Галицький економічний вісник https://doi.org/10.33108/galicianvisnyk_tntu
Galician economic journal, No 3 (100) 2026
https://doi.org/10.33108/galicianvisnyk_tntu2026.03
ISSN 2409-8892. Web: **http://galicianvisnyk.tntu.edu.ua**

UDC 656.13:658.7:338.47

ANALYSIS OF TRANSPORTATION COSTS FOR THE SUPPLY CHAIN OPTIMISATION

Jarosław Ziółkowski
Military University of Technology, Warsaw, Poland
ORCID: 0000-0001-8880-5142

Volodymyr Hutsaylyuk
Military University of Technology, Warsaw, Poland
ORCID: 0000-0003-4812-5737

Lyubomir Antonov
Varna Free University, Varna, Bulgaria
ORCID: 0009-0006-6238-9017

Iryna Martyniak
Ternopil Ivan Puluj National Technical University, Ternopil, Ukraine
ORCID: 0000-0003-0224-6410

Summary. *Supply chain optimisation is a key factor in the operations of trading companies. Depending on the characteristics of the target market, companies can optimise costs by analysing factors such as seasonality, supply routing, vehicle type, and whether to use their own fleet or logistics intermediaries. An important factor is the choice of transportation mode for products from the supplier to the trading intermediaries. The choice of transport mode depends on several factors, such as the type and size of cargo, the distance to be travelled, delivery time, and costs. Economic considerations are always important and should be carefully assessed, as transport costs constitute the primary and largest share of a distribution company's expenses. This paper analyses three options for delivering goods by road. The first option involves using a transport company, which is responsible for the timely and safe delivery of cargo within the supply chain. The second option is based on an agreement in which the leasing company provides the vehicle in exchange for regular leasing payments from the customer. The third option is an agreement to use the vehicle for a longer (contractual) period, without the need to purchase it, known as long-term rental. The study period was one calendar year, for which operating costs were estimated for each option. Due to seasonality, these costs for each option are presented in detail monthly (Table 2, Table 3, and Table 4). Next, the average variable unit delivery cost for each option was estimated, along with the fixed costs, which were understandably omitted for the outsourcing option. Expected values were then calculated, a break-even analysis was performed, and conclusions were developed. The use of effective, clear, and understandable mathematical analysis tools allows companies to optimise costs as much as possible, which is especially relevant amid instability in global fuel and lubricant prices. It also serves as a basis for strategic decisions that ensure the sustainable development of companies.*

Key words: *road transport, supply chain, cost analysis, expected value, break-even point.*

Received 07.03.2026
Accepted 21.03.2026
Published 25.06.2026

UDC 656.13:658.7:338.47

АНАЛІЗ ТРАНСПОРТНИХ ВИТРАТ ДЛЯ ОПТИМІЗАЦІЇ ЛАНЦЮГА ПОСТАВОК

Ярослав Зьолковський
Військовий технологічний університет, Варшава, Польща

Володимир Гуцайлюк
Військовий технологічний університет, Варшава, Польща

Любомир Антонов
Вільний університет Варни, Варна, Болгарія

Ірина Мартиняк
Тернопільський національний технічний університет імені Івана Пулюя, Тернопіль, Україна

Резюме. *Оптимізація ланцюга поставок є одним із визначальних факторів діяльності торговельних фірм. Залежно від особливостей цільового ринку, фірми можуть оптимізувати власні витрати на основі* *аналізу різних факторів, включаючи сезонність, маршрутизацію поставок, вибір виду транспортного засобу, використання власного автопарку чи послуг логістичних посередників. Важливим фактором є вибір виду транспортування продукції від постачальника до торговельних посередників. Вибір виду транспорту залежить від кількох факторів, таких як тип вантажу, що перевозиться, його розмір, відстань транспортування, час доставки та витрати. Економічні розрахунки завжди превалюють та повинні бути ретельно оцінені, оскільки транспортні витрати складають основну та найбільшу частку витрат дистриб'юторської компанії. Проаналізовано три варіанти доставки товарів автомобільним транспортом. Перший варіант передбачає використання послуг транспортної компанії, яка бере на себе відповідальність за своєчасну та безпечну доставку вантажу в межах ланцюга поставок. Другий варіант базується на угоді, за якою лізингова компанія надає транспортний засіб в обмін на регулярні лізингові платежі від клієнта. Третій варіант – це угода, що передбачає використання транспортного засобу протягом тривалішого (договірного) періоду, але без необхідності його придбання, тобто довготривала оренда. Період дослідження становив один календарний рік, протягом якого експлуатаційні витрати оцінювалися для кожного варіанту. Через сезонність ці витрати для кожного варіанту детально представлені помісячно (Таблиця 2, Таблиця 3 та Таблиця 4). Далі оцінено середню змінну вартість доставки одиниці товару для кожного варіанту, а також постійні витрати, які, вочевидь, були опущені для варіанту аутсорсингу. Розраховано очікувані значення, проведений аналіз точки беззбитковості та розроблено остаточні висновки. Використання ефективного, чіткого і зрозумілого інструментарію математичного аналізу дозволить фірмам максимально оптимізувати витрати, що стає особливо актуальним в період нестабільності світових цін на паливно-мастильні матеріали. Також він є підґрунтям для прийняття стратегічних рішень, що забезпечить фірмам розвиток на принципах сталості.*

Ключові слова: *автомобільний транспорт, ланцюг поставок, аналіз витрат, очікувана вартість, точка беззбитковості.*

Дата надходження 07.03.2026
Дата прийняття 21.03.2026
Дата публікації 25.06.2026

Problem statement. The total cost of transport services is calculated by taking into account factors such as transportation time, distance, fuel and other operating costs, which affect the cost of renting a vehicle. Often, simplified indicators are conventionally accepted for calculation, in particular, the distance of cargo transportation, which allows calculating average indicators for the entire transportation. At the same time, such simplification often inaccurately reflects compensation for individual transportations.

