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Influence of Transport Process Management on Exceeding Permitted Load Weights in Transport Companies

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Abstract
Poland is the leader in the performance of international transport in the EU, serving more than half of its market. The most common branch of transport is road transport, predominantly heavy goods transport, which contributes to the strain on road infrastructure. Furthermore, around one-fifth of those vehicles may exceed the permissible total mass. In this respect, the increasing demand for road transport further complicates the slowdown and prevention of road network degradation. Overloads have significant consequences for road infrastructure, economics, and traffic safety. Load management in transport companies is crucial for eliminating overloads. This article aims to assess how companies conducting freight transport manage the cargo weighing process in the context of potential overloads. Data from a survey among transport industry companies in Poland were analysed. Using non-parametric U Mann-Whitney and Kruskal-Wallis tests, the influence between propensity for cargo overloading and the method of cargo weighing was examined. The results indicated that the propensity for cargo overloading in TSL industry companies is significantly associated with both the occurrence of the weighing process and its method, as well as the responsibility for this process among individual participants in the transport process.

Keywords
Road transport, cargo overloads, overloaded vehicles, vehicle weighing

Introduction

Despite many dynamic and often unfavourable changes in the macroeconomic environment, the popularity of road freight transport continues to grow. Currently, the size of the global road freight transport market is valued at USD 3.86 trillion (in 2022), and the projected revenue in the coming years could be around USD 5 trillion (Global Road Freight Transportation Market, Eurostat, 2024). It is forecasted that the use of road transport in 2050 could reach up to 30 trillion tonne-kilometers, which is up to five times more transport performance than in 2020 (Möller, 2023). In the European Union, total road freight transport in 2022 amounted to over 13.6 billion tonnes and 1,920 billion tonne-kilometres (Road freight transport statistics, Eurostat, 2023). Analysing only the European market, it is observed that almost 80% of EU road freight transport in tonne-kilometres in 2022 was carried out by trucks with a gross vehicle weight of more than 30 tonnes. Furthermore, over three-quarters (77.8%) of road freight transport in the EU measured in tonne-kilometers, and almost two-thirds (65.5%) of freight transport measured in vehicle kilometres, are attributed to road tractors and semi-trailers (Road freight transport by vehicle characteristics, Eurostat, 2023). Among all EU countries, Poland accounts for the largest share of transport performance (63.6%) performed in total international transport within the EU (Road freight transport by vehicle characteristics, Eurostat, 2023), and for more than 40% of EU cabotage performed (Road freight transport statistics - cabotage, Eurostat, 2023). In Poland in 2022, almost 2 billion tonnes of freight, mainly carried by heavy goods vehicles, will be transported by road (GUS, Transport – activity results in 2022). Heavy goods vehicles constitute the second largest category of motor vehicles registered in this country (share in the total number of registered motor vehicles was 11.3% in 2021) (GUS2, Road transport in Poland in 2020 and 2021). Moreover, this share is increasing year by year. The main market growth drivers are the growing demand for road transport and increasing international trade. The high number of heavy goods vehicles associated with the need to meet the high demand for road freight services also adversely affects social, environmental, and technical surroundings. The issue of overloaded transport occupies an important place in ensuring an efficient and safe transport system. Therefore, the process of managing cargo weight, focused on controlling permissible weight, is crucial both for the state of the country's road infrastructure and the transport capabilities of companies conducting commercial transport. Thus, the article aims to investigate how companies conducting freight transport manage the cargo weighing process in the context of potential overloads.

Factors shaping demand for freight processes

Freight transport is a crucial component of the transport system, which in turn is part of a specific economic framework and social infrastructure. The development of transport acts as an engine driving the entire economy, influencing the structure of the production of goods and services across other sectors of the economy (Kamińska, 2021). There are close relationships between the state of the economy and the volume of passenger and freight transport.

The characteristics of transport processes in terms of overloads involve analysing various aspects, including the strain on the transport system, which encompasses infrastructure, technology, management, as well as political and legal factors (Urbański et al., 2021). Overloads in transportation can have significant consequences for efficiency, safety, and operational costs. The most important domestic factors influencing the development of transport, and consequently, cargo overloads, include economic growth accompanied by an increase in societal income, resource growth, changes in settlement network structures, price relationships, and employment structures (Dorosiewicz, 2009; Kamińska et al., 2023).

Cargo overloads can occur in situations such as increased demand for transport due to increased production and trade or increased demand for transportation during peak periods. Among carriers, there are also cases of unfair competition where unauthorised amounts of goods are transported to achieve financial gains while minimising transport costs (Slezak et al., 2019; Petrescu, 2015).

