CETRA^{2026} 27-30 May 2026, Bol, Island Brač, Croatia
9th International Conference on Road and Rail Infrastructure

CARGO SECURING ASPECTS DEPENDING ON MILEAGE

Petr Prochazka[1], **Martin Vlkovsky**[1], **Jiri Malisek**[1], **Alexander Ilkstrom-Kravcov**[2]
[1] *University of Defence, Faculty of Military Leadership, Department of Logistic, Czech Republic*
[2] *University of Defence, Research, Expertise and Technology Centre, Czech Republic*

Abstract

The technical condition of a vehicle is crucial for ensuring cargo securing. One aspect is the age of the vehicle and its mileage. Modern sensor technology makes it possible to collect data during transport relatively cheaply and easily and then evaluate it using Freight Vehicle Management for the purpose of rationalizing cargo transport. The paper deals with aspects of cargo securing in relation to the mileage of T-815-7 Multilift vehicles. The assumption is that higher mileage will have a significant impact on the choice of cargo securing method. To identify differences, appropriate statistical methods (Kruscal-Walis tests) are used to evaluate acceleration coefficients from real transport experiments of two pairs of tested vehicles. Acceleration coefficients are measured using a three-axis accelerometer with a data logger, and for extreme values, the corresponding inertial forces affecting the cargo securing system, demonstrating different requirements for cargo securing. The results show that there are statistically significant differences between selected vehicles, determining different requirements for the fastening system, which are summarized in the recommendations. In the tested vehicles (both pairs), it was proven that mileage has a significant impact on cargo securing even in cases where the difference in mileage is relatively small.

Keywords: transportation, cargo securing, mileage, acceleration coefficient, truck

1 Introduction

Road freight transport is a key element of today's transport system, ensuring the smooth functioning of the economy, logistics, and the state's security structures. Within the European Union, it has long been the dominant mode of transport in terms of transport performance compared with other modes, and its importance continues to grow due to door-to-door concepts, routing flexibility, and the ability to respond to dynamic market demands. This trend is also evident in the Czech Republic, where road transport accounts for the majority of the volume of goods transported and at the same time places increasing demands on vehicle technical condition, infrastructure, and the organization of transport processes.

One of the key safety aspects of road cargo transport is adequate cargo securing. Insufficient or incorrect cargo securing is a significant risk factor that may lead not only to damage to the transported goods, but above all to threats to road traffic safety. Estimates by the European Commission indicate that up to 25% of accidents involving heavy goods vehicles may be related to incorrect or insufficient cargo securing; the real impacts are likely even higher when accidents not attended by the Police and damage occurring off public roads are also considered [1]. In Europe, cargo securing is normatively anchored primarily in DIN EN 12195-1:2021-01 [2], which defines calculation procedures and normative acceleration coefficients for dimensioning securing equipment.

DOI: https://doi.org/10.5592/CO/CETRA.2026.1783

These values are based on empirical measurements carried out mainly in the 1980s and 1990s and represent a simplified model of the dynamic loading of cargo during transport. However, a number of authors point out that current road-transport conditions have changed substantially since these standards were developed, both in terms of the technical condition of infrastructure and in terms of vehicle design, operating load, and utilization patterns [3]. An important factor that is not yet systematically considered in normative approaches is the technical condition of the vehicle, i.e., its age and the number of kilometers driven. Mileage is closely linked to wear of chassis assemblies, suspension, shock absorbers, and other structural components, which fundamentally affect the transfer of dynamic effects from the road surface to the cargo area. Experimental studies show that different vehicle types, even under comparable operating conditions, generate statistically significantly different acceleration values in individual axes, which directly affects the magnitude of inertial forces acting on the cargo securing system [1]. At the same time, modern sensor technologies make it relatively easy and cost-effective to monitor dynamic transport parameters in real time. The use of three-axis accelerometers with data loggers, or their integration into Freight Vehicle Management systems, opens new possibilities for detailed analysis of transport processes and their rationalization. The measured acceleration coefficients can subsequently be evaluated statistically and used not only for retrospective safety analysis, but also to optimize the choice of securing methods and to dimension securing equipment [4]. Existing research on cargo securing focuses mainly on the influence of road quality, vehicle type, or driving speed on the magnitude of dynamic effects during transport. The effect of mileage, i.e., gradual vehicle wear, remains relatively underexplored in literature, even though it can be expected to have a significant impact on the character of generated shocks and vibrations. This gap is what the present paper addresses.

