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Discrepancies between inspection results and actual technical condition of passenger cars: a Polish case study

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Ensuring the technical reliability of vehicles through periodic inspections is one of the key elements of road safety policy. However, discrepancies between inspection results and the actual condition of vehicles raise concerns about the effectiveness of current diagnostic practices. This study evaluates the technical condition of passenger cars operating in western Poland, based on data from over one thousand periodic inspections conducted between 2024 and 2025. Statistical analyses were performed to identify relationships between vehicle age, mileage, and defects such as suspension looseness, corrosion, oil leakage, and lighting adjustment. In addition, a detailed technical assessment was conducted on a Volkswagen Golf V 1.4 TSI that had a valid inspection certificate. Despite compliance with formal requirements, the vehicle exhibited severe mechanical faults, including worn timing components and incorrect chassis geometry. The results demonstrate that vehicles often pass inspections despite having defects that can compromise road safety. The findings underline the need to improve diagnostic accuracy, enhance inspector training, and ensure the use of standardized repair procedures. Strengthening inspection quality control would contribute to increased traffic safety and a more reliable assessment of vehicle technical condition.

Key words: *vehicle inspection, diagnostic accuracy; mechanical defects; technical condition; statistical analysis*

1. Introduction

Ensuring that vehicles remain in proper technical condition is one of the fundamental pillars of road safety and environmental protection. The purpose of periodic vehicle inspections is to confirm that each vehicle operating on public roads complies with legal requirements and safety standards [4]. In practice, however, the inspection process is influenced by numerous factors, including the applied diagnostic procedures, the technical condition of the measuring equipment, and – perhaps most importantly – the experience and competence of the inspector.

The reliability of a technical inspection depends not only on the diagnostic technology used but also on the human factor. Inspectors must be able to identify faults whose symptoms may be subtle or intermittent, and they must properly interpret diagnostic readings. Many defects, particularly those related to wear, improper assembly, or material fatigue, can only be identified through experience and thorough mechanical verification. The increasing complexity of vehicle systems, the use of electronic control units, and the integration of driver-assistance technologies further complicate the diagnostic process. Previous studies and reports have also emphasized that the quality and reliability of vehicle inspections depend not only on diagnostic equipment, but primarily on the proper execution of procedures and effective supervision of inspection stations [8, 20, 22, 24].

Modern inspection stations are equipped with advanced devices for measuring braking forces, suspension parameters, and exhaust emissions. Vehicles produced over the past two decades are also equipped with OBD/EOBD systems, enabling partial electronic diagnostics. Despite this, numerous studies indicate that even vehicles with a valid inspection certificate may still pose safety or environmental risks. The inspector's role remains decisive, as human error, time constraints, or procedural shortcuts can lead to undetected defects that later contribute to road accidents or mechanical failures.

Vehicle inspection procedures across the European Union have been harmonized under Directive 2014/45/EU, which specifies the scope, frequency, and technical requirements of periodic inspections. These include verification of vehicle identification, braking and steering efficiency, lighting and visibility, suspension and axle components, and environmental aspects such as pollutant emissions and fluid leakage. However, the implementation and supervision of these inspections remain the responsibility of individual member states, which results in variations in diagnostic quality and enforcement.

Several researchers have addressed these issues. Leontiev et al. [9] analysed mathematical models of deceleration for vehicles with brake system failures, showing that small differences in measurement assumptions can lead to significant errors in determining braking efficiency. Shoin [23] discussed the role of automotive expertise in legal proceedings, emphasizing the responsibility of experts and the importance of reliable documentation in judicial and insurance contexts. Karev and Volkov [6] examined the uncertainties arising from technical evaluations used as court evidence and proposed improved analytical models for assessing braking dynamics.