Analysis of recent research and publications. The literature on the subject often discusses the application of linear programming problems, both single-criteria (Jung, Lee, and Lee, 2026; Youness & Lahoussine, 2026) and multi-criteria (Mohamed Alshabibi, Matar, and H. Abdelati, 2025; Topaloglu Yildiz & Doymuş, 2025). A significant part of the publications concerns the optimisation of time delivery (Ziółkowski et al., 2022), schedule (Chandiramani, Soni, and Mittal, 2026; Purshamsian et al., 2026), fleet size (Mallidis et al., 2026), the optimal choice of means of transport in terms of load capacity (Sang et al., 2025; Ziółkowski et al., 2025) and total costs of ownership (Wróblewski et al., 2021; Anussornnitisarn et al., 2025). These factors are often the primary criteria for selecting a given transportation option. A detailed analysis of road transport costs usually focuses on operating costs, which take into account factors such as cargo type, fuel type, distance, and transit time (Alves, Hora i Galvão, 2026; Gładysz et al., 2026), which are the primary selection criteria. Economic criteria include transportation costs and transportation efficiency, defined as the ability to consolidate cargo (e.g., groupage) based on the destination or customer orders. Furthermore, regularity of deliveries, scheduling (X. Zhou et al., 2026), reliability (Żurek, Zieja i Ziółkowski, 2018; Rosiński et al., 2024), and safety (T. Zhou et al., 2026) are also important. Special attention is also paid to issues such as conditions of municipal transport (Folęga et al., 2025; Guo & Zhang, 2026). However, the economic foundation of transport companies is revenue, which influences company profitability. Therefore, operating costs are frequently monitored, and companies try to reduce them. In (Grzelak et al., 2024), Grzelak et al. examined the economic efficiency of vehicle operation in terms of enterprise financial security. The authors investigated how the various parameters of a transport order affect its profitability.

A separate collection comprises publications on fuel consumption and atmospheric emissions (Damaziak et al., 2025). Borucka et al. (Borucka i Sobczuk, 2025) analysed the relationships among total final energy consumption in transport, CO2 emissions from transport, and government revenues, using Poland as a case study. Results indicate that energy consumption in transport significantly affects both CO2 emissions and government revenues. The study (Waygood et al., 2026) investigates the difficulty or ease of different climate change-related behaviours, particularly those associated with transportation. The paper also aims to examine the link between those behaviours and a robust measure of individuals' environmental behaviours and attitudes, the Climate Change Stage of Change (CC-SoC). Authors in (F. Wang et al., 2026) identified a lack of systematic quantification of their carbon emission reduction efficiency, which hindered comparative evaluation and informed decision-making. This study addresses this gap by developing a carbon emission calculation framework for key energy-saving technologies, incorporating an enhanced Bass diffusion model to forecast future emissions. Research (Ferro, Leopoldo, and Maggiore, 2026) examines the economic viability and environmental impact of this innovative transport method. By utilising hydrogen for lift and incorporating a hybrid energy system, the airship ensures a cost-efficient power supply. The study specifically compares the operating costs of truck and airship fleet management along the Murcia-Munich route, highlighting key metrics such as cruise velocity, economic sustainability, and reduced greenhouse gas emissions.

A transportation scheduling problem aimed at minimising the maximum completion time, incorporating key real-world considerations such as multiple drivers, loading and unloading times, round-trip transportation, distributed logistics centres, and the deterioration effect, was developed in the paper (Lu et al., 2026). Wang et al. (Z. Wang et al., 2026) proposed a real-time risk-based dynamic optimisation model for dangerous materials transportation routes, guiding vehicles to avoid congested or incident-affected road sections. A dual-objective initial path planning model for transportation risk and cost is constructed to obtain the optimal driving path for hazardous materials vehicles under static road network conditions. The authors of the paper (Rönnqvist et al., 2026) presented a pricing model for truck transportation that extends traditional distance-based models. The new model includes measures of cost-driving factors along the route, such as hills, road surface, curves, speed limits, intersections, speed changes, long ascents, and other physical difficulties. This measure is extracted from the Calibrated Route Finder, a route selection support system used for roundwood transportation in Sweden.

Purpose of the study is to present, using the example of a rather simple supply chain, a methodology for calculating the total transport costs for three variants of road transport, including: deliveries made by the transport company (on-call delivery), leasing and long-term rental.

Statement of the task. The main tasks were to conduct a literature review of transport process modelling, highlighting the diverse set of potential criteria that depend on the objective function; to describe the model's assumptions and the calculation of total transport-related costs, including fixed and variable costs; and to present analyses of various transportation options.

During the execution of the last task, technical data was collected for the means of transport used in the analysed supply chain. Next, the average unit delivery cost per calendar year was calculated in detail for each of the three analysed transport options. (Table 2, Table 3, Table 4). Estimating this cost required taking into account monthly deliveries due to potential seasonality. The last section summarises fixed and variable costs for each transport option, calculates expected values, and conducts a break-even analysis.

Statements of the main material of the study. In this paper, we are focused on the three possible options (variants, scenarios) of road transport for meeting transport needs, i.e. deliveries made by the transport company (on-call delivery), leasing and long-term rental. Deliveries are made within the supply chain shown in Fig. 1, where: S- supplier (marked in red); R1-R4 recipients (marked in green).

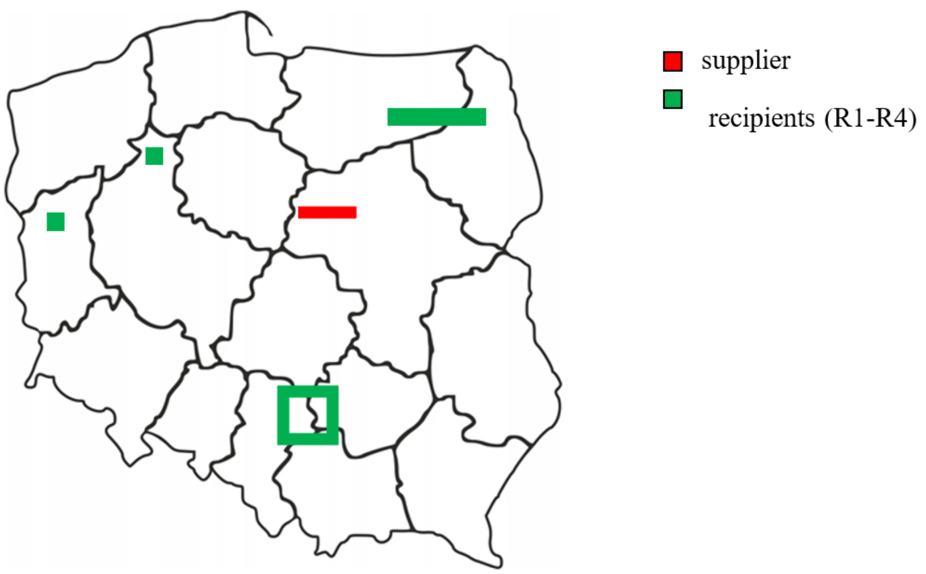

Figure 1. Key supply chain locations*

*Generated by the authors.

In the first stage of this work, it was necessary to estimate fixed and variable costs for each option, and then to analyse the expected value and the break-even point to select the best solution, with the selection criterion being total costs. Total costs are interpreted as the sum of two components, i.e. the product of the unit cost of delivery and the number of deliveries and fixed costs, according to the following equation:

$$T_C = F_C + AV_{UC} \cdot X \tag{1}$$

where: T_C – total costs;

F_c – fixed costs;

V_C – variable costs;

($V_C = AV_{UC} \cdot X$) – average variable unit cost of delivery;

X – intensity of transport work performed (measured by the number of deliveries).