Furthermore, factors such as societal income growth and current changes in consumer behaviour, such as the increased popularity of online shopping, increase the demand for delivery services, which can translate into increased vehicle overload. The rise in online shopping popularity has been significantly influenced by the COVID-19 pandemic (Gu et al., 2021). Therefore, unexpected global events that radically alter previously implemented transport processes cannot be ignored in their structure and volume. Research conducted by Slusarczyk et al. confirmed the sustained interest in road transport, further strengthening its market position during the pandemic period (Slusarczyk et al., 2023). Similar conclusions were drawn by Łącka and Suproń, indicating that sanitary restrictions imposed in many enterprises and the ban on economic activity among industries requiring road transport directly affected the volume of road transport carried out by Polish transport companies. Ultimately, there was an increase in the number of kilometres covered by vehicles on a larger scale than in previous years (Łącka & Suproń, 2021).

Another significant event impacting the economy, including the TSL industry, is the ongoing war in Ukraine instigated by Russia. This conflict has led to the disruption and reorganisation of many supply chains and the

shifting of global trade routes, primarily to avoid Russia and Belarus. Within Poland, the situation has necessitated the distribution of coal delivered by ships to ports, aid to Ukraine in conducting foreign trade, and the activation of the north-south corridor servicing landlocked Central European countries (Ołdak, 2023). Poland's geographical location is highly advantageous from an economic standpoint due to its intersection of communication routes. However, the high intensity of transit car traffic exposes road infrastructure to significant operational loads, leading to the destruction and degradation of public roads (Ossowski & Burnos, 2016).

Impact of overloaded vehicles on the economic environment

Overloaded trucks have a significant impact on infrastructure, economics, and road traffic safety. The impact of overload on infrastructure can be very serious, as it can cause permanent damage to the road surface (Judycki et al., 2013). Transit transport also affects road infrastructure (Kozerska, 2021). Excessive exploitation of road infrastructure has a negative impact on its durability, which is even more exposed to damage when heavy vehicles transport overloaded loads. It has been calculated that the average share of overloaded vehicles in traffic is 18.5 per cent, contributing to half of the excessive fatigue wear on road surfaces (Rys et al., 2014). Moreover, the violation varies depending on the type of overload and includes about 15% of vehicles in the case of maximum allowable axle load or 5% in the case of exceeding the permissible total weight of the vehicle (Ryś & Jaskuła, 2019). This means that reducing the share of overloaded vehicles can contribute to extending the service life of the road surface by up to one-third. Overloading contributes to a shorter asphalt surface life, as a 0-20% increase in overloading reduces the fatigue life of an asphalt surface by 50% (Mulyono & Antameng, 2010). According to Pais, Amorim and Minhoto (2013), load intensity, axle, traffic frequency, and tyre configuration are the main factors causing road surface problems due to the weight exerted on the axles and tyres of the vehicle. Moreover, an overloaded truck can lead to fatigue damage to bridges and, in extreme cases, reduce the load-bearing capacity of old bridges or cause severe damage to them (Prochowski & Żuchowski, 2011).

Overloaded trucks shorten the life of the roadway, which translates into increased maintenance costs. It has been demonstrated that increased enforcement of weight regulations discourages violations of weight rules (Taylor et al., 2000), thus extending the lifespan of highways and generating savings in road maintenance expenses. All of this contributes to the economic cost of overloading, which arises from regulatory violations and includes infrastructure usage fees, axle taxes, and registration fees (Borghetti et al., 2024). Insufficient regulation results in reduced access to infrastructure maintenance funds and exacerbates road degradation.

An overloaded vehicle increases the risk of accidents due to imbalance and braking issues. In countries where the transportation of materials and goods occurs primarily by road, these problems are particularly severe (Sadeghi & Fathali, 2007). Moreover, overloaded trucks pose a serious threat to road safety as they increase the risk of accidents by causing truck instability, overheating, and brake failure (Zainuddina et al., 2023).

Overloading also disrupts competition in freight transport between different infrastructure options. This situation is confirmed by the fact that studies have shown that a 5-axle articulated truck operating with a 20% overload annually would generate an additional €25,000. Such disruptions prompt a shift from rail and water transport to road transport, increasing overloading and exacerbating road infrastructure damage and maintenance costs. Continuous overloading practices lead to unsustainable strain on roads and related infrastructure (Alkhoori, 2019). Therefore, overloading has economic consequences in the form of high maintenance costs and significant disruptions in freight transport competition (Jacob & La, 2010).