Malinowski et al. [12] demonstrated that braking test results can vary significantly across inspection stations, even for the same vehicle tested under similar conditions. This variability highlights the influence of human factors and station-specific calibration procedures. Suyanto et al. [25] emphasized that professional competence, discipline, and honesty are essential soft skills determining the quality of work in the automotive service and inspection sectors. Driving behavior, maintenance practices, and vehicle age all have a strong impact on technical condition and operational safety [15]. Studies from several European countries show that privately owned vehicles are generally better maintained than company fleets due to lower usage intensity and greater owner responsibility. Ioniță et al. [5] found that even vehicles compliant with inspection standards may pose risks when overloaded or modified. Christensen and Elvik [3] reached similar conclusions in Norway, showing that while inspections reduce the number of technically defective vehicles, they do not necessarily reduce accident rates – likely due to compensatory driver behavior or undetected faults.

In many Central and Eastern European countries, the aging vehicle fleet remains a major challenge. In Ukraine, the average age of passenger cars exceeds 22 years [17], while in Poland it is approximately 14 years, increasing annually. Older vehicles are more prone to corrosion, suspension looseness, and fluid leaks, all of which reduce their operational safety. Statistical analyses conducted in western Poland [18] have demonstrated strong correlations between vehicle age, mileage, and the presence of mechanical or structural defects, emphasizing the importance of reliable inspection procedures.

Other studies have addressed specific aspects of vehicle condition assessment, including post-accident repairs [10], exhaust emissions [13, 14, 26], wheel and tire diagnostics [2, 19], bearing wear [10], and suspension degradation [28]. Recent work has also explored diagnostic challenges related to electric and hybrid vehicles [1, 27], highlighting the need to modernize inspection systems and provide specialized training for technicians. Earlier studies have also addressed the effectiveness of vehicle inspection systems and their impact on road safety, including analyses presented in Polish technical journals [16, 26].

Despite regulatory frameworks and technological progress, significant shortcomings remain in the inspection process. The most common problems identified in the literature include procedural limitations, where standard inspection methods are insufficiently sensitive to detect hidden or intermittent faults. Human factor variability, resulting from differences in inspector expertise, diligence, and interpretation of results. Poor-quality repairs, often involving non-original or improperly installed components, which may pass inspection but reduce long-term reliability.

Therefore, there is a growing need to evaluate the actual effectiveness of technical inspections in identifying safety-critical vehicle defects. It is particularly important to determine whether vehicles with valid inspection certificates can still pose potential hazards due to undetected mechanical issues.

The present study addresses these issues by analyzing the technical condition of passenger cars operating in western Poland. The dataset includes vehicles inspected between 2024 and 2025 and covers key parameters such as vehicle age, mileage, corrosion, oil leakage, and suspension condition. Statistical analyses were conducted to identify significant relationships between these variables and to determine how factors such as brand, mileage, and age influence inspection outcomes.

To complement the statistical analysis, a detailed case study was performed on a Volkswagen Golf V 1.4 TSI. The selected vehicle, despite holding a valid inspection certificate, underwent a comprehensive technical evaluation that revealed multiple defects undetected during the official inspection.

By combining quantitative data analysis with an in-depth technical case study, this research aims to assess the reliability of periodic inspection procedures and to verify whether a vehicle certified as roadworthy can, in fact, meet the required safety standards. The findings contribute to improving the effectiveness of inspection systems, enhancing inspector training and supporting policy initiatives to increase road safety and environmental protection.

While numerous studies have proposed mathematical and analytical models describing selected aspects of vehicle diagnostics and braking processes [6, 9], these approaches are typically developed under simplified assumptions and do not fully reflect the complexity of real inspection conditions. In particular, they do not capture human factors, variability between inspection stations, or the impact of repair quality on actual vehicle condition.

For this reason, the present study deliberately does not focus on the development of new mathematical models. Instead, it addresses a clearly identified gap in the literature by providing large-scale empirical evidence from over 1000 real inspection records, complemented by an in-depth technical case study. Such an approach enables verification of how inspection systems perform in practice, which cannot be reliably assessed using model-based methods alone.