The aim of this paper is to analyze cargo securing aspects as a function of the number of kilometers driven for selected T-815-7 Multilift vehicles. Based on experimental transports, the measured acceleration coefficients obtained using a three-axis accelerometer are evaluated and then statistically analyses using non-parametric methods (Kruskal-Wallis tests). The results are interpreted in terms of their impact on the magnitude of shocks (inertial forces) and the requirements for the cargo securing system. The paper thus contributes to a deeper understanding of the relationship between a vehicle’s technical condition, its operational history, and road freight transport safety, and provides a basis for practical recommendations applicable in transport practice and in the revision of current normative approaches.

From the perspective of further advancing knowledge, it is also evident that existing experimental approaches, based on measurements from selected vehicle configurations and routes, need to be systematically expanded to a larger and more diverse fleet in order to robustly generalize the findings for practical use. Specifically, vehicles covering a broader range of age and accumulated mileage should be included, since wear of chassis and suspension components may alter the transmission of shocks to the loading platform and, consequently, the requirements for sizing load-securing devices. It is equally desirable to work with different types and weights of cargo (e.g., palletized units, containers, sensitive equipment, dangerous goods) and to distinguish the purpose of trips (routine commercial transport vs. specific operational deployments). This need is particularly important for agencies within the Integrated Rescue System, typically fire and rescue services, where higher operational dynamics, time pressure, and the transport of specialized equipment coincide; in such contexts, underestimating real shock loads can increase the risk of equipment damage as well as secondary incidents [1, 14].

2 Literature review

Cargo securing in road transport has traditionally been framed as a combination of normatively defined calculations, practical procedures, and verification in real operation, with failures potentially having safety and economic impacts. Vlkovský et al. point out that even with formal compliance with procedures, the assumed shock effects may be exceeded, leading to cargo damage or accidents, which then translates into financial losses for carriers and society [3]. From a risk-management perspective, this framework is complemented by review papers that systematize types of cargo loss/damage risks and emphasis the need to link technical, organizational, and data-driven approaches [21]. The practical dimension is also reflected in professional sources (e.g., the European Safe Transport and Logistics Association), which summarize basic principles and recommendations for cargo securing with respect to operational practice [22].

2.1 Normative and institutional basis for cargo securing

The main foundation of the calculation-based concept of cargo securing in Europe is DIN EN 12195-1:2021-01, which sets out principles and procedures for calculating lashing (securing) forces in road transport [2]. A number of empirical and modelling studies in this area explicitly build on the EN 12195-1 methodology (in its earlier editions), especially the concept of acceleration coefficients in three axes as a representation of dynamic effects during driving [1, 3]. The current literature emphasizes that normative settings should be continuously confronted with current vehicle behavior and infrastructure; work aimed at validating existing standards and guidelines by measuring accelerations on commercial vehicles follows this direction [13]. The institutional and best-practice framework is complemented by professional and sector platforms that stress standardization of procedures, responsibilities, and control activities within the transport chain [22].

2.2 Empirical studies of shocks, accelerations, and their effects on securing

Empirical research focuses on measuring shocks and accelerations in real operation and on assessing to what extent actual dynamic effects match normative assumptions. Vlkovský, Veselík and Grzesica conducted a case study measuring acceleration coefficients during road transport and showed that exceeding the normatively assumed values may occur for a non-negligible portion of time, with significant implications for dimensioning securing equipment and for economic losses [3]. This line of work is followed by a comparative experiment on two types of trucks, where the authors statistically test differences in measured acceleration coefficients and demonstrate that the”vehicle factor” can substantially change the magnitude of shocks relevant to securing [1]. Other studies in the same research stream develop the topic of the impact of shocks on cargo securing as a broader problem and connect measurements with considerations regarding the choice of securing method [4]. For the question of dependence on distance travelled (kilometers), it is crucial that these approaches work with time series of accelerations on specific road sections, which makes it possible to consider not only extremes, but also the frequency of critical states per unit distance (e.g., the”number of limit exceedances per 1 km”). This shift from instantaneous values to”exposure” is also supported by studies comparing securing methods when driving on roads of different quality [8], examining the influence of shocks on pallet units and their securing [9], and evaluating differences between loaded and unloaded runs of container trucks [10]. Taken together, the literature confirms that risk estimation cannot rely on a single”typical” scenario; it is determined by combinations of vehicle, cargo, road surface, and operating conditions [8-10].

