel consumption in this transport company, the next stage of the research will be to check the data of fifteen 355 kW DAF XF 106 LowDeck vehicles in the months of March, June, September, and December corresponding to the end of the calendar year quarters to determine whether the same factors affect the end result of fuel consumption in these months as in the data model in Table 1. All of the vehicles in this trial are driven by double crews (two drivers) that perform similar shuttle routes (Poland - Bennelux/Germany/Denmark) of the same design (configuration) and were manufactured at the same time (Q1 2021). All of these features are key to minimizing survey errors associated with varying site specifications. Each vehicle is also equipped with predictive cruise control (PCC) and TraXon automatic transmission software, which, based on the GPS module, constantly monitors the topography of the terrain and the actual vehicle load and creates the best mode for the vehicle at any given time (increasing prediction and ergonomics) (Daftrucks, 2023).

Table 2: Performance data of fifteen DAF LowDeck vehicles March 2022

Vehicle	y	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
1	5 396,30	23999,37	1044950	4,4	1 034	82,68	799949	6147	23190
2	5 272,90	22563,65	991394	6,7	1 003	81,93	675558	7752	16145
3	5 858,90	23387,86	1032496	3,1	1 000	81,55	437837	9553	17701
4	5 154,60	23391,26	1077762	5,0	972	78,13	689596	4876	23138
5	5 045,20	21892,59	946942	8,1	1 014	83,23	718996	5210	16333
6	5 938,50	25052,15	1134196	5,5	973	79,52	792477	6519	20111
7	5 198,10	22796,35	999012	8,0	1 014	82,15	750584	5224	18041
8	5 487,40	23265,77	1038404	8,3	1 014	80,66	586614	5970	25063
9	4 970,90	23017,06	992888	7,1	1 015	83,45	731786	5214	18736
10	4 551,90	20076,42	879274	8,1	1 026	82,20	669209	4040	29269
11	5 608,10	24136,49	1073512	7,4	1 016	80,94	799503	4745	33664
12	5 313,60	23272,37	1015347	6,8	1 034	82,51	648721	7355	15298
13	5 540,80	22479,97	990706	7,3	1 016	81,69	594285	7205	22916
14	4 741,40	21117,28	918399	7,4	1 008	82,78	655789	3261	18650
15	4 957,90	22284,98	955432	5,0	1 025	83,97	696183	4389	21446

The estimated and selected best linear model made from the data x_n from Table 2 has the following form:

$$y = 783{,}4 + 0{,}0038x_2 + 0{,}1086x_7 \tag{2}$$

The R-square coefficient of determination is approximately 0,868 (the model created describes 86,8% of the variability (variance) of total fuel consumption during driving). White's test for heteroskedasticity showed that the least squares method was correctly used to create the model. An evaluation of the collinearity of the explanatory variables entered into the model indicates that there are no collinearity problems. The average observed total fuel consumption while driving differed from these model values by 0,02879 (2,88%). That is, the influence of the random factor is small and within a fixed value. The model reads as follows:

- When the duration of driving increases by 1 s, the total fuel consumption increases by 0,0038 l, ceteris paribus. A 1 h increase in driving duration is associated with 13.68 l of fuel consumption.
- When the number of braking cycles (the number of times the service brake is used) increases by 1 unit, the driving fuel consumption increases by 0,1086 l ceteris paribus.

Factor x_2 (driving time) in this model has a significance level of p=0,0001, and factor x_7 (number of braking events) has a significance level of p=0,0017. Other factors (x_1, x_3, x_4, x_5, x_6, x_8) were not used in the model because for this sample, they had no significant impact (p>5%).