Variable costs V_C depends on the number of deliveries X and the average variable unit delivery cost AV_{UC}, whereas fixed costs F_c are incurred regardless of the level of intensity of the company's activities.

The following assumptions were made to develop the model:

1. Deliveries are made only within the network.
2. The vehicle used for transportation is the Mercedes Sprinter 315 CDI (technical specification is set in Table 1).
3. Each recipient determines the number of deliveries in each month for the calendar year under analysis based on the forecasted demand.
4. For each option (variant), the unit cost of delivery should be estimated, including other types of expenses.
5. Variable costs depend on the number of deliveries during the year and the unit cost of delivery.

The first task was to estimate the unit delivery cost for each option. Table 2-4 lists the components crucial for the calculations.

Table 1. Technical specification of the transport means

Vehicle	*Mercedes*
Model of vehicle	Sprinter 315 CDI
Year of production	2023
Engine displacement	1997 [cm^3]
Engine type	Diesel
Fuel consumption (average consumption)	10,1 [l/100 km]
Monthly leasing instalment	3294 [PLN]
Monthly long-term rental instalment	2049 [PLN]

Table 2. Deliveries made by the transport company (on-call delivery)

Route	*Distance, km*	*Rate per 1 km, PLN*	*Cost of delivery, PLN*	*Number of deliveries*	*Percentag e share, %*	*Cost on the transport route, PLN*	*Average cost, PLN*	*Total costs, PLN*	*Total distance, km*
1	2	3	4	5	6	7	8	9	10
January									
S-R1	198	2,5	495	5	17	2475	426,72	17447,50	6979
S-R2	310	2,5	775	7	24	5425	1309,48		
S-R3	267	2,5	667,5	9	31	6007,5	1864,40		
S-R4	177	2,5	442,5	8	28	3540	976,55		
February									
S-R1	198	2,5	495	8	29	3960	1131,43	17045,00	6818
S-R2	310	2,5	775	8	29	6200	1771,43		
S-R3	267	2,5	667,5	7	25	4672,5	1168,13		
S-R4	177	2,5	442,5	5	18	2212,5	395,09		
March									
S-R1	198	2,5	495	9	30	4455	1336,50	16310,00	6524
S-R2	310	2,5	775	5	17	3875	645,83		
S-R3	267	2,5	667,5	4	13	2670	356,00		
S-R4	177	2,5	442,5	12	40	5310	2124,00		
April									
S-R1	198	2,5	495	3	11	1485	159,11	18260,00	7304
S-R2	310	2,5	775	5	18	3875	691,96		
S-R3	267	2,5	667,5	18	64	2670	7723,93		
S-R4	177	2,5	442,5	2	7	5310	63,21		
May									
S-R1	198	2,5	495	5	16	2475	399,19	17207,50	6883
S-R2	310	2,5	775	7	23	5425	1225,00		
S-R3	267	2,5	667,5	4	13	2670	344,52		
S-R4	177	2,5	442,5	15	48	6637,5	3211,69		
June									
S-R1	198	2,5	495	10	33	4950	1650,00	18260,00	7304
S-R2	310	2,5	775	8	27	6200	1653,33		
S-R3	267	2,5	667,5	8	27	5340	1424,00		
S-R4	177	2,5	442,5	4	13	1770	236,00		
July									
S-R1	198	2,5	495	2	6	990	63,87	16717,50	6687
S-R2	310	2,5	775	6	19	4650	900,00		
S-R3	267	2,5	667,5	4	13	2670	344,52		
S-R4	177	2,5	442,5	19	61	8407,50	5152,98		
August									
S-R1	198	2,5	495	7	23	3465	782,42	18770,00	7508
S-R2	310	2,5	775	8	26	6200	1600,00		
S-R3	267	2,5	667,5	9	29	6007,50	1744,11		
S-R4	177	2,5	442,5	7	23	3097,50	699,44		

End of the table 2

1	2	3	4	5	6	7	8	9	10
September									
S-R1	198	2,5	495	3	10	1485	148,50	19360,00	7744
S-R2	310	2,5	775	7	23	5425	1265,83		
S-R3	267	2,5	667,5	16	53	10680	5696,00		
S-R4	177	2,5	442,5	4	13	1770	236,00		
October									
S-R1	198	2,5	495	5	16	2475	399,19	16445,00	6578
S-R2	310	2,5	775	2	6	1550	100,0		
S-R3	267	2,5	667,5	8	26	5340	1378,06		
S-R4	177	2,5	442,5	16	52	7080	3654,19		
November									
S-R1	198	2,5	495	12	40	5940	2376,0	17915,00	7166
S-R2	310	2,5	775	8	27	6200	1653,33		
S-R3	267	2,5	667,5	6	20	4005	801,00		
S-R4	177	2,5	442,5	4	13	1770	236,00		
December									
S-R1	198	2,5	495	16	53	7920	4224,00	16892,50	6757
S-R2	310	2,5	775	7	23	5425	1265,83		
S-R3	267	2,5	667,5	2	7	1335	89,00		
S-R4	177	2,5	442,5	5	17	2212,50	368,75		

Table 3. Deliveries made by the leasing

Route	*Distance, km*	*Rate per 1 km, PLN*	*Cost of delivery, PLN*	*Number of deliveries*	*Percentage share, %*	*Cost on the transport route, PLN*	*Average cost, PLN*	*Total costs, PLN*	*Total distance, km*
1	2	3	4	5	6	7	8	9	10
January									
S-R1	198	0,6	118,79	5	17	593,94	102,40	4186,98	6979
S-R2	310	0,6	185,98	5	24	1301,87	314,24		
S-R3	267	0,6	160,18	9	31	1441,66	447,41		
S-R4	177	0,6	106,19	8	28	849,52	234,35		
February									
S-R1	198	0,6	118,79	8	29	950,30	271,52	4090,39	6818
S-R2	310	0,6	185,98	8	29	1487,85	425,10		
S-R3	267	0,6	160,18	7	25	1121,29	280,32		
S-R4	177	0,6	106,19	5	18	530,95	94,81		
March									
S-R1	198	0,6	118,79	9	30	1069,09	320,73	3914,01	6524
S-R2	310	0,6	185,98	5	17	929,91	154,96		
S-R3	267	0,6	160,18	4	13	640,74	85,43		
S-R4	177	0,6	106,19	12	40	1274,27	509,71		
April									
S-R1	198	0,6	118,79	3	11	356,36	38,18	4381,96	7304
S-R2	310	0,6	185,98	5	18	929,91	166,05		
S-R3	267	0,6	160,18	18	64	2883,31	1853,56		
S-R4	177	0,6	106,19	2	7	212,38	15,17		
May									
S-R1	198	0,6	118,79	5	16	593,94	95,80	4129,39	6883
S-R2	310	0,6	185,98	7	23	1301,87	293,97		
S-R3	267	0,6	160,18	4	13	640,74	82,68		
S-R4	177	0,6	106,19	15	48	1592,84	770,73		
June									
S-R1	198	0,6	118,79	10	33	1187,88	395,96	4381,96	7304
S-R2	310	0,6	185,98	8	27	1487,85	396,76		
S-R3	267	0,6	160,18	8	27	1281,47	341,73		
S-R4	177	0,6	106,19	4	13	424,76	56,63		