Cargo management in transport companies

Transport companies that plan and organise freight processes play a crucial role in effectively eliminating overloaded cargo. Improper cargo management can be caused by exceeding the maximum allowable load weight as well as overloading individual vehicle axles, resulting from improper load distribution on the vehicle's semi-trailer. Both the type of cargo and the type of packaging affect the ability to evenly distribute it in relation to the drive axles (Trzciński & Tymendorf, 2022).

The tendency to overload cargo can result from various aspects of loading operations management. One reason may be the lack of appropriate tools and technologies for managing cargo, both at the ordering stage and during its placement in the semi-trailer. Another reason might be improper management of vehicle availability, leading to situations where available vehicles are overloaded to meet sudden transport needs. A significant obstacle can also be the lack of clearly defined loading procedures and the associated assignment of responsibility for the cargo weight. Implementing and enforcing SOPs regarding the maximum allowable load weight and proper weight distribution is essential (Berghman et al., 2010). Nonetheless, both conscious and unconscious overloading of vehicles causes numerous negative effects on the environment and the TSL industry, as presented in Table 1.

Tab. 1 Consequences of overloading trucks (Miftahulkhair et al., 2024; Syadullah & Setyawan, 2021; Budiharjo et al., 2021)

Type of effect	Description
Economic	- degradation of road infrastructure requiring costly repairs and upgrades
Operational	- increased operating costs related to fuel consumption and vehicle maintenance; - costs of penalties for detected overloads; - risk of loss of customer confidence
Environmental	- increased emissions of exhaust fumes and air pollution
Social	- deterioration in the quality of life of residents in areas of high truck traffic related to noise; - increased risk of road and rail accidents

On a macroeconomic scale, the effective management of transport processes and the associated elimination of overloaded vehicles should be directed towards investments in infrastructure aimed at modernising and expanding road, rail, port and airport networks, implementing intelligent transport systems (ITS) for traffic management and capacity improvement, and expanding and improving the system for controlling the weighing of vehicles in traffic (Ryguła et al., 2020). An important aspect is the systematic review and updating of laws and regulations that limit overloading, including setting weight limits for vehicles (Alkhoori & Maghelal, 2021). In transport companies, actions should include better route planning and scheduling to minimise downtime and overloading (Honková, 2022). Communication and coordination with suppliers and customers should not be overlooked, as improper communication can lead to unexpected changes in the loading plan, resulting in overloading. Proper cargo management processes prevent delays and time pressure related to delivery (Zasadzień, 2020). An effective solution is installing a real-time cargo monitoring system, allowing drivers and managers to continuously control cargo weight (Abu-Abed & Ivanov, 2021). Personnel responsible for loading should be regularly trained in loading techniques and maximum load weight regulations. Automated loading systems can ensure even weight distribution on the trailer relative to its axles. Regular risk assessment related to loading operations can help identify potential overloading issues, develop strategies to avoid them and increase the safety of transport operations (Tubis & Werbińska-Wojciechowska, 2017).

Research methodology

Selection of the research sample

The study was conducted in the second quarter of 2024 among 400 transport companies registered in Poland, providing domestic and international freight transport services. Data were collected using a CAWI (Computer-Assisted Web Interview) questionnaire. The study covered companies in the TSL industry that have at least one truck in the N2 category (vehicles intended for the transport of goods with a maximum total mass exceeding 3.5 tons but not exceeding 12 tons) and N3 category (vehicles intended for the transport of goods with a maximum total mass exceeding 12 tons) (Directive 2007/46/EC of the European Parliament and of the Council of 5 September 2007). The sample selection was a simple random sample. The sampling frame was the database of national business registers CEIDG and KRS. The minimum sample size for the studied statistical population of N = 77,705 was estimated as follows (Kock & Hadaya, 2018; Halik, 2002):

$$n = \frac{\mu_\alpha^2\, p(1-p)N}{\mu_\alpha^2\, p(1-p)+(N-1)d^2} = \frac{(1{,}64^2)*0{,}5*0{,}5*77705}{(1{,}64)^2*0{,}5*0{,}5+77705*(0{,}05)^2} = 268 \quad [1]$$

For the assumed confidence level of α = 95%, maximum error value e = 5%, and fraction size P = 0.5, it was estimated that the minimum sample size should be 268 companies.
The established target sample size of 400 transport companies was sufficient to conduct the analyses and constituted a representative sample of the studied population.