2.3 Measurement and sensing: from accelerometers to operational monitoring

The methodological literature focuses on how to reliably measure dynamic effects relevant to securing. Jagelčák and Kubáňová explicitly analyze the influence of accelerometer position on the measurement of lateral acceleration in a delivery van, which is crucial for data comparability and for interpreting the risk of cargo displacement [5]. An alternative measurement approach is the use of GNSS/INS to determine turning radius and lateral acceleration, i.e., parameters directly associated with lateral dynamic effects [15]. Rajamani focuses on lateral acceleration in commercial vehicles with regard to cargo safety, underlining the importance of lateral dynamics for dimensioning and assessing securing [6]. For tractor–semitrailer combinations, the literature provides studies evaluating dynamics on highways and the related risks for securing [12] as well as work oriented towards practical monitoring of securing during highway driving [11]. In terms of mileage, the key point is that such monitoring approaches open the way to continuous data collection over the entire route and subsequent evaluation of cumulative exposure.

2.4 Modelling, optimization, and testing: from the laboratory to transport planning

Alongside field measurements, laboratory and modelling approaches are emerging. The stability of palletized cargo can be examined using a dynamic test method performed on a laboratory test bench, enabling controlled reproduction of loading scenarios [17]. The dynamic responses of a trailer when driving over an obstacle further show that even single events (road unevenness/obstacle) can generate pronounced dynamic effects that should be considered in securing design [18]. Securing materials are also investigated in pilot studies, contributing to an understanding of the behavior of palletized units under alternative fixing methods [19]. Although maritime transport uses different standards, work optimizing lashing layouts on ships by comparing international maritime standards shows that formalization of constraints and optimization logic can be transferable to other modes as well [20]. In road transport, this logic is directly reflected in optimization models that consider securing under multi-drop distribution while respecting axle-load constraints [16], situations where the number of stops and kilometers travelled change the weight distribution and, consequently, securing requirements.

2.5 Summary of findings and identification of the research gap

The sources indicate that current cargo securing research is grounded in the normative basis [2], develops it through measurements and statistical methods [1, 3, 7], and gradually moves towards data-driven optimization (e.g., the use of MEMS accelerometers to rationalize the securing system) [14]. At the same time, emphasis is increasing on validating prescriptive assumptions in real operation [13] and on systematically mapping risk factors and future directions [21]. In the context of the topic ”depending on the number of kilometers driven”, however, the literature more often deals with partial routes, specific road sections or situations (cornering, obstacles, highways) [1, 11, 12, 18] rather than with an explicit model that would link distance travelled as cumulative exposure to the probability of securing loosening/damage. This opens space for research that combines continuous sensor data [5, 15], operating conditions and transport type (including multi-drop regimes) [16] into a unified framework for risk assessment and securing design over time and per kilometer, in line with the requirements of standards and sector recommendations [2, 22].

3 Transport experiment

3.1 Experiment conditions

The transport experiment was carried out with four Tatra 815-7 Multilift MSH-165-SCA vehicles with mileage between 2, 500 and 16, 000 km (table 1), without cargo, on a class III road between the villages of Mestecko and Rakovnik (figure 1).

Table 1 Mileage of tested vehicles

A	B	C	D
3, 772 km	13, 634 km	16, 204 km	2, 417 km

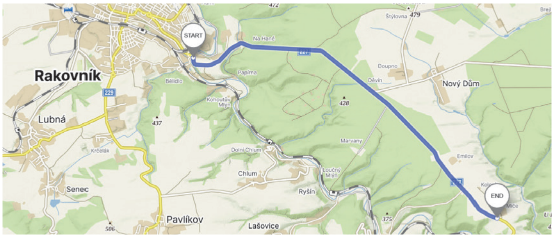

Figure 1 Route of the transport experiment

In total, four runs were performed on the selected route. The evaluation was carried out in the direction from Mestecko to Rakovnik. The distance travelled was therefore 4 × 8.9 km, and the average speed during the experiment was 63.1 to 70.0 km/h. The experiment was conducted under relatively favorable weather conditions at a temperature of 5.0 to 9 °C; the road surface was dry, without snow or ice, and no precipitation (rain or snowfall) occurred during the measurements. Traffic intensity was low and did not affect the experiment; the runs took place in the right-hand lane.