The novelty of this study lies in the use of large-scale, real-world inspection data combined with a detailed technical case study. Unlike model-based or purely theoretical analyses, this approach enables direct verification of discrepancies between formal inspection results and the actual technical condition of vehicles. The study contributes to the field by providing practical evidence of limitations in current inspection procedures and identifying factors that influence the occurrence of undetected defects.

2. Materials and methods

All statistical calculations were conducted using the STATISTICA software package from StatSoft Inc. (Tulsa, OK, USA, 2020), version 13.3 [30]. Quantitative variables were described by arithmetic mean and standard deviation (SD), median, minimum and maximum values (range), and a 95% confidence interval (95% CI). Due to deviations from normality and the presence of non-unimodal distributions, non-parametric tests were applied in the analysis.

The study was carried out at a vehicle inspection station between September 2024 and September 2025, similarly to the survey conducted two years earlier. The statistical analysis focused primarily on identifying relationships among vehicle age, mileage, and defect occurrence, while brand-related comparisons were treated as supplementary.

2.1. Results

The analysis primarily focuses on relationships between operational parameters (age and mileage) and defect occurrence, while brand-based comparisons are included for complementary interpretation.

The observed distributions were not assumed to be normal; therefore, non-parametric statistical methods were applied. As in the 2023 study [18], the majority of vehicles were powered by gasoline – 592 vehicles (57.32%) – followed by diesel vehicles, numbering 383 (37.08%). The mean vehicle age was slightly higher (by approximately two months) than in the 2023 analysis, while the average mileage was greater by about 4500 km (Table 1).

Table 1. Baseline characteristics of the study population (N = 1033); mean (SD), median; Range; [95% CI X_{mean}]

Age (years)	14.6 (6.3) 15 1 – 37 [14.2; 15.0]	Diesel (n = 383)	14.5 (5.3) 15 1–30 [14.0; 15.1]
		Fuel (n = 592)	14.7 (6.9) 15 1–37 [14.2; 15.3]
		Fuel + Gas (n = 50)	15.3 (6.2) 15.5 2–27 [13.5; 17.1]
		Hybrid (n = 7)	4.6 (1.8) 4 3–7 [2.9; 6.2]
		p-value	0.0004[1]
Mileage (km)	172999 (93465) 162974 9783–646497 [167293; 178705]	Diesel (n = 383)	226951 (91957) 224871 23116 – 646497 [217712; 236190]
		Fuel (n = 592)	136467 (76316) 128499 9783 – 428612 [130307; 142628]
		Fuel + Gas (n = 50)	203750 (81403) 198464 44250 – 384736 [18616; 226885]
		Hybrid (n = 7)	108195 (60824) 132978 34368 – 169667 [51942; 164448]
		p-value	< 0.0001[1]
Capacity (cm^3)	1605.4 (454.9) 1591 65 –5461 [1577.6; 1633.1]	Diesel (n=383)	1866.2 (351.2) 1896 1199–3996 [1830.9; 1901.5]
		Fuel (n = 592)	1441.2 (437.8) 1389 652–5461 [1405.9; 1476.6]
		Fuel + Gas (n = 50)	1525.6 (459.2) 1396 995–3604 [1395.1; 1656.1]
		Hybrid (n = 7)	1725.0 (205.3) 1798 1395–1991 [1535.1; 1914.9]
		p-value	< 0.0001[1]
1 – Kruskal-Walli's test			

When comparing vehicle brands, a statistically significant difference in age was observed only between Opel and the other brands (Fig. 1). For mileage, significant differences were observed between Toyota and Volkswagen, as well as between Toyota and Ford. The mileage of Volkswagen vehicles also differed significantly from that of cars classified as "other brands." Engine capacity values varied significantly across the analysed brands.