End of the table 3

July									
1	2	3	4	5	6	7	8	9	10
S-R1	198	0,6	118,79	2	6	237,58	15,33	4011,80	6687
S-R2	310	0,6	185,98	6	19	1115,89	215,98		
S-R3	267	0,6	160,18	4	13	640,74	82,68		
S-R4	177	0,6	106,19	19	61	2017,60	1236,59		
August									
S-R1	198	0,6	118,79	7	23	831,52	187,76	4504,35	7508
S-R2	310	0,6	185,98	8	26	1487,85	383,96		
S-R3	267	0,6	160,18	9	29	1441,66	418,55		
S-R4	177	0,6	106,19	7	23	743,33	167,85		
September									
S-R1	198	0,6	118,79	3	10	356,36	35,64	4645,94	7744
S-R2	310	0,6	185,98	7	23	1301,87	303,77		
S-R3	267	0,6	160,18	16	53	2562,94	1366,90		
S-R4	177	0,6	106,19	4	13	424,76	56,63		
October									
S-R1	198	0,6	118,79	5	16	593,94	95,80	3946,41	6578
S-R2	310	0,6	185,98	2	6	371,96	24,00		
S-R3	267	0,6	160,18	8	26	1281,47	330,70		
S-R4	177	0,6	106,19	16	52	1699,03	876,92		
November									
S-R1	198	0,6	118,79	12	40	1425,46	570,18	4299,17	7166
S-R2	310	0,6	185,98	8	27	1487,85	396,76		
S-R3	267	0,6	160,18	6	20	961,10	192,22		
S-R4	177	0,6	106,19	4	13	424,76	56,63		
December									
S-R1	198	0,6	118,79	16	53	1900,61	1013,66	4053,79	6757
S-R2	310	0,6	185,98	7	23	1301,87	303,77		
S-R3	267	0,6	160,18	2	7	320,37	21,36		
S-R4	177	0,6	106,19	5	17	530,95	88,49		

Table 4. Deliveries made by the long-term rental

Route	*Distance, km*	*Rate per 1 km, PLN*	*Cost of delivery, PLN*	*Number of deliveries*	*Percentage share, %*	*Cost on the transport route, PLN*	*Average cost, PLN*	*Total costs, PLN*	*Total distance, km*
1	2	3	4	5	6	7	8	9	10
January									
S-R1	198	0,48	95,27	5	17	1641,3	476,33	3357,88	6979
S-R2	310	0,48	149,15	7	24	1025,3	1044,07		
S-R3	267	0,48	128,46	9	31	746,4	1156,18		
S-R4	177	0,48	85,16	8	28	218,6	681,29		
February									
S-R1	198	0,48	95,27	8	29	762,13	217,75	3280,41	6818
S-R2	310	0,48	149,15	8	29	1193,23	340,92		
S-R3	267	0,48	128,46	7	25	899,25	224,81		
S-R4	177	0,48	85,16	5	18	425,81	76,04		
March									
S-R1	198	0,48	95,27	9	30	857,39	257,22	3138,96	6524
S-R2	310	0,48	149,15	5	17	745,77	124,29		
S-R3	267	0,48	128,46	4	13	513,86	68,51		
S-R4	177	0,48	85,16	12	40	1021,94	408,78		
April									
S-R1	198	0,48	95,27	3	11	285,80	30,62	3514,25	7304
S-R2	310	0,48	149,15	5	18	745,77	133,17		
S-R3	267	0,48	128,46	18	64	2312,36	1486,52		
S-R4	177	0,48	85,16	2	7	170,32	12,17		

End of the table 4

May									
1	2	3	4	5	6	7	8	9	10
S-R1	198	0,48	95,27	5	16	476,33	76,83	3311,69	6883
S-R2	310	0,48	149,15	7	23	1044,07	235,76		
S-R3	267	0,48	128,46	4	13	513,86	66,30		
S-R4	177	0,48	85,16	15	48	1277,43	618,11		
June									
S-R1	198	0,48	95,27	10	33	952,66	317,55	3514,25	7304
S-R2	310	0,48	149,15	8	27	1193,23	318,19		
S-R3	267	0,48	128,46	8	27	1027,72	274,06		
S-R4	177	0,48	85,16	4	13	340,65	45,42		
July									
S-R1	198	0,48	95,27	2	6	190,53	12,29	3217,38	6687
S-R2	310	0,48	149,15	6	19	894,92	173,21		
S-R3	267	0,48	128,46	4	13	513,86	66,30		
S-R4	177	0,48	85,16	19	61	1618,07	991,72		
August									
S-R1	198	0,48	95,27	7	23	666,86	150,58	3612,40	7508
S-R2	310	0,48	149,15	8	26	1193,23	307,93		
S-R3	267	0,48	128,46	9	29	1156,18	335,66		
S-R4	177	0,48	85,16	7	23	596,13	134,61		
September									
S-R1	198	0,48	95,27	3	10	285,80	28,58	3725,95	7744
S-R2	310	0,48	149,15	7	23	1044,07	243,62		
S-R3	267	0,48	128,46	16	3	2055,43	1096,23		
S-R4	177	0,48	85,16	4	13	340,65	45,42		
October									
S-R1	198	0,48	95,27	6	16	476,33	76,83	3164,94	6578
S-R2	310	0,48	149,15	5	6	298,31	19,25		
S-R3	267	0,48	128,46	2	26	1027,72	265,22		
S-R4	177	0,48	85,16	8	52	1362,59	703,27		
November									
S-R1	198	0,48	95,27	12	40	1143,19	457,28	3447,85	7166
S-R2	310	0,48	149,15	8	27	1193,23	318,19		
S-R3	267	0,48	128,46	6	20	770,79	154,16		
S-R4	177	0,48	85,16	4	13	340,65	45,42		
December									
S-R1	198	0,48	95,27	16	53	1524,25	812,93	3251,06	6757
S-R2	310	0,48	149,15	7	23	1044,07	243,62		
S-R3	267	0,48	128,46	2	7	256,93	17,13		
S-R4	177	0,48	85,16	5	17	425,81	70,97		

The detailed data presented in the tables above regarding the three possible transport options were used to determine the average variable unit cost of delivery (Table 5).