Table 3: Performance data of fifteen DAF LowDeck vehicles June 2022

Vehicle	y	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
1	4 564,70	20235,30	895112	4,4	1 042	81,54	639503	6433	23840
2	4 356,00	20429,17	892586	8,1	1 000	81,61	480506	8556	15230
3	4 332,40	16763,08	891223	4,0	1 011	82,52	542651	7487	12697
4	3 681,00	19585,19	772158	3,9	978	78,15	397647	3523	17985
5	4 193,50	23509,41	842475	7,4	1 031	83,69	653990	4633	15192
6	5 260,80	22535,77	1055102	3,2	993	80,21	719221	6358	24537
7	4 828,30	22906,51	1001247	7,4	1 013	81,03	697655	6205	20461
8	5 153,20	20417,10	1014898	8,0	1 013	81,25	750047	5591	23453
9	4 312,80	18707,43	899640	7,3	1 017	81,70	647215	6689	20409
10	4 170,80	21774,45	837966	8,8	1 034	80,37	609786	4743	34532
11	4 756,90	22684,50	964256	8,1	1 024	81,29	747369	4285	36661
12	5 061,80	21154,04	987127	6,9	1 025	82,73	611029	7008	15476
13	4 772,90	19412,75	940562	4,5	1 010	80,97	577585	7377	24657
14	4 161,30	19888,16	848254	7,7	1 009	82,39	602598	3424	19635
15	4 239,70	20235,30	865847	4,8	1 016	82,69	578405	5219	22864

The estimated and selected best linear model made from the data x_n from Table 3 has the following form:

$$y = -496{,}273 + 0{,}0055x_2 \quad (3)$$

The R-square coefficient of determination is approximately equal to 0.953 (the model created describes 95.3% of the variation (variance)). White's test for heteroskedasticity showed that the least squares method was correctly used to create the model. There were also no problems with assessing collinearity of the explanatory variables. The average observed total fuel consumption while driving differed from these model values by 0.02181 (2.18%), which means that the influence of the random factor in this model is within a fixed value and has a negligible effect on the final result. The model reports that for a 1 s increase in driving duration, total driving fuel consumption increases by 0,0055 l, ceteris paribus. A 1 h increase in driving duration is 19.8 l of fuel consumption, ceteris paribus. Factor x_2 (driving time) in this model has a level of significance of p=5,02e^{-10}. Other factors (x_1, x_3, x_4, x_5, x_6, x_7, x_8) were not used because for this sample, they had no significant impact (p>5%).

Table 4: Performance data of fifteen DAF LowDeck vehicles September 2022

Vehicle	y	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
1	5 293,90	23677,30	1049326	4,1	1 049	81,23	708644	8483	29814
2	4 618,00	21493,43	932973	7,8	1 006	82,94	443076	7883	14693
3	4 941,90	22311,03	973937	3,8	1 023	82,47	631161	8508	14436
4	4 624,40	22351,21	1029874	5,3	978	78,13	602402	5000	20636
5	4 645,10	20534,20	898850	7,9	1 017	82,24	627587	6304	19785
6	5 630,60	24449,69	1098954	4,9	986	80,09	745637	7318	24192
7	5 309,80	22677,63	1013804	8,4	1 031	80,53	722649	6851	30237
8	5 100,50	22889,10	1015751	7,9	1 020	81,12	743592	6286	22084
9	4 647,30	21987,94	955272	6,6	1 017	82,86	754147	5812	19144
10	4 629,20	21945,52	961504	7,7	1 030	82,17	761201	4449	31756
11	5121,3	22778,58	1001134	6,4	1 024	81,91	751276	6498	14323
12	4 886,90	21401,29	934847	7,0	1 022	82,41	516696	7496	12913
13	4 206,50	18253,50	817803	5,9	1 011	80,35	501482	8089	23750
14	3 118,30	14331,66	629436	7,5	1 009	81,97	452577	2522	16472
15	4 694,90	21692,01	938002	5,4	1 031	83,25	666844	5522	23131

The estimated and selected best linear model made from the data x_n from Table 4 has the following form:

$$y = 117{,}763 + 0{,}0044x_2 + 0{,}0762x_7 \quad (4)$$

The coefficient of determination R-square is approximately equal to 0,929 (the created model describes 92,9% of the variation (variance) of "y". In the model, there is no heteroskedasticity in the residuals, so the least squares method was correctly used to create the model. There are also no problems with assessing the collinearity of the explanatory variables entered into the model. The average observed total fuel consumption while driving differed from these model values by 0,03516 (3,52%), so the impact of the random factor was negligible.