Structure of the research sample

Among the surveyed companies, there were both firms with relatively short experience in the TSL industry (up to 5 years: 25.1%) and those with over 20 years of experience (15.3%). Almost all surveyed enterprises provide transport services (97.5%), one-fifth are involved in forwarding activities (21%), and 6% offer courier services. The vast majority of companies have a licence for domestic carriage of goods (88.5%). Half as often, companies declared having a licence for international carriage (44.5%). One-quarter of the surveyed companies had only vehicles between 3.5 and 12 tonnes GVW (25.8%). The largest group of companies had two-axle trucks (47%) and two-axle tractor units (40.5%). Trailers were the least frequently declared (from 0.5% to 6.8% of companies, depending on the type of trailer). Among the surveyed companies, the contract market has a larger share of the total orders, accounting for nearly 59% of all orders. The SPOT market accounts for an average of 41.41% of orders.

Hypotheses and research methods

The study aimed to assess the propensity of TSL industry companies to overload cargo based on selected aspects of loading operations management. Based on this, the general assumption was adopted:

Main research hypothesis: Management of selected loading operations affects decisions on cargo overloading, where:

Detailed hypothesis 1: There is a statistically significant impact between the propensity to overload cargo and the method of weighing the cargo.

Detailed hypothesis 2: There is a statistically significant impact between the propensity to overload cargo and the person responsible for loading operations.

To verify the stated hypotheses, the study analysed selected variables, the characteristics of which are presented in Table 2.

Tab. 2. Characteristics of the variables included in the study

Variable type	Variable name	Variable description	Variable designation
Dependent variable	Number of overloaded orders in the last year	Absence or presence of overloaded orders in the last year	Order_weight_2
	Number of overloaded orders in the last year	Absence of overloaded orders or presence of 1 to 5 overloaded orders, or more than 5 in the last year	Order_weight_3
Independent variable	Vehicle weighing before transport operation	The company weighs the vehicle using a scale installed on-site, uses the nearest weighing station, weighs each vehicle before departure, or does so selectively	Vehicle_weighing
	A person responsible for loading operations	Identification of the person responsible for loading operations: Driver, Shipper (freight forwarding company, customer), Transport manager, or Owner/authorised person	Person_responsible

The statistical analysis of the collected data, aimed at comparing groups of companies in terms of selected characteristics, was performed using the non-parametric Mann-Whitney U test for two groups of independent variables and the Kruskal-Wallis test for more than two groups of independent variables. A significance level of 0.05 was adopted. In the study of the measure of association between two qualitative features presented in the form of a contingency table, the value of Pearson's contingency coefficient was also used.

Results

Propensity of companies to overload orders vs vehicle weighing before transport

The conducted research has led to the following observations. Preliminary exploratory analysis showed that overloaded transport orders occur in the operations of TSL industry companies (Table 3). One-third of companies admit to violating load weight regulations, most often up to five transport orders per year (36.8%), while 5.8% of companies have more than five such orders. In total, over 40% of entities declared overloaded transport orders in the last twelve months. Interestingly, the structure of order types by weight is very similar in companies with heavy goods vehicles over 12 tonnes and those with vehicles between 3.5 tonnes and 12 tonnes. In the former, the share of overloaded orders relative to the group size is 39%, and in the latter, 44%.

Tab. 3. Number of orders received in the last 12 months that violated load weight regulations

Number of overloaded orders	Number (N)	Percentage (%)
No such orders	230	57.5
1-5 orders	147	36.8
6-10 orders	16	4.0
11-20 orders	7	1.8
Total	400	100.0

Source: own study based on research results

The reasons for exceeding the load weight can be attributed to difficulties in weighing the load. In the vast majority of cases, vehicles are not weighed at the company before departure due to the company's inability to do so (35.3%) or because of the availability of weight information in waybills (37%). Only one in ten companies has a scale installed on their premises. Nearly one-fifth of companies declare that the load is weighed selectively (18.3%).