3.2 Primary data

For primary data acquisition, a triaxial MEMS accelerometer with an integrated data logger and calibration certificate (OM-CP-ULTRASHOCK-5) was used, mounted to the rear-axle frame using neodymium magnets. It measured acceleration in three axes (x – longitudinal, y – lateral, z – vertical) over a ±5 g range with a calibration accuracy of ±0.2 g and a resolution of 0.01 g [23]. With a sampling rate of 64 Hz, peak (maximum) values were recorded, yielding a total of 355, 326 samples (118, 442 per axis) expressed as acceleration coefficients in multiples of g. The device was selected because it enables non-invasive installation directly on the rear-axle frame using neodymium magnets while covering the expected dynamic loading in the x/y/z axes within the ±5 g range. The measured data were exported from the device to a Microsoft Excel file. Based on the time stamps, the specific data relevant to the measurement were identified and subsequently processed statistically.

4 Statistical analysis

To identify differences between vehicles with different mileage, a statistical analysis using the standard non-parametric Kruskal-Wallis test was performed. Specifically, four vehicles (labels A–D) with different mileage were compared within the transport experiment described in the previous section.

The non-parametric Kruskal-Wallis test works with the ranks of values from at least three independent groups and tests whether the distributions differ between datasets (measured acceleration coefficients for the individual vehicles). Kruskal and Wallis provide the original derivation and interpretation of the H statistic (approximately chi-square distributed) [24]. Subsequently, Dunn's post-hoc test is used for pairwise comparisons (two-sided test) based on rank sums [25], together with the Bonferroni correction (control of the family-wise error rate – a conservative approach).

Table 2 Results of the Kruskal–Wallis test for sensor no. 5

	Sensor no. 5		
	Axis x	**Axis y**	**Axis z**
H	1 938.06	1 076.43	322.05
p	0	0	0
ε^2	0.009336	0.005181	0.001531

The effect size ε^2 is on the order of thousandths: $\varepsilon^2(x) = 0.009336$; $\varepsilon^2(y) = 0.005181$; $\varepsilon^2(z) = 0.001531$. This implies that statistically significant differences between the tested vehicles do exist, but they explain only a very small part of the variability of the measured values (especially in the z-axis). This is typical for high-frequency recordings (64 values per second): with a very large number of observations, the statistical power of the test increases and even small systematic shifts become extremely significant. At the same time, the H values as a measure of differences between groups are very high (x-axis: $H = 1938.06$, y-axis: $H = 1076.43$, z-axis: $H = 322.05$) and p-values are reported as 0 (i.e., numerically"below the threshold", typically $p \ll 0.001$). This means that, given the data size and variability, the existence of a statistically significant difference between vehicles is demonstrated in all three observed axes.

Table 3 Results of Dunn's post-hoc test

Axis x	**Axis y**	**Axis z**
B › A	B › A	B › A
C › A	C › A	C › A
C › B	B › C	B › C
B › D	B › D	B › D
C › D	C › D	C › D
A › D	D › A	D › A

From table 2, it is evident that statistically significant differences were found between vehicles with a larger difference in mileage (rows shaded in green), which also corresponds to the difference in age (2 years of operation). For clarity, vehicles B and C with higher mileage are shown in bold: there is a statistically significant difference between trucks A and B (mileage difference 9, 862 km), A and C (mileage difference 12, 432 km), B and D (mileage difference 11, 217 km), and C and D (mileage difference 13, 787 km). Between vehicles with similar mileage (pairs A/D and B/C), the relationship differs by axis and is irrelevant for technical/operational conclusions. For illustration, the following relationships apply between vehicles in the respective axes: Axis x: C › B › A › D, Axis y: B › C › D › A, Axis z: B › C › D › A.

Deviations occur in the x-axis, although this is a different relationship (inequality) for vehicles with similar mileage. Only the relevant pairs A/B, A/C, B/D and C/D are evaluated.
Table 4 summarizes the basic characteristics of the statistical datasets for the individual tested vehicles and axes. The green area indicates higher average acceleration coefficients for vehicles with higher mileage (B, C). On the other hand, values such as the kurtosis coefficient are higher for vehicles A and D, which is a consequence of the presence of outliers in these datasets (see the red value for vehicle D, x-axis). The occurrence of extreme values in individual datasets/axes is random and no conclusions can be drawn from it. The values in the z-axis are corrected for the axis offset of the measurement device (accelerometer – measurement includes 1g).