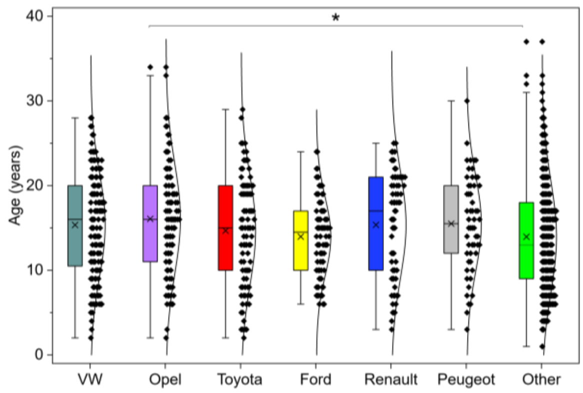

Fig. 1. Age vs brand of the 1033 personal cars

Table 2. Baseline characteristics of car brand (N = 1033); mean (SD), median; Range; [95% CI Xmean]

Brand	Age [years]	Mileage [km]	Capacity [cm^3]
VW (n = 144)	15.3 (6.1) 16 2–28 [14.3; 16.4]	212187 (110150) 209334 19487–646497 [194042; 230331]	1683.5 (371.3) 1896 999–2967 [1622.3; 1744.6]
Opel (n = 93)	16.1 (6.5) 16 2–34 [14.8; 17.4]	173182 (90809) 171987 15509–529722 [154976; 191388]	1499.1 (270.7) 1443.5 973–2172 [1444.9; 1553.4]
Toyota (n = 93)	14.7 (6.5) 15 2–29 [13.3; 16.0]	143958 (84170) 143247 14494–404067 [126624; 161293]	1438.5 (377.4) 1329 998–2231 [1360.7; 1516.2]
Ford (n = 84)	14.0 (4.6) 14.5 6–24 [13.0; 15.0]	189152 (79432) 197574 34795–344802 [171914; 206390]	1689.0 (439.3) 1596 998–3700 [1593.6; 1784.3]
Renault (n = 69)	15.4 (6.3) 17 3–25 [13.8; 16.9]	166513 (79612) 161570 28961–375903 [147389; 185638]	1456.2 (308.7) 1461 898–1998 [1382.0; 1530.4]
Peugeot (n = 56)	15.5 (5.7) 15.5 3–30 [14.0; 17.0]	188528 (99089) 177304 16864–434568 [161992; 215064]	1492.7 (259.4) 1560 954–1997 [1423.2; 1562.1]
Other (n = 489)	14.0 (6.6) 13 1–37 [13.4; 14.5]	163308 (89970) 152474 9783–475066 [155314; 171302]	1655.0 (533.4) 1591 652–5461 [1607.6; 1702.4]
p-value	0.0056[1]	< 0.0001[1]	< 0.0001[1]
1 – Kruskal-Walli's test			