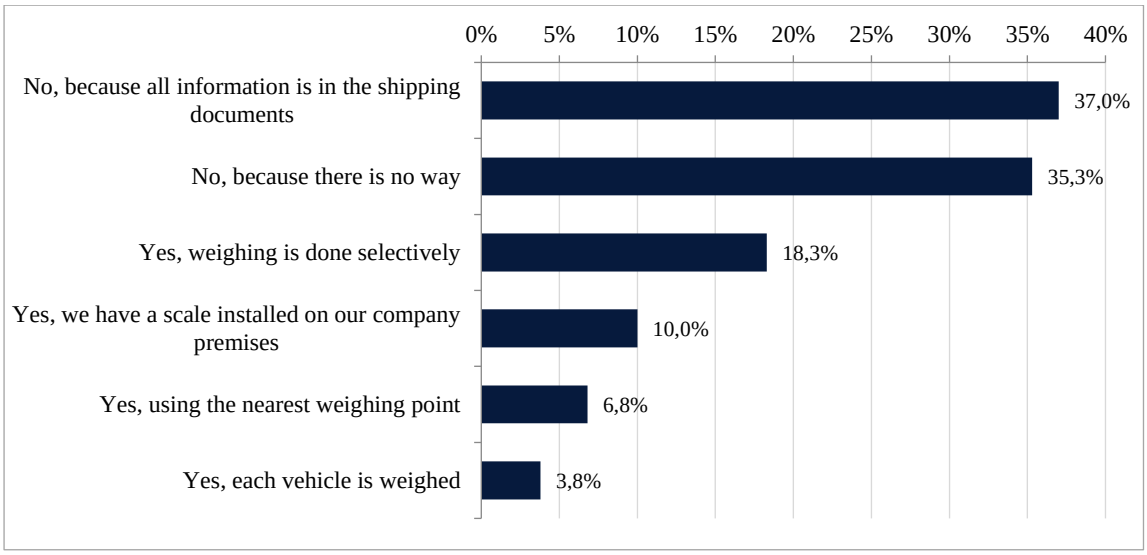

Fig. 1. Are the company's vehicles weighed before transport operation?

The distribution of responses (Figure 1) shows that less than half of the surveyed companies take steps to weigh the cargo (a total of 38.9%), which brings the possibility of errors in the cargo weight, also related to exceeding the permissible weight.

Combined with the previously obtained results (Table 4), it can be said that there is a high risk of overloading the national road network by vehicles exceeding the permissible weight. More than half of the surveyed TSL industry companies with heavy vehicles do not check the cargo weight before departure. Moreover, almost half of the surveyed companies declare that they have carried out overloaded orders in the last 12 months. It was identified that among the surveyed transport companies, one in four (26%) simultaneously did not weigh the vehicle before starting the order and had exceeded the permissible cargo weight.

To verify Detailed Hypothesis 1, statistical significance testing was conducted between the variables Order_weight_2 and Vehicle_weighing using the Mann-Whitney U test. The grouping variable was the number of orders received in the last 12 months that violated or did not violate the cargo weight regulations. The groups of companies by number of overloaded orders (Order_weight_2):

- Group 1: No overloaded orders;
- Group 2: Overloaded orders.

The results in Table 3 show that the average rank in Group 1 of companies is higher than the rank in Group 2 for Vehicle_weighing_A and Vehicle_weighing_C and the average rank in Group 2 is higher than the rank in Group 1 for Vehicle_weighing_D.

Tab. 4. Rank statistics

Vehicle_weighing	Group of companies by number of overloaded orders	N	Average rank	Sum of ranks
Yes, we have a scale installed on our company premises	Group 1	230	205.72	47315.00
	Group 2	170	193.44	32885.00
Yes, using the nearest weighing point	Group 1	230	199.17	45810.00
	Group 2	170	202.29	34390.00
Yes, each vehicle is weighed	Group 1	230	204.30	46990.00
	Group 2	170	195.35	33210.00
Yes, weighing is done selectively	Group 1	230	183.13	42120.00
	Group 2	170	224.00	38080.00

The test value for the variable Vehicle_weighing_A: U = 18350; Vehicle_weighing_C: U = 18675; Vehicle_weighing_D: U = 15555 is statistically significant at the $p < 0.05$ level (Table 5).

Tab. 5. Results of analyses using the Mann-Whitney U test

	Vehicle_weighing_2			
	A. Yes, we have a scale installed on our premises	B. Yes, using the nearest weighing point	C. Yes, each vehicle is weighed	D. Yes, weighing is done selectively
Mann-Whitney U test	18350.000	19245.000	18675.000	15555.000
Wilcoxon's W	32885.000	45810.000	33210.000	42120.000
Z	-2.020	-0.614	-2.326	-5.224
Asymptotic significance	0.043	0.539	0.020	<0.001