Table 5. Average variable unit cost of delivery for each option

	On-call delivery	*Leasing*	*Long-term rental*
Total number of deliveries	359		
Total distance, km	84252		
Total sum of variable costs, PLN	193182,50	46359,16	37179,13
Average variable unit cost of delivery, PLN	538,11	129,13	103,56

The next component adopted for the calculation is fixed costs. The only variant in which they do not occur is on-call delivery. The remaining three options had to be estimated. Additional assumptions were adopted for the estimation:

1) Deliveries were made by the Mercedes Sprinter 315 CDI (2.0; Power 150 HP);
2) The number of deliveries was a random variable in each month X϶{28-31};

3) Due to the distance between network nodes and the number of deliveries in a given month, 2 vehicles and 2 drivers were used for analysis.

A summary of fixed costs for leasing and long-term rental is presented in Tables 6 and 7, respectively.

Table 6. Fixed cost breakdown for leasing

Leasing-fixed costs	*Fixed costs per month*	*Fixed costs per year*	*Number of vehicles/drivers*	*Annual costs*
Leasing instalment, PLN	3295		2	79056
Drivers salary, PLN	6100		2	146400
Vehicle insurance, PLN		1500	2	3000
Annual vehicle inspection, PLN		1000	2	2000

Table 7. Fixed cost breakdown for long-term rental

Long-term rental-fixed costs	*Fixed costs per month*	*Fixed costs per year*	*Number of vehicles/drivers*	*Annual costs*
Leasing instalment, PLN	3010		2	72240
Drivers salary, PLN	6100		2	146400

Taking into account the relationship [1] for the analysed network, we can therefore compare the components of fixed and variable costs. Each option is presented in Table 8.

Table 8. Summary of fixed and variable cost components for the 3 considered transport options

	On-call delivery	*Leasing*	*Long-term rental*
Fixed costs, PLN	0	230456	218640
Average variable unit cost of delivery, PLN	538,11	129,13	103,56

The functions symbolising the individual options are linear, so they can be easily visualised on graphs using formula (1).

Visible on Fig. 2 two Intersection Points (IP) essentially represent the same total transportation costs for both options (for on-call delivery/long-term rental IP= 503,14 and for on-call delivery/leasing IP= 563,49). The missing intersection point for leasing and long-term rental indicates the absence of identical costs for both variants (IP =- 462,08).

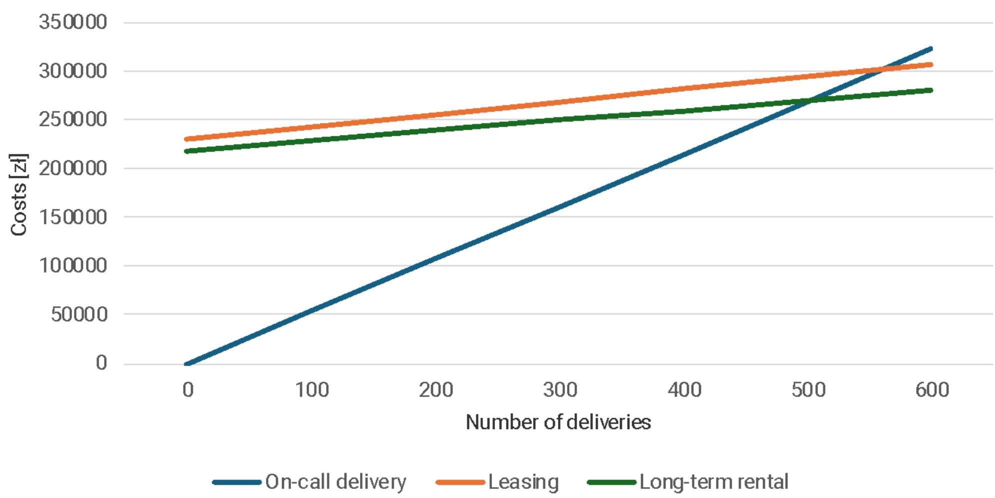

Figure 2. Intersection Points (IP) for two options*

*Generated by the authors.

Detailed calculations are summarised in Table 9.

Table 9. Total costs for each option depending on the number of deliveries

Number of deliveries	*On-call delivery, PLN*	*Leasing, PLN*	*Long-term rental, PLN*
0	0	230456	218640
100	53811,28	243369,42	228996,30
200	107622,56	256282,83	239352,61
300	161433,84	269196,25	249708,91
400	215245,13	282109,66	260065,22
500	269056,41	295023,08	270421,52
600	322867,69	307936,50	280777,82

The next step is to estimate low, medium, and high demand based on the supply scenario presented below, derived from the company's market research conducted last year. For this purpose, the studied group, measured by the number of cruises in individual months (Table 10), should be divided into three intervals of the same width.

Table 10. Demand volumes in individual months of the year

Route/month	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*
S-R1	5	8	9	3	5	10	2	7	3	5	12	16
S-R2	7	8	5	5	7	8	6	8	7	2	8	7
S-R3	9	7	4	18	4	8	4	9	16	8	6	2
S-R4	8	5	12	2	15	4	19	7	4	16	4	5

In order to divide the population into three ranges symbolising low, medium and high demand, the range should be determined mathematically. Then the analysed population should be divided into three ranges of the same width, according to equation (2):

$$R_x = (X_{max} - X_{\min})/3 \tag{2}$$

Then, based on the frequency of occurrence of individual values within a given range, the percentage share of that range (demand level) should be determined. In the next step, the total value of cruises in each of the specified series is calculated. Based on this value, dividing it by the number of recorded events in a given range allows determining the average demand for that level (Table 11).

Table 11. Calculation of low, medium and high demand and estimation of percentage share

Demand quantity/ scenario	*Number of deliveries/ year*	*Upper limit*	*Frequency*	*Lower limit*	*Compartment width*	*Sum of demand*	*Percentage share, %*	*Average arithmetic*
Low	115	7	28	2	<2,8)	134	58	5
Medium	214	13	14	7	<8,14)	125	29	9
High	400	19	6	13	<14,19>	100	13	17

Based on the above analysis, which determined the levels of individual types of demand and their probabilities of occurrence, the expected value was calculated in the following section. It is the sum of the products of the expected cost of each level of demand and the probability of occurrence of a given quantity, in accordance with equation (3).

$$EW_j = \sum_{i=1}^{I} P_i C_i \tag{3}$$

where: EW_j – expected value for the *j*-th option;
P_i – *i*-th scenario probability;
C_i – financial result for *i*-th scenario.