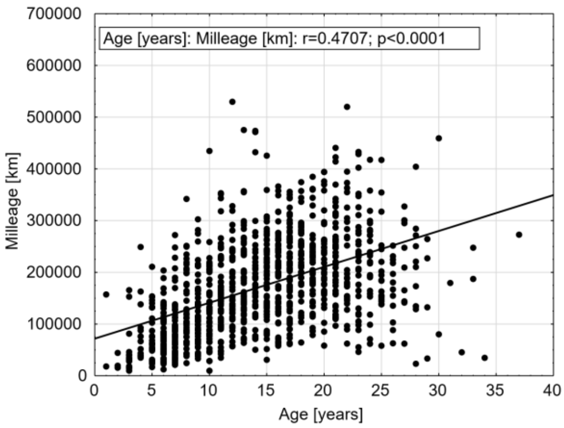

Fig. 2. Mileage vs. age of the 1033 personal cars

The braking force of the left front wheel differed significantly between Toyota and Volkswagen (p = 0.0324), Ford (p = 0.0001), and other brands (p = 0.0012). A statistically significant difference was also observed between Opel and Ford (p = 0.0027). The same pattern was found for the right front wheel. For the left rear wheel, braking force differed significantly between Toyota and Volkswagen (p < 0.0001), Ford (p = 0.0002), and other brands (p = 0.0020). Significant differences were also found between Volkswagen and Peugeot (p = 0.0117) and between Volkswagen and Renault (p = 0.0123). The braking force of the right rear wheel in Toyota vehicles differed from that in Volkswagen (p = 0.0001), Ford (p = 0.0002), and other brands (p = 0.0030). Peugeot vehicles also showed differences compared with Volkswagen (p = 0.0015), Ford (p = 0.0022), and other brands (p = 0.0405). For the parking brake, significant differences were noted between Volkswagen and Toyota (p = 0.0285), Opel (p < 0.0001), and Renault (p = 0.0459). Opel also differed from Ford (p = 0.0023) and from other brands (p = 0.0007), as illustrated in Fig. 3.

Brake performance was analysed as a key parameter routinely assessed during periodic technical inspections, providing an objective measure of vehicle safety and diagnostic effectiveness.

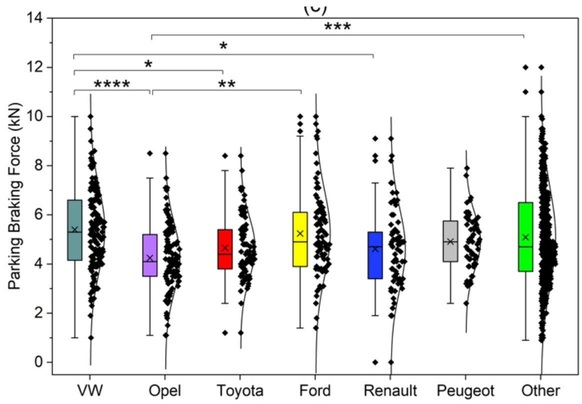

Fig. 3. Force of parking brake (kN) of the 1033 personal cars

Headlight alignment was corrected in 469 vehicles (45.4%). The highest proportions of vehicles requiring adjustment were Ford (54.8%) and Opel (50.0%), while the lowest was recorded for Toyota (34.4%). In this case, vehicle age had no significant effect on whether adjustment was required (p = 0.2560; Mann-Whitney U test), whereas mileage was a decisive factor. Vehicles requiring adjustment had an average mileage of 184,339 km, compared to 163,570 km for those not requiring adjustment (p = 0.0005; Mann-Whitney U test).

Table 3. Braking force: LF – left front, RF – right front, LR – left rear, RR – right rear, parking brake