The model shown in Table 4 describes the following:

- As the driving duration increases by 1 s, the total driving fuel consumption increases by 0,0044 l, ceteris paribus. A 1 h increase in driving duration is a consumption of 15,84 l of fuel, ceteris paribus.
- When the amount of braking (the number of service brakes used) increases by 1 unit, the driving fuel consumption increases by 0,0762 l ceteris paribus.

Factor x_2 in this model has a significance level of p=6,66e^{-7}, and factor x_7 has a significance level of p=0.0316. The other factors (x_1, x_3, x_4, x_5, x_6, x_8) were not used in the model because for this sample, they had no significant impact (p>5%).

Table 5: Performance data of fifteen DAF LowDeck vehicles December 2022

Vehicle	y	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
1	5 293,90	23677,30	1049326	4,1	1 049	81,23	708644	8483	29814
2	4 618,00	21493,43	932973	7,8	1 006	82,94	443076	7883	14693
3	4 941,90	22311,03	973937	3,8	1 023	82,47	631161	8508	14436
4	4 624,40	22351,21	1029874	5,3	978	78,13	602402	5000	20636
5	4 645,10	20534,20	898850	7,9	1 017	82,24	627587	6304	19785
6	5 630,60	24449,69	1098954	4,9	986	80,09	745637	7318	24192
7	5 309,80	22677,63	1013804	8,4	1 031	80,53	722649	6851	30237
8	5 100,50	22889,10	1015751	7,9	1 020	81,12	743592	6286	22084
9	4 647,30	21987,94	955272	6,6	1 017	82,86	754147	5812	19144
10	4 629,20	21945,52	961504	7,7	1 030	82,17	761201	4449	31756
11	5121,3	22778,58	1001134	6,4	1 024	81,91	751276	6498	14323
12	4 886,90	21401,29	934847	7,0	1 022	82,41	516696	7496	12913
13	4 206,50	18253,50	817803	5,9	1 011	80,35	501482	8089	23750
14	3 118,30	14331,66	629436	7,5	1 009	81,97	452577	2522	16472
15	4 694,90	21692,01	938002	5,4	1 031	83,25	666844	5522	23131

The estimated and selected best linear model made from the data x_n from Table 5 has the following form:

$$y = -451{,}701 + 0{,}0061x_2 \quad (5)$$

When the driving duration increases by 1 s, the total driving fuel consumption increases by 0,0061 l, ceteris paribus. A 1 h increase in driving duration is an increase in driving fuel consumption by 21,96 l of fuel, ceteris paribus. Its coefficient of determination R-square is approximately 0,925 (the model created describes 92,5% of the variation (variance)). The facto x_2 in this model has a significance level of p=1,05e^{-8}. The other factors were not used in the model because they had no significant effect on this sample. The effect of the random factor is small, as the average observed total fuel consumption while driving differed from these model values by 0,04739 (4,74%) according to the models for the designated data from Tables 2, 3, 4 and 5. The most significant factor affecting total fuel consumption while driving is x_2, and each of them indicates that increasing the duration of driving by 1 s increases the total fuel consumption of driving while keeping other factors unchanged. This can be interpreted to mean that the longer the driving duration is, the more unfavourable the driving duration is from a fuel (diesel) consumption perspective. For example, based on the model for the data in Table 2, at an average highway speed (80 km/h), the model describes a consumption of 17,1 l Ceteris paribus, while at a speed in built-up areas (50 km/h), the model describes a consumption of 27,36 l. This is a hint to transport managers that when planning the routing of transport tasks for this sample of vehicles, it is better to choose highway routes that avoid urbanized areas (limiting the average speed of travel). Additionally, in the months of March and September, the factor of x_7. Thus, the driver's driving technique related to effective braking becomes crucial. Arriving at a parking space or intersection becomes more economical if the vehicle precipitates by downshifting to lower gears without using a service brake (Farion & Zbadyński, 2019). This results in a fuel consumption of 0, and the wear and tear on the vehicle's brakes are reduced. Models indicate that each precipitation vehicle speed also increases the energy loss produced by diesel fuel consumption and, at the same time, causes faster wear of the vehicle's braking components, which entails additional costs for the transport company.