Table 4 Descriptive statistics and extreme values (absolute values)

	A			B			C			D		
	x	**y**	**z**	**x**	**y**	**z**	**x**	**y**	**z**	**x**	**y**	**z**
AM	0.29	0.22	1.42	0.36	0.32	1.52	0.43	0.28	1.51	0.27	0.24	1.46
Mo	0.25	0.19	1.38	0.31	0.31	1.50	0.38	0.25	1.44	0.25	0.19	1.38
Me	0.28	0.21	1.41	0.34	0.31	1.51	0.42	0.26	1.50	0.26	0.22	1.45
V	0.01	0.01	0.04	0.01	0.01	0.05	0.03	0.01	0.06	0.01	0.01	0.05
SC	0.80	1.38	0.30	0.83	0.71	0.26	0.58	0.93	0.30	1.59	1.09	0.37
KC	2.15	5.42	0.97	2.52	1.30	0.35	0.74	2.41	0.47	21.35	2.42	0.96
E	1.46	1.64	1.84	2.11	1.42	1.76	1.41	1.71	1.97	2.76	1.09	1.81

Note: AM – Arithmetic Mean.Mo – Mode.Me – Median.V – Variance.SC – Skewness Coefficient.KC – Kurtosis Coefficient.E - Extremes

Nevertheless, it is evident that, in isolated cases, the values exceed the normatively specified acceleration coefficients in the individual axes according to DIN EN 12195-1:2021-01:

$$c_{x,\,y,\,z} = (0.8,\ 0.6,\ 1.0) \tag{1}$$

Overall (in absolute values; negative values indicate only the direction of the force), there are 256 values for vehicle A, 1, 274 for vehicle B, 1, 878 for vehicle C and 559 for vehicle D (see detailed table 5). The values in table 5 again illustrate a markedly higher number of exceedances of the normatively specified acceleration coefficients for vehicles with higher mileage (B, C).

Table 5 Number of values exceeding the normatively specified limit

	A	**B**	**C**	**D**
x	12	84	633	12
y	136	628	364	151
z	108	562	881	396

5 Conclusion

The results showed that vehicles with higher mileage exhibited, on average, higher shock levels, in the form of acceleration coefficients, which are the basic component for calculating inertial forces. This conclusion was statistically demonstrated and is therefore significant at the given significance level; it is also evident from table 4, where the central tendency measures (arithmetic mean, mode and median) are higher for the higher-mileage vehicles. From the perspective of extreme values (table 5), this is consistent with a markedly higher occurrence of out-of-limit values in the individual axes for higher-mileage vehicles (the largest difference is in the x-axis, where vehicle C generated more than fifty times as many exceedances, outside the standard [2], as vehicles A and D). For practical purposes, this means that vehicles B and C (older vehicles with higher mileage) generate stronger shocks, which translate into higher theoretical inertial forces. This needs to be reflected in the choice of the securing system, i.e., the cargo should be secured with regard to the potential action of higher inertial forces on the cargo. Overall, ceteris paribus, the influence of mileage on the cargo and its securing system is substantial (statistically significant), and the hypothesis of an effect even for a relatively small difference in vehicle age and mileage was confirmed. It can also be inferred that if a multiplicative effect, the concurrence of factors (adverse vehicle condition, road surface, driver style, etc.), were considered, the requirements for the cargo securing system would be entirely different (significantly higher in terms of required lashing capacity) than those specified in [2]. The results are therefore applicable mainly to specific transports where such a concurrence of events may occur and fundamentally different securing requirements can be expected compared with what would be theoretically assumed based on the empirical data in the standard [2]. Following on from the introductory thesis of the article, the contribution of the aforementioned research is primarily in the requirement to correct the averaged values of acceleration coefficients and assumptions in European standards. The key conclusion is limited validity [2] for specific types of transport (off-road vehicles, vehicles traveling on lower-quality roads, etc.). The conclusions are applicable not only to military needs, but also to the needs of selected components of the Integrated Rescue System (primarily firefighters). In crisis situations (fire, traffic accident, flood, armed conflict, etc.), it is much more important that the required material/vehicle arrives at the required location on time and in the required quality (i.e., with undamaged cargo). While in the commercial sphere, damage or loss of material is more or less a financial loss (with the exception of accidents involving loss of life, etc.), in crisis situations, failure to deliver the relevant cargo or failure of a vehicle to arrive at its destination on time can result in loss of life or endanger human health, the environment, etc. Future research will gradually include the duration of the shock event, which may affect cargo displacement/loosening and, in some cases, may result in a traffic accident, or at least damage the cargo or vehicle, or negatively affect human health or the environment. Additional data sources (Big Data) [26] and sensing/data acquisition technologies will be used [27, 28]. The research will include additional data samples, not only from military movements, but also using measurements taken in cooperation with the Fire and Rescue Service. Within this framework, it will also be appropriate to include other factors (movement on poor-quality roads, maintenance, etc.).