Brand	Braking force LF [kN]	Braking force RF [kN]	p-value	Braking force LR [kN]	Braking force RR [kN]	p-value	Braking force parking [kN]
VW (n = 144)	6.5 (1.4) 6.4 3.4–11.2 [6.3; 6.7]	6.5 (1.3) 6.5 3.3–11.3 [6.3; 6.7]	0.8308[2]	2.0 (0.6) 2.1 0.5–3.5 [1.9; 2.1]	2.0 (0.6) 2.0 0.4–3.6 [1.9; 2.1]	0.1798[2]	5.4 (1.7) 5.3 1.0–10.0 [5.1; 5.7]
Opel (n = 93)	6.1 (1.6) 5.9 2.7–11.0 [5.8; 6.4]	6.0 (1.6) 5.8 2.9–10.0 [5.7; 6.3]	0.6553[2]	1.9 (0.6) 1.8 0.6–3.4 [1.8; 2.0]	1.8 (0.5) 1.7 0.6–3.8 [1.7; 1.9]	0.1980[2]	4.2 (1.4) 4.1 1.1–8.5 [4.0; 4.5]
Toyota (n = 93)	5.9 (1.4) 5.5 3.0 – 9.6 [5.6; 6.2]	5.8 (1.4) 5.7 3.2 – 9.6 [5.5; 6.1]	0.8190[2]	1.7 (0.5) 1.6 0.6 – 2.8 [1.6; 1.8]	1.7 (0.9) 1.5 0.7 – 9.0 [1.5; 1.9]	0.1981[2]	4.7 (1.3) 4.4 1.2 – 8.4 [4.4; 4.9]
Ford (n = 84)	6.9 (1.4) 6.8 3.9–10.0 [6.6; 7.2]	6.8 (1.4) 6.7 3.9–9.9 [6.5; 7.1]	0.7067[3]	2.1 (0.6) 2.1 0.5–3.5 [1.9; 2.2]	2.0 (0.6) 2.0 0.5–3.6 [1.9; 2.1]	0.2856[3]	5.2 (1.7) 4.9 1.4–10.0 [4.9; 5.6]
Renault (n = 69)	6.4 (1.5) 6.3 3.7–10.0 [6.0; 6.7]	6.3 (1.5) 6.0 3.7–10.0 [5.9; 6.6]	0.5872[2]	1.8 (0.4) 1.7 0.9–2.9 [1.6; 1.9]	1.7 (0.4) 1.6 0.7–3.4 [1.6; 1.8]	0.2331[2]	4.6 (1.6) 4.7 0.0–9.1 [4.2; 5.0]
Peugeot (n = 56)	6.4 (1.4) 6.5 4.0–10.0 [6.0; 6.8]	6.3 (1.3) 6.2 3.7–10.0 [5.9; 6.6]	0.6935[3]	1.7 (0.5) 1.7 0.4–3.1 [1.6; 1.9]	1.6 (0.4) 1.6 0.3–2.9 [1.5; 1.7]	0.0845[2]	4.9 (1.1) 4.9 2.4–7.9 [4.6; 5.2]
Other (n =489)	6.6 (1.4) 6.5 4.0–10.0 [6.0; 6.8]	6.5 (1.7) 6.4 1.1–11.0 [6.4; 6.7]	0.7931[1]	2.0 (0.8) 1.9 0.3–6.1 [1.9; 2.1]	1.9 (0.8) 1.8 0.1–9.0 [1.8; 2.0]	0.3263[1]	5.1 (2.0) 4.7 0.9–12.0 [4.9; 5.3]
p-value	< 0.0001[1]	< 0.0001[1]	---	< 0.0001[1]	< 0.0001[1]	---	< 0.0001[1]

[1] – Kruskal-Wallis's test; [2] – U Mann–Whithney test; [3] – t Student test

Suspension play was detected in 133 vehicles (12.9%), occurring most frequently in Renault cars (18.8%) and only once in Toyota vehicles (1.1%). Mileage was again a significant factor: vehicles with suspension play had an average mileage of 205,669 km, while those without play averaged 168,171 km ($p < 0.0001$; Mann-Whitney U test).

Corrosion spots were found in 52 vehicles (5.0%), and through-holes in 16 vehicles (1.5%). Vehicles without any corrosion defects were on average 14.2 years old, those with corrosion spots 22.5 years, and those with perforations 24.6 years ($p < 0.0001$; Kruskal-Wallis test). Corrosion was most frequent among Volkswagen (8.3%) and Opel (6.1%) vehicles. The average mileage of vehicles with corrosion was 262,891 km, compared to 166,617 km for corrosion-free cars ($p < 0.0001$; Kruskal-Wallis test).

Visible oil drops were detected in 78 vehicles (7.6%), while oil sweating was observed in 125 vehicles (12.1%). Vehicles without any oil leakage were on average 13.1 years old, those with oil drops 21.1 years, and those with sweating 19.1 years ($p < 0.0001$; Kruskal-Wallis test). Both vehicle age and mileage significantly influenced the presence of oil leaks ($p < 0.0001$; Kruskal-Wallis test). Vehicles without leaks had an average mileage of 147,690 km, those with visible oil drops 210,879 km, and those with sweating 237,705 km. Oil drops occurred most frequently in Opel (19.4%), Volkswagen (10.4%), and Renault (10.1%) vehicles.