Then, using the above values, costs were calculated for each scenario and transport option. They are needed to calculate the expected values for each option (Table 12).

Table 12. Total costs T_C for each scenario and calculating the expected value EW_j for each option

Demand quantity/scenario	*Low demand*	*Medium demand*	*High demand*	EW_j
Number of deliveries/ percentage share, %	115/58	214/29	400/13	-
On-call delivery, PLN	61882,97	115156,14	215245,13	96591,25
Long-term rental, PLN	230549,75	240802,49	260065,22	237229,56
Leasing, PLN	245306,43	258090,71	282109,66	253635,58

Based on the expected value analysis, the most cost-effective option is on-call delivery, which has the lowest expected value (Table 12).

Conclusions. When making decisions, it is also necessary to examine the company's break-even point, which is expressed mathematically by the following equation (4):

$$BE_P = \frac{F_c}{UR_g - AV_{UC}} \tag{4}$$

where: BE_P – break-even point;
F_c – fixed costs;
UR_g – gross unit revenue (1253,48 PLN);
AV_{UC} – average variable unit delivery cost.

Table 13. Calculations the basic indicators for three modes of transport

Basic indicators	*On-call delivery*	*Long-term rental*	*Leasing*
Total number of deliveries	359		
Fixed costs, PLN	0,00	218 640,00	245 306,43
Average variable unit delivery cost, PLN	538,11	103,56	129,13
Break-even point, $BE_P BE_P$	0,00	190,14	218,18
Min. number of delivery/net income, PLN	0/715,37	191/988,83	219/921,97
Number of delivery/net income, PLN	0/715,37	192/1149,92	220/1124,35
Annually net income for 359 deliveries, PLN	256 817,50	277 544,41	254 484,87

This paper presents a comparative analysis of the total transport costs for three transport options/variants within the supply chain. The cost structure is based on a basic criterion: dividing costs into fixed and variable. The article also presents a comparative analysis of the estimated costs over a one-calendar (fiscal) year for three transport options: contract transport, long-term rental, and leasing. For contract transport, fixed costs were not identified (Table 13). This is because the above option involves ordering and executing delivery through an external entity (carrier), which performs the transport service each time the order is completed and ready for shipment. Therefore, the delivery cost is the product of the per-kilometre rate and the distance travelled. Considering the above, the option of using an external carrier has the highest transport rate per kilometre (see Table 2) and the highest average variable unit delivery cost (see Table 13).

Long-term rentals and leasing, on the other hand, have fixed and variable costs. For long-term rentals, the fixed cost is the monthly rental rate; for leasing, it is the monthly instalment, which is relatively fixed and decreasing. The slightly higher average variable unit delivery cost for leasing compared to long-term rentals resulted from including, in addition to fuel consumption, additional costs such as insurance, maintenance, and other expenses incurred by the lessee (e.g., changing tyres from summer to winter twice, random repairs, replenishing operating fluids, fines, etc.). These costs are directly dependent on the amount of work performed by the vehicle, measured by its mileage, and therefore were included as the average variable cost per km – compare the rates in Table 3 and Table 4.

The calculations performed for the break-even analysis (Table 13) show that:

1. The least risky option is on-call delivery, which, due to the lack of fixed costs, has a break-even point of zero deliveries (BEp = 0). For this option, the company begins earning net profits of PLN 715.37 per delivery from the first delivery.

2. The break-even point for long-term rental is BEp = 190.14 deliveries. For this transport option, the company begins earning net profits from the 192nd delivery, earning PLN 1,149.92 per subsequent delivery. The net profit for the 191st delivery is PLN 988.83.

3. The highest break-even point is leasing, which is BEp = 218.18 deliveries. Considering the above, this break-even point makes leasing the riskiest option. For the 219th delivery, the company's net profit is PLN 921.97, while from the 220th delivery, the company earns PLN 1,124.35 net.

Annual net profits for the company's intensity level of 359 deliveries considered in this study are similar across options (Table 13). However, the largest profits are generated by the long-term rental option. Therefore, in the analysed case, long-term rental is the most advantageous choice based on the total cost analysis.

References

1. Alves R., Hora J., Galvão T. (2026). Optimizing Transit Connectivity: A Synchronization Model Applied to Porto Campanhã, w *Lecture Notes in Mobility*. Springer, pp. 708–714. DOI: https://doi.org/10.1007/978-3-032-04774-8_102
2. Anussornnitisarn P. *et al.* (2025) Urban freight Electrification: Total cost of ownership comparison of medium-duty BEVs and ICEVs in Thailand», *Case Studies on Transport Policy*, 22. DOI: https://doi.org/10.1016/j.cstp.2025.101600
3. Borucka A., Sobczuk S. (2025) Analysis of the Relationship Between Energy Consumption in Transport, Carbon Dioxide Emissions and State Revenues: The Case of Poland, *Energies*, 18 (9). DOI: https://doi.org/10.3390/en18092291
4. Chandiramani H., Soni G., Mittal M. L. (2026). Advances in Intelligent Urban Transportation: New Approaches to Routing, Scheduling, and Network Design, w *Mech. Mach. Sci. Mechanisms and Machine Science*, Springer Science and Business Media B. V., pp. 503–515. DOI: https://doi.org/10.1007/978-3-031-93327-1_29
5. Damaziak K. *et al.* (2025). Multi-objective optimization of the deck structure of the lightweight micro-vehicle for improved reliability and desired comfort and stability while driving, *Eksploatacja i Niezawodnosc*, vol. 27 (4). DOI: https://doi.org/10.17531/ein/206048
6. Ferro C. G., Leopoldo L., Maggiore P. (2026). Cost and Sustainability Comparison of Airship vs. Long-Haul Trucking for Cold Chain Vegetable Logistics in Europe, w *Sustainable Aviation*. Springer Nature, pp. 247–258. DOI: https://doi.org/10.1007/978-3-031-89553-1_17
7. Folęga P. *et al.* (2025) Application of the life cycle assessment method in public bus transport, *Eksploatacja i Niezawodnosc*, vol. 27 (3). DOI: https://doi.org/10.17531/ein/204539
8. Gładysz P. et al. (2026). Reliability of Unmanned Aerial Vehicles in the Context of Selected Factors, *Eksploatacja i Niezawodnosc*, vol. 28 (1). DOI: http://doi.org/10.17531/ein/210312
9. Grzelak M. *et al.* (2024). Application of Logistic Regression to Analyze The Economic Efficiency of Vehicle Operation in Terms of the Financial Security of Enterprises, *Logistics*, vol. 8 (2). DOI: https://doi.org/10.3390/logistics8020046