Finally, differences in trends between the Czech Armed Forces (and NATO armed forces in general) and the civilian sector will be monitored. Partial differences can also be observed at the national and EU level. An interesting national trend is stagnation in the transported amount while the transport distance is increasing [29]. This is closely related to the number of kilometers driven in a given period and thus to the potential impact on cargo securing. In this context, it is also necessary to emphasize the collection and evaluation of relevant data. Technical influences on accident rates are often only estimates and are not systematically monitored. With the use of modern sensor technology, this is much more accessible, and key transport attributes can also be monitored online, as demonstrated, for example, by the US Army's In-Transit Visibility system [30].

Acknowledgement

This research was funded by the Ministry of Defense of the Czech Republic, grant DZRO-FVL22-INTAL ”Implementation of new technologies and procedures into the logistic support of the Army of the Czech Republic”.

References

[1] Vlkovský, M., Veselík, P.: Cargo securing – comparison of the selected trucks, Transport Problems, 15 (2020) 4, pp. 265–274, DOI: 10.21307/tp-2020-065

[2] DIN EN 12195-1:2021-01: Load restraint assemblies on road vehicles – Safety – Part 1: Calculation of lashing forces, Deutsches Institut für Normung (DIN), Berlin, 2021.

[3] Vlkovský, M., Veselík, P., Grzesica, D.: Cargo securing and its economic consequences, 22nd International Scientific Conference Transport Means, pp. 129–135, Trakai, Lithuania, 3-5 October 2018.

[4] Vlkovský, M., Binar, T., Svarc, J., Nemec, P., Bucsuhazy, K.: Impact of shocks on cargo securing during the road transport, IOP Conference Series: Materials Science and Engineering, 603 (2019) 032045, DOI: 10.1088/1757-899X/603/3/032045

[5] Jagelčák, J., Kubáňová, J.: Influence of Accelerometer Sensor Position for Measurement of Lateral Acceleration of Delivery Van for Cargo Securement, Sensors, 23 (2023) 23, 9478, DOI: 10.3390/s23239478

[6] Rajamani, V.: Lateral Acceleration in Commercial Vehicles with Regard to Cargo Security, ATZ Heavy Duty worldw, 17 (2024), pp. 44-48, DOI: 10.1007/s41321-024-1351-y

[7] Neubauer, J., Vlkovský, M., Michálek, J.: Statistical modeling of cargo securing on selected military trucks and road surfaces, The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology, 21 (2024) 3, pp. 341–355, DOI: 10.1177/15485129241227012

[8] Vlkovský, M., Vlachová, H.: Comparison of Cargo Securing Methods During Transport on Different Quality Roads, Smart Cities, Green Technologies and Intelligent Transport Systems, 2021., pp. 200–219, DOI: 10.1007/978-3-030-68028-2_10

[9] Vlkovský, M., Malíšek, J., Kutil, R.: Influence of Shocks on Pallet Load and Cargo Securing, Transportation Research Procedia, 55 (2021), pp. 50-56, DOI: 10.1016/j.trpro.2021.06.005

[10] Vlkovský, M.: A comparison of cargo securing on laden/unladen container trucks, International Journal of Logistics Systems and Management, 40 (2021) 4, pp. 510-524, DOI: 10.1504/IJLSM.2021.120489

[11] Kuba, O.: Monitoring the load securing on semi-trailer when driving on the highway, Transportation Research Procedia, 74 (2023), pp. 1419-1427, DOI: 10.1016/j.trpro.2023.11.291

[12] Jagelčák, J., Kubáňová, J.: Risks of goods transport focused on the assessment of semi-trailer dynamics on highways for cargo securing, Applied Sciences, 14 (2024) 9, 3846, DOI: 10.3390/app14093846