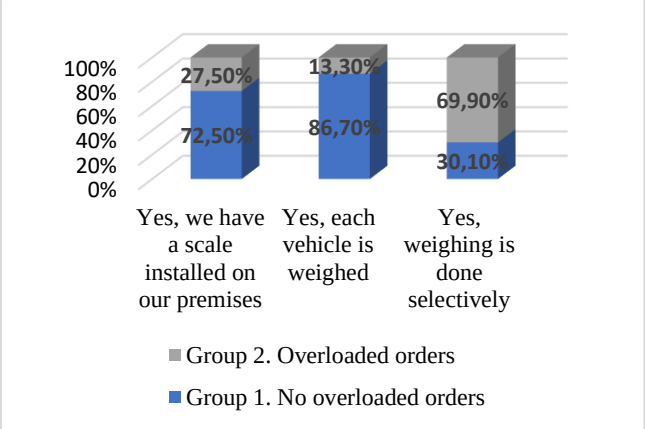

Fig. 2. Structure of differences between groups by order weight and the method of weighing the cargo

Companies that have an installed scale on their premises to weigh vehicles, as well as companies that declare that every vehicle is weighed before departure, significantly more often report no orders violating permissible cargo weight regulations (72.5% and 86.7%, respectively). In contrast, companies that declare selective vehicles weighing significantly more often report overloaded orders (30.1%) (Figure 2).

Propensity of companies to overload orders vs designation of the person responsible for cargo

Various individuals may be involved in the management of loading and control of cargo weight, depending on the type of activity and organisational structure of the transport or logistics company. The analysis of the survey (Table 6) showed that the driver is most often responsible for loading processes (44.5% of companies), followed by the shipper (32.8%). The responsibility for loading is much less frequently borne by the company owner or transport manager (11% - 11.8%).

Tab. 6. Person most frequently responsible for loading operations in the company

Person_responsible	Number	Percentage (%)
Driver	178	44.5
Shipper (forwarding company, customer)	131	32.8
Transport manager	47	11.8
Owner/authorised person	44	11.0
Total	400	100.0

It is assumed that the choice of the person responsible for the cargo may affect the overloading of the cargo. To verify Detailed Hypothesis 2, further statistical testing was conducted to examine the difference between the variables Vehicle_weighing_3 and Person_responsible. Due to the number of groups of the grouping variable, which was the number of orders received in the last 12 months in terms of violations of permissible weight regulations, the Kruskal-Wallis H test was conducted. Groups of companies by number of overloaded orders (Vehicle_weighing_3):

- Group 1: No overloaded orders;
- Group 2: Number of overloaded orders: 1-5;
- Group 3: Number of overloaded orders: 5 and above.

The results in Table 7 show that the average rank in Group 1 is higher than the ranks in the other groups of companies for Person_responsible_A. The average rank in Group 2 is higher than the ranks in the other groups of companies for Person_responsible_B. The average rank in Group 3 is higher than the ranks in the other groups of companies for Person_responsible_D.

Tab. 7. Rank statistics

Person_responsible	Groups of companies by number of overloaded orders	N	Average rank
Driver	Group 1	230	211.50
	Group	147	193.13
	Group 3	23	137.59
Shipper (forwarding company, customer)	Group 1	230	188.91
	Group 2	147	216.63
	Group 3	23	213.26
Transport manager	Group 1	230	197.00
	Group 2	147	201.49
	Group 3	23	229.17
Owner/authorised person	Group 1	230	204.59
	Group 2	147	190.74
	Group 3	23	221.98

The test value for the variable Person_responsible_A: H = 12.808; Person_responsible_B: H = 8.252; Person_responsible_D: H = 7.245 is statistically significant at the $p < 0.05$ level (Table 8).

Tab. 8. Results of analyses using the Kruskal-Wallis H test

	Person responsible for loading operations			
	Driver	Shipper (forwarding company, customer)	Transport manager	Owner/authorised person
H Kruskal-Wallis	12.808	8.252	5.260	7.245
df	2	2	2	2
Asymptotic significance	0.002	0.016	0.072	0.027

When the shipper or owner is responsible for loading, overloaded orders occur significantly more frequently. Conversely, no overloaded orders occur significantly more often when the driver is responsible for loading operations within the company.

To complement the obtained results (Table 9), post hoc pairwise comparisons were conducted using the Bonferroni correction method. These comparisons indicate that a statistically significant difference exists between Group 1 and Group 3 of companies (where $p < 0.001$), as well as between Group 2 and Group 3 of companies (where $p < 0.005$).