10. Guo Y., Zhang M. (2026). Joint optimization of electric bus infrastructure planning, fleet composition, and charging schedule with multiple charging modes, *Expert Systems with Applications*, 297 p. DOI: https://doi.org/10.1016/j.eswa.2025.129402
11. Jung Y., Lee U., Lee I. (2026). An integrated framework for reliability analysis and design optimization using input, simulation, and experimental data: Confidence-based design optimization under aleatory and epistemic uncertainty, *Reliability Engineering and System Safety*, 267 p. DOI: https://doi.org/10.1016/j.ress.2025.111895
12. Lu S. *et al.* (2026). Multi-driver transportation scheduling for improving supply chain resilience, *Omega (United Kingdom)*, 140 p. DOI: https://doi.org/10.1016/j.omega.2025.103461
13. Mallidis I. *et al.* (2026). Optimizing fleet size for on-demand taxi and ridehailing services: application to the case of Madrid, *Transport Policy*, 175 p. DOI: https://doi.org/10.1016/j.tranpol.2025.103868
14. Mohamed Alshabibi N., Matar A.-H. H., Abdelati M. (2025). Multi-Objective Mixed-Integer Linear Programming for Dynamic Fleet Scheduling, Multi-Modal Transport Optimization, and Risk-Aware Logistics, *Sustainability (Switzerland)*, vol. 17 (10). DOI: https://doi.org/10.3390/su17104707
15. Purshamsian R. *et al.* (2026) Optimizing maritime transport schedule recovery strategies: a novel approach for speeding up and port-skipping in case of disruption, *Multimodal Transportation*, vol. 5 (1). DOI: https://doi.org/10.1016/j.multra.2025.100233
16. Rönnqvist M. *et al.* (2026) An enhanced pricing model for truck transportation: a case study in Swedish forestry, *International Transactions in Operational Research*, vol. 33 (2), pp. 775–797. DOI: https://doi.org/10.1111/itor.70062
17. Rosiński A. *et al.* (2024) Method for Assessing Reliability of the Power Supply System for Electronic Security Systems of Intelligent Buildings Taking Into Account External Natural Interference, *Eksploatacja i Niezawodnosc*, vol. 26 (1). DOI: https://doi.org/10.17531/ein/176375
18. Sang T. *et al.* (2025) An uncertain programming model for fixed charge transportation problem with item sampling rates, *Eksploatacja i Niezawodnosc*, vol. 27 (1). DOI: https://doi.org/10.17531/ein/192165
19. Topaloglu Yildiz S., Doymuş M. (2025) Multi-objective intermodal transportation planning with real-life application, *Maritime Policy and Management*, vol. 52 (5), pp. 745–763. DOI: https://doi.org/10.1080/03088839.2024.2407381
20. Wang F. *et al.* (2026) Multi-dimensional integrated development strategy for urban rail transit optimized via a carbon emission model driven by new quality productive forces, *Case Studies on Transport Policy*, vol. 23. DOI: https://doi.org/10.1016/j.cstp.2025.101664
21. Wang Z. *et al.* (2026) Dynamic optimization of hazardous materials vehicle transportation routes based on real-time risk, *Journal of Loss Prevention in the Process Industries*, vol. 100. DOI: https://doi.org/10.1016/j.jlp.2025.105864
22. Waygood E. O. D. *et al.* (2026) Transport emissions and climate change: Which actions are the hardest?, *Case Studies on Transport Policy*, vol. 23. DOI: https://doi.org/10.1016/j.cstp.2025.101660
23. Wróblewski P. *et al.* (2021) Total cost of ownership and its potential consequences for the development of the hydrogen fuel cell powered vehicle market in poland, *Energies*, vol. 14 (8). DOI: https://doi.org/10.3390/en14082131
24. Youness E.-Y., Lahoussine L. (2026) Optimization problems with nonconvex multiobjective generalized Nash equilibrium problem constraints, *Communications in Combinatorics and Optimization*, vol. 11 (1), pp. 93–116. DOI: https://doi.org/10.22049/cco.2024.29435.1993
25. Zhou T. *et al.* (2026). Integrated recovery of air cargo transportation under various abnormal scenarios, *European Journal of Operational Research*, vol. 329 (3), pp. 864–877. DOI: https://doi.org/10.1016/j.ejor.2025.08.037
26. Zhou X. *et al.* (2026) A collaborative evolution algorithm for unmanned equipment project distributed scheduling optimization with grouping and due window constraints, *Expert Systems with Applications*, 296. DOI: https://doi.org/10.1016/j.eswa.2025.129143
27. Ziółkowski J. *et al.* (2022) Optimization of the Delivery Time within the Distribution Network, Taking into Account Fuel Consumption and the Level of Carbon Dioxide Emissions into the Atmosphere, *Energies*, vol. 15 (14) DOI: https://doi.org/10.3390/en15145198
28. Ziółkowski J. *et al.* (2025). Optimization Of Road Transport Within The Supply Network – A Case Study From Poland, *Transport Problems*, vol. 20 (1), pp. 193–206. DOI: https://doi.org/10.20858/tp.2025.20.1.16
29. Żurek J., Zieja M., Ziółkowski J. (2018). Reliability of supplies in a manufacturing enterprise, w *Saf. Reliab. – Safe Soc. Chang. World – Proc. Int. Eur. Saf. Reliab. Conf. Safety and Reliability – Safe Societies in a Changing World – Proceedings of the 28th International European Safety and Reliability Conference, ESREL 2018*, CRC Press/Balkema, pp. 3143–3148.

Список використаних джерел

1. Alves R., Hora J., Galvão T. Optimizing Transit Connectivity: A Synchronization Model Applied to Porto Campanhã, w *Lecture Notes in Mobility*. Springer, 2026. P. 708–714. DOI: https://doi.org/10.1007/978-3-032-04774-8_102