[13] Rajamani, V., Lampkowski, A.: Acceleration Behaviour on Commercial Vehicles to Validate Existing Norms and Guidelines for Load Securing, TRA Conference 2024, pp. 125-130, Dublin, Ireland, DOI: 10.1007/978-3-031-88974-5_19

[14] Vlkovský, M., Malíšek, J.: Optimization of the fastening system of the truck using MEMS accelerometers, Scientific Journal of Silesian University of Technology, Series Transport, 114 (2022), pp. 169-178, DOI: 10.20858/sjsutst.2022.114.14

[15] Jagelčák, J., Gnap, J., Kuba, O., Frnda, J., Kostrzewski, M.: Determination of turning radius and lateral acceleration of vehicle by GNSS/INS sensor, Sensors, 22 (2022) 6, 2298, DOI: 10.3390/s22062298

[16] Çalik, H., Juwet, M., Yaman, H., Vanden Berghe, G.: Cargo securing under multi-drop and axle weight constraints, European Journal of Operational Research, 307 (2023) 1, pp. 157-176, DOI: 10.1016/j.ejor.2022.08.031

[17] Tkaczyk, S., Drozd, M., Kędzierski, Ł., Santarek, K.: Study of the stability of palletized cargo by dynamic test method performed on laboratory test bench, Sensors, 21 (2021) 5129, DOI: 10.3390/s21155129

[18] Barta, D., Blatnický, M., Lovska, A., Kowalski, S., Slíva, A., Dizo, J.: Dynamic responses of a single-axle trailer when driving over a road obstacle, Sensors, 25 (2025) 5246, DOI: 10.3390/s25175246

[19] Tkaczyk, S., Jagelčák, J., Szpotański, M., Sędrowicz, R.: Pilot study of stretch film for securing palletized loads, Sensors, 25 (2025) 6883, DOI: 10.3390/s25226883

[20] Pérez-Canosa, J.M., van't Hek, W., López, M.N., Orosa, J.A.: Optimizing cargo securing layouts on general cargo ships using lashing lines through comparison of international maritime standards, Logistics, 9 (2025) 83, DOI: 10.3390/logistics9030083

[21] Panjee, P., Kaewchueaknang, V., Amornsawadwatana, S.: A systematic literature review of cargo loss risks in road transportation: impacts and future directions, Safety, 11 (2025) 20, DOI: 10.3390/safety11010020

[22] European Safe Transport and Logistics Association (ESTL): Cargo securing, https://www.estl.be/en/cargo-securing/, 18.01.2026.

[23] OMEGA.: User's Guide – OM-CP SERIES: Data Logger and Software, https://assets.omega.com/manuals/M3667.pdf, 18.01.2026.

[24] Kruskal, W.H., Wallis, W.A.: Use of Ranks in One-Criterion Variance Analysis, Journal of the American Statistical Association, 47 (1952) 260, pp. 583-621, DOI: 10.1080/01621459.1952.10483441

[25] Dunn, O.J.: Multiple Comparisons Using Rank Sums, Technometrics, 6 (1964) 3, pp. 241-252, DOI: 10.1080/00401706.1964.10490181

[26] Růžička, J., Tichý, T., Hajčiarová, E.: Big data application for urban transport solutions, Proceedings of the 2022 Smart City Symposium Prague (SCSP), IEEE, 2022., pp. 1–7, DOI: 10.1109/SCSP54748.2022.9792538

[27] Tichý, T., Švorc, D., Růžička, M., Bělinová, Z.: Thermal feature detection of vehicle categories in the urban area, Sustainability, 13 (2021) 12, 6873, DOI: 10.3390/su13126873

[28] Švorc, D., Tichý, T., Růžička, M.: An infrared video detection and categorization system based on machine learning, Neural Network World, 31 (2021) 4, pp. 261–277, DOI: 10.14311/NNW.2021.31.014

[29] Ministerstvo dopravy České republiky: Mezioborové srovnání přepravních výkonů nákladní dopravy (Section 5.2.1.1), Ročenka dopravy České republiky 2024, https://www.sydos.cz/cs/rocenka_pdf/Rocenka_dopravy_2024.pdf, 18.01.2026.

[30] Combined Arms Support Command: In-Transit Visibility (ITV), https://cascom.army.mil/g_staff/cdi/esd/itv/, 16. 2. 2026.