Lighting faults were recorded in 55 vehicles (5.3%), occurring most often in Ford (7.1%), Volkswagen (6.3%), and Opel (6.1%) cars, and least frequently in Toyota (3.2%).

3. Case study

Although such components are not directly assessed during standard vehicle inspections, their condition provides valuable insight into the limitations of current diagnostic procedures. To compare the results of statistical analyses conducted at the vehicle inspection station, a detailed technical assessment was performed on a selected passenger car – a Volkswagen Golf V 1.4 TSI, model year 2008, with the CAXA engine code, operated in the western region of Poland. The vehicle's odometer reading at the time of disassembly was 216,514 km. The car held a valid inspection certificate and had undergone a series of repairs at a service associated with the network of workshops eight months earlier. Since that repair, the vehicle had been driven approximately 20,000 km and had subsequently passed another periodic inspection with a positive result.

Before verification of its technical condition, the user reported abnormal noise during engine start-up. It was also noted that the engine tended to run unevenly at idle speed. A computer-based diagnostic test of the warmed-up engine was conducted using the OBD-II (On-Board Diagnostics) system under normal operating temperature. The analysis revealed irregular engine operation at idle and abnormal readings from both lambda sensors – the first sensor indicated a constant voltage, while the second showed no response to increased engine speed, suggesting sensor malfunction or circuit error. It should be noted that not all identified defects are directly detectable during standard vehicle inspections; however, their presence indicates broader limitations in the inspection process and the potential coexistence of detectable and non-detectable faults.

The timing drive mechanism was disassembled to verify the technical condition of its components and subassemblies. Figure 4 shows the components of the engine timing system after disassembly. It was found that aftermarket components of unidentified manufacture had been installed, including the timing chain, camshaft sprocket, and chain guides. The crankshaft sprocket and timing chain tensioner were also of unknown origin. Moreover, the sprocket equipped with the variable valve timing mechanism and the sprocket driving the oil pump chain had not been replaced during the repair. The oil pump drive chain itself appeared to be an original factory component (its markings corresponded with those on the oil pump sprocket), and its guide rail exhibited visible frictional wear. It should be emphasized that the use of non-original components does not imply non-compliance with homologation requirements; however, incomplete replacement of cooperating elements and uncertain component history may adversely affect system reliability.

Fig. 4. Components of the engine timing drive mechanism: timing sprocket, chain tensioner (visible scuff marks on the tensioner piston surface), chain tensioner piston (signs of frictional wear), and timing chain guides

Figure 5 shows the gear assembly integrated with the variable valve timing control system. The component dates from 2008 and is evidently the original part installed during the vehicle's production. With a mileage exceeding 200,000 km, and in accordance with the manufacturer's repair technology and commonly available service guidelines, this subassembly should have been unquestionably replaced with a new one during the timing drive repair.

The variable valve timing mechanism forms an integral part of the camshaft drive system, and replacement of this component is mandatory when the timing chain is renewed. According to the repair procedures for chain-driven systems – including those specified by the Volkswagen manufacturer – all cooperating elements of the chain transmission should be replaced with new components. The rationale for this requirement lies in the gradual change in gear tooth geometry that occurs naturally over time.

The CAXA engine oil pump is driven by a steel chain, which, in this case, was replaced with a new component from an unidentified manufacturer. Consequently, a new timing chain was combined with sprockets and chain guides that had been in continuous use since the vehicle's production. Such a combination of new and worn components may lead to improper load distribution and accelerated wear within the system.

Fig. 5. Variable valve timing gear assembly integrated with the camshaft drive sprocket, and oil pump drive gear

Figure 6 shows the guide rail of the oil pump drive chain, which is an original component from the vehicle's production period. Distinct traces of frictional wear are visible on the sliding surface.