2. Anussornnitisarn P. *et al.* Urban freight Electrification: Total cost of ownership comparison of medium-duty BEVs and ICEVs in Thailand», *Case Studies on Transport Policy*. 2025. 22. DOI: https://doi.org/10.1016/j.cstp.2025.101600
3. Borucka A., Sobczuk S. Analysis of the Relationship Between Energy Consumption in Transport, Carbon Dioxide Emissions and State Revenues: The Case of Poland, *Energies*. 2025. 18 (9). DOI: https://doi.org/10.3390/en18092291
4. Chandiramani H., Soni G., Mittal M. L. Advances in Intelligent Urban Transportation: New Approaches to Routing, Scheduling, and Network Design, w *Mech. Mach. Sci. Mechanisms and Machine Science*, Springer Science and Business Media B. V., 2026. P. 503–515. DOI: https://doi.org/10.1007/978-3-031-93327-1_29
5. Damaziak K. *et al.* Multi-objective optimization of the deck structure of the lightweight micro-vehicle for improved reliability and desired comfort and stability while driving, *Eksploatacja i Niezawodnosc*. 2025. Vol. 27 (4). DOI: https://doi.org/10.17531/ein/206048
6. Ferro C. G., Leopoldo L., Maggiore P. Cost and Sustainability Comparison of Airship vs. Long-Haul Trucking for Cold Chain Vegetable Logistics in Europe, w *Sustainable Aviation*. Springer Nature, 2026. P. 247–258. DOI: https://doi.org/10.1007/978-3-031-89553-1_17
7. Folęga P. *et al.* Application of the life cycle assessment method in public bus transport, *Eksploatacja i Niezawodnosc*. 2025. vol. 27 (3). DOI: https://doi.org/10.17531/ein/204539
8. Gładysz P. et al. Reliability of Unmanned Aerial Vehicles in the Context of Selected Factors, *Eksploatacja i Niezawodnosc*. 2026. Vol. 28 (1). DOI: http://doi.org/10.17531/ein/210312
9. Grzelak M. *et al.* Application of Logistic Regression to Analyze The Economic Efficiency of Vehicle Operation in Terms of the Financial Security of Enterprises, *Logistics*. 2024. Vol. 8 (2). DOI: https://doi.org/10.3390/logistics8020046
10. Guo Y., Zhang M. Joint optimization of electric bus infrastructure planning, fleet composition, and charging schedule with multiple charging modes, *Expert Systems with Applications*, (2026. 297 p. DOI: https://doi. org/10.1016/j.eswa.2025.129402
11. Jung Y., Lee U., Lee I. An integrated framework for reliability analysis and design optimization using input, simulation, and experimental data: Confidence-based design optimization under aleatory and epistemic uncertainty, *Reliability Engineering and System Safety*, 2026. 267 p. DOI: https://doi.org/10.1016/j.ress.2025.111895
12. Lu S. *et al.* Multi-driver transportation scheduling for improving supply chain resilience, *Omega (United Kingdom)*, 2026. 140 p. DOI: https://doi.org/10.1016/j.omega.2025.103461
13. Mallidis I. *et al.* Optimizing fleet size for on-demand taxi and ridehailing services: application to the case of Madrid, *Transport Policy*, 2026. 175 p. DOI: https://doi.org/10.1016/j.tranpol.2025.103868
14. Mohamed Alshababi N., Matar A.-H. H., Abdelati M. Multi-Objective Mixed-Integer Linear Programming for Dynamic Fleet Scheduling, Multi-Modal Transport Optimization, and Risk-Aware Logistics, *Sustainability (Switzerland)*. 2025. Vol. 17 (10). DOI: https://doi.org/10.3390/su17104707
15. Purshamsian R. *et al.* Optimizing maritime transport schedule recovery strategies: a novel approach for speeding up and port-skipping in case of disruption, *Multimodal Transportation*. 2026. Vol. 5 (1). DOI: https://doi.org/10.1016/j.multra.2025.100233
16. Rönnqvist M. *et al.* An enhanced pricing model for truck transportation: a case study in Swedish forestry, *International Transactions in Operational Research*. 2026. Vol. 33 (2). P. 775–797. DOI: https://doi.org/10.1111/itor.70062.
17. Rosiński A. *et al.* Method for Assessing Reliability of the Power Supply System for Electronic Security Systems of Intelligent Buildings Taking Into Account External Natural Interference, *Eksploatacja i Niezawodnosc*. 2024. Vol. 26 (1). DOI: https://doi.org/10.17531/ein/176375
18. Sang T. *et al.* An uncertain programming model for fixed charge transportation problem with item sampling rates, *Eksploatacja i Niezawodnosc*. 2025. Vol. 27 (1). DOI: https://doi.org/10.17531/ein/192165
19. Topaloglu Yildiz S., Doymuş M. Multi-objective intermodal transportation planning with real-life application, *Maritime Policy and Management*. 2025. Vol. 52 (5), pp. 745–763. DOI: https://doi.org/10.1080/03088839.2024.2407381
20. Wang F. *et al.* Multi-dimensional integrated development strategy for urban rail transit optimized via a carbon emission model driven by new quality productive forces, *Case Studies on Transport Policy*. 2026. Vol. 23. DOI: https://doi.org/10.1016/j.cstp.2025.101664
21. Wang Z. *et al.* Dynamic optimization of hazardous materials vehicle transportation routes based on real-time risk, *Journal of Loss Prevention in the Process Industries*. 2026. Vol. 100. DOI: https://doi.org/10.1016/j.jlp.2025.105864.
22. Waygood E. O. D. *et al.* Transport emissions and climate change: Which actions are the hardest?, *Case Studies on Transport Policy*. 2026. Vol. 23. DOI: https://doi.org/10.1016/j.cstp.2025.101660

23. Wróblewski P. *et al.* Total cost of ownership and its potential consequences for the development of the hydrogen fuel cell powered vehicle market in poland, *Energies*. 2021. Vol. 14 (8). DOI: https://doi.org/10.3390/en14082131
24. Youness E.-Y., Lahoussine L. Optimization problems with nonconvex multiobjective generalized Nash equilibrium problem constraints, *Communications in Combinatorics and Optimization*. 2026. Vol. 11 (1). P. 93–116. DOI: https://doi.org/10.22049/cco.2024.29435.1993
25. Zhou T. *et al.* Integrated recovery of air cargo transportation under various abnormal scenarios, *European Journal of Operational Research*. 2026. Vol. 329 (3). P. 864–877. DOI: https://doi.org/10.1016/j.ejor.2025.08.037
26. Zhou X. *et al.* A collaborative evolution algorithm for unmanned equipment project distributed scheduling optimization with grouping and due window constraints, *Expert Systems with Applications*. 2026. 296. DOI: https://doi.org/10.1016/j.eswa.2025.129143
27. Ziółkowski J. *et al.* Optimization of the Delivery Time within the Distribution Network, Taking into Account Fuel Consumption and the Level of Carbon Dioxide Emissions into the Atmosphere, *Energies*. 2022. Vol. 15 (14) DOI: https://doi.org/10.3390/en15145198
28. Ziółkowski J. *et al.* Optimization Of Road Transport Within The Supply Network – A Case Study From Poland, *Transport Problems*. 2025. Vol. 20 (1). P. 193–206. DOI: https://doi.org/10.20858/tp.2025.20.1.16
29. Żurek J., Zieja M., Ziółkowski J. Reliability of supplies in a manufacturing enterprise, w *Saf. Reliab. – Safe Soc. Chang. World – Proc. Int. Eur. Saf. Reliab. Conf. Safety and Reliability – Safe Societies in a Changing World – Proceedings of the 28th International European Safety and Reliability Conference, ESREL 2018*, CRC Press/Balkema, pp. 3143–3148.