Tab. 9. Significance values for multiple tests adjusted using the Bonferroni method

Sample 1-Sample 2	Test statistics	Standard error	Standardised test statistic	Significance
Group 1 – Group 2	-6.878	11.412	-0.603	0.547
Group 1 – Group 3	-83.111	23.635	-3.516	< 0.001
Group 2 – Group 3	-76.233	24.234	-3.146	0.002

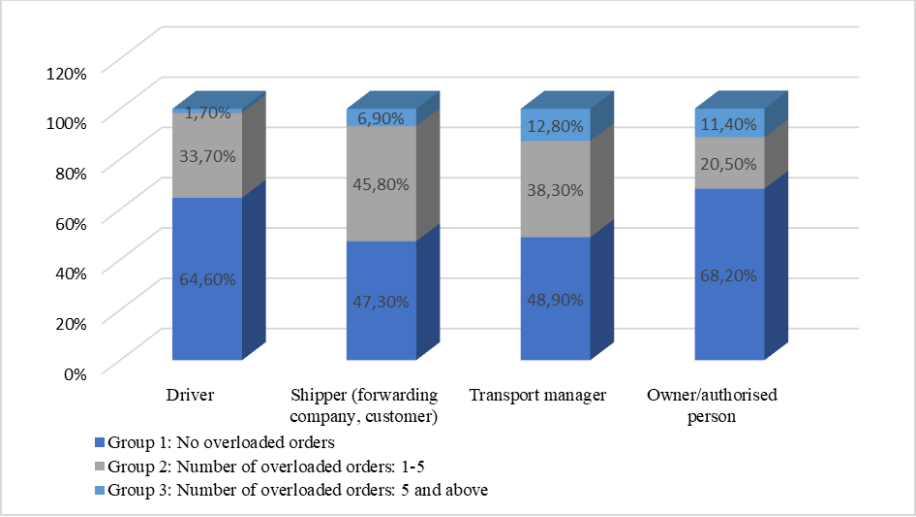

Fig. 3. Structure of differences between groups by order weight order and person in charge of loading operations

This means that exceeding the permissible weight of the load occurs significantly more often in companies where the transport manager (51.1%) or the owner (31.8%) is responsible for loading operations than in other companies. The absence of overloading situations is most common in companies where the driver is responsible for loading operations (64.6%) (Figure 3).

Intentional propensity of TSL companies to overload cargo

The analyses carried out made it possible to observe that the propensity for cargo overloading in TSL industry companies is significantly associated with both the occurrence of the weighing process and its method, as well as the responsibility for this process among individual participants in the transport process. At the same time, it is observed that vehicles can be overloaded intentionally (Figure 4). Only 3% of the companies indicated that they are not guided by any of the proposed factors that could increase the risk of deciding to overload a vehicle. Almost all companies surveyed indicated at least one factor that causes them to overload deliberately. The most common factors are the needs of the customer (39%) and the type of load being transported (38.8%), especially when it is non-standard or dangerous cargo. One in three companies (29%) are also prepared to take a risk because of the potential profits, taking into account the possible cost of a penalty. Less frequently cited reasons for overloading cargo include driver's working time restrictions (25.5%) and competitive pressure (23%).