4. Conclusion

The transport company did not lend information related to the cost of implementing and using the transics telematic system. Considering the above data, the cost of purchasing equipment for 55 vehicles is 46,750 €, which is 207,607,4 PLN at the current average exchange rate of the euro (4,4408 PLN/€) (InternetowyKantor, 2023). The external costs of installation (use of third-party services) are not included because the company has its own service, or when buying new vehicles, the installation of the devices was carried out by an authorized dealer (dealer) of the brand of the purchased vehicle as an additional free service (free of charge). The monthly cost for the use of 55 devices (subscription) is 1,650 € (7 327,32 PLN). Interestingly, with this number of device subscriptions, the repair costs associated with their damage (manufacturing defects) are on the side of the service provider (Zf, 2023). In summary, the estimated cost of implementing and using the telematics system for one year for the surveyed transport company is 295 535,24 PLN. Considering the degree of use of the transics telematics system at the studied company, which facilitates the management of transport processes and collects relevant operational and economic data, many benefits can translate into capital.

The analysis of all the factors acquired through the telematic system at the transport company allows us to conclude that the implementation of this system undoubtedly provides benefits. Therefore, the level of control over the company's costs increases due to the data it has and the possibility of analysing and reducing them. A transics telematics system is a solid basis for determining employees' knowledge of the influence of various factors on the final costs associated with diesel consumption. It can be a tool for business development because of its ability to create models that can become the basis for important decisions related to investment in the purchase of specific vehicle models and in planning and accepting favourable transportation orders. The data can also be used to introduce ecodriving, which contributes to improving the operation of a transport company's fleet (Farion, & Zbadyński, 2019). The cost of training for one driver with a C+E licence in ecodriving using the services of training companies is 400 PLN. The training included a two-hour theoretical lecture and 1 practical hour (driving a truck) (Kierowcasieszkoli, 2023). With a fleet of 55 vehicles, the total cost for all drivers is between 22 000 PLN and 44 000 PLN. The indicated range depends on whether the vehicles are driven by single or double crews. For this company, it would be better to hire a driving technique instructor responsible for training in the driving style of drivers in a practical form and a person who analyses data related to fuel-efficient driving obtained from the telematics system. The average cost of hiring a driving technique instructor is 5 710 PLN gross (Pracuj, 2023) per month, and the average cost of managing, analysing and executing reports (operation and administration of databases from the telematics system) is 7 951 PLN gross (Poradnikpracownika, 2023) per month. This is more convenient because with this number of vehicles of the company under study, there is a high turnover in the employment of professional drivers, and it will allow continuous control over the progress of their driving technique (verification of training results). Studies have indicated that eco-driving can improve fuel economy by 15-25% (Zhou, Jin, & Wang, 2016). With the calculated average monthly value of total fuel consumption while driving in 2022 vehicles in the studied company (3 616,50 l), fuel savings were in the range of 542,48 l 904,13 l. Considering all vehicles, the range would be 29 836,40 l – 49 727,15 l savings per month. This gives a monthly savings of 152 165,64 PLN – 253 608,47 PLN net. Ecodriving also has an impact on reducing the rate of wear and tear on worn parts (Farion & Zbadyński, 2019). In addition, the transics telematics system at the surveyed company is so optimized that it can automatically generate ready-made driving style assessment reports for each driver; only the creation of a driving technique assessment model at the company's discretion is needed. The introduction of a telematic system as a basis for the implementation of ecodriving is proving to be very cost-effective. Deducting the cost of introducing the telematics system, the cost of purchasing telematic equipment and its subscription for a year, and the cost of employing 2 ecodriving specialists (a trainer and a data administrator) for a year from the minimal annual savings on fuel consumption after the introduction of ecodriving results in a considerable savings of 1 366 520 PLN a year.

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Conflicts of Interest

The authors declare no conflict of interest.

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