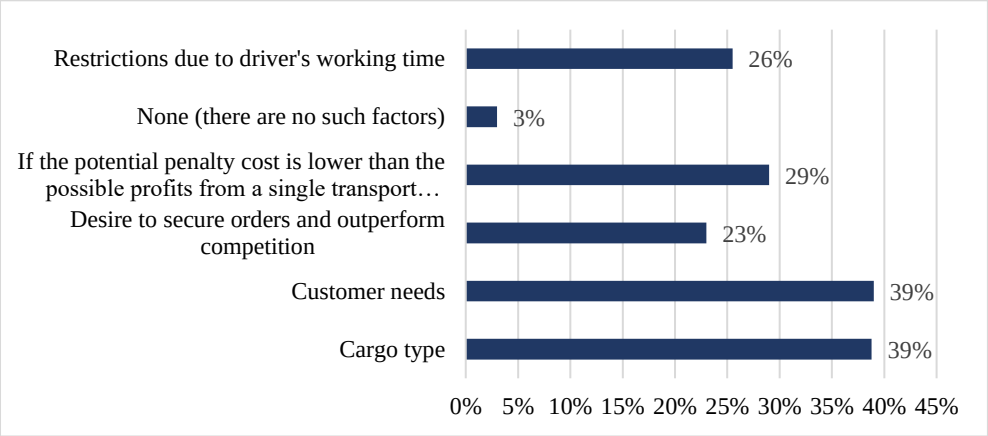

Fig. 4. Factors that may increase the risk of deciding to overload a vehicle

At the same time, a simple Pearson's chi-squared test showed (Table 10) that in companies where the shipper is in charge of loading operations, the favourable relationship between the potential penalty and the possible profit is considered to be a factor driving the risk of overloading the driveway significantly more often (than in those where the driver is in charge) ($C = 0.192$; $p < 0.005$). In companies where the owner is responsible for loading operations, there is a significantly higher tendency (compared to cases where drivers are responsible) for customer demands to be considered a factor increasing the risk ($C = 0.141$; $p < 0.05$). In companies where drivers are responsible for loading operations, there is a significantly higher tendency (compared to other cases) to cite the impact of driver working time restrictions ($C = 0.199$; $p < 0.001$).

Tab. 10. Relationship between factors increasing the risk of the decision to overload a vehicle and the person responsible for loading operations

Selected factors increasing the risk of decisions to overload the vehicle	A person responsible for loading operations				Pearson's chi-square
	Driver	Shipper	Transport manager	Owner/authorised person	
If the potential penalty cost is lower than the possible profits from a single transport operation	21.9%	39.7%	36.2%	18.2%	p=0.002 C=0.192
Customer needs	34.8%	36.6%	44.7%	56.8%	p=0.044 C=0.141
Restrictions due to driver's working time	33.7%	16.8%	12.8%	31.8%	p <0.001 C=0.199

The conscious decision to overload a vehicle in violation of the regulations causes companies to tend to bypass weighing points. This practice is followed by approximately 17% of the surveyed TSL operators. Testing with Pearson's chi-squared method (Table 11) made it possible to observe that companies which have been subjected to orders that violate the regulations related to the permissible weight of the load significantly more often take into account the bypassing of vehicle weight control points when planning their routes ($C = 0.121$; $p < 0.05$).

Tab. 11. Relationship between exceeding load weight regulations and route planning with bypassing weighing points

Number of orders violating regulations for exceeding load weight	Planning a route with the bypassing vehicle weighing checks	
	Yes	No
No overloaded orders	43.9%	60.2%
Overloaded orders	56.1%	39.8%

Statistically significant relationship, Pearson's chi-squared: $p = 0.015$; $C = 0.121$

More than half of the companies (56.1%) that reported overloaded orders decide to bypass vehicle weighing control points. Notably, some companies (43.9%) that do not perform overloaded transports also plan routes with this criterion, likely due to reluctance to waste time on procedural checks. According to three-quarters of the respondents, vehicle weighing results in a loss of less than an hour (74.8%), but 21.8% believe it takes between 1 and 2 hours.

Discussion and summary

The results of the conducted research shed new light on several key observations in the investigated area. The phenomenon of overloaded vehicles in the TSL industry may be more widespread than the statistics and industry reports developed to date suggest. The anonymity of the survey caused surveyed companies to admit to overloading violations more readily. Nearly half of them declared that they executed at least one transport order that exceeded permissible load weight in the last year, highlighting the potential scale of the issue and its impact on national infrastructure. Furthermore, the propensity for cargo overloading in TSL industry companies is significantly associated with both the occurrence of the weighing process and its method, as well as the responsibility for this process among individual participants in the transport process.

The sources of the problem can be traced to the approach used to weigh a loaded vehicle. In most cases, vehicles are not weighed in the company before departure due to the lack of such facilities or trust in the shipper who declared the weight earlier. What is more, the results of statistical testing proved that companies that weigh their vehicles before departure are significantly more likely to declare that there are no orders that violate cargo weight regulations. Furthermore, the role in the freight process is also important, as overloaded cargo is far less common in companies where the driver is in charge of loading operations. However, it should be noted that almost all overloaded cargo was carried out consciously as a result of decisions made, which were mainly based on the desire to satisfy the customer, the type of cargo and the positive ratio of potential benefits to costs.

Overloading has negative economic and social consequences. On the other hand, cargo overloading has numerous causes in the interest of transport companies conditioned by external factors. Consequently, the propensity of TSL companies to overload cargo is determined by many aspects related to customer service, route planning or the management of loading operations. The implementation of advanced technologies, standard operating procedures, effective fleet management and compliance with rules and regulations can significantly reduce the risk of overloads and improve operational efficiency. However, it is important to note the limitations of the study, which did not analyse the types of cargo. Oversized cargo can, with special permission, exceed the permissible vehicle load and is therefore carried out with the approval of the relevant authorities and is fully justified. Despite completing the formalities, even these can negatively impact road infrastructure.

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