Fig. 6. Guide rail of the oil pump drive chain, identified as an original component from the vehicle's production period. Distinct frictional wear marks are visible on the sliding surface

The CAXA engine oil pump is driven by a steel chain, which in this case was replaced with a new but non-original component. Consequently, the new timing chain of unknown quality was combined with sprockets and chain guides that had been in continuous use since the vehicle's production.

The left rear wheel bearing produced noticeable noise during driving – a symptom typical of a bearing that has either undergone prolonged wear or been incorrectly installed, for example, due to mechanical damage or contamination. When the vehicle was lifted, significant longitudinal play in the left-rear wheel hub assembly was detected. It should be emphasized that operating a vehicle with such a defective bearing is unacceptable and poses a serious safety hazard.

The rear left wheel bearing assembly consists of the hub, two rows of rolling balls, and two inner rings. Visual inspection revealed clear signs of long-term operation, including traces of lubricant leakage and grease with a dense, plastic consistency typical of bearings used for an extended period. Figures 7–9 show the examined bearing, where distinct fatigue damage to the raceways and surface wear of the rolling elements are clearly visible.

Fig. 7. Left rear wheel bearing removed from the vehicle, showing leakage of lubricating grease with a dense, viscous consistency typical of long-term exploitation

Fig. 8. Elements of the left rear wheel bearing: rolling balls on the right display characteristic signs of fatigue-related surface damage

Fig. 9. Outer and inner rings of the left rear wheel bearing with visible surface fatigue and pitting damage on the raceways

Based on the dismantled components, it can be concluded that the wheel bearing had been in operation for much longer than indicated by the repair documentation, which stated a period of 9 months and approximately 20,000 km. The damage observed on the bearing is typical of wheel bearings that have been used for a very long time. Clear fatigue-related wear was visible on the contact surfaces between the rolling elements and the bearing raceways. Such damage patterns are characteristic of bearings subjected to prolonged loading.

The chassis geometry was measured using a certified computer-based wheel alignment system (four-wheel 3D geometry analyzer, accuracy ±0.01°), commonly used in professional vehicle inspection stations in Poland. The measurement revealed significant deviations from the manufacturer's specified tolerances (Fig. 10). This raises an important question: can a vehicle that has undergone workshop repairs and passed an official periodic inspection still exhibit such large discrepancies in chassis geometry? Furthermore, can a vehicle with a valid inspection certificate but with suspension geometry values outside the manufacturer's tolerance range be considered safe?

The answer is clear – the vehicle was unsafe and did not provide the required level of safety for its occupants or other road users.

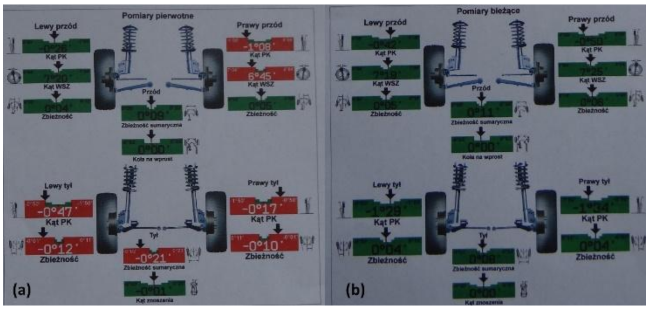

Fig. 10. Results of chassis geometry measurement for the Volkswagen Golf 2004-09 (1K), standard suspension (2UA/1JA), mileage at the time of testing: 216,738 km. (a) Initial measurement before repair; (b) values after suspension repair and alignment adjustment

4. Discussion

The results of the statistical analysis and the detailed technical inspection of the selected passenger car together provide a comprehensive, evidence-based picture of the actual roadworthiness of vehicles operating in western Poland. Unlike model-based approaches, this study is grounded in real inspection data and direct technical verification. The findings demonstrate that even vehicles that successfully pass periodic inspections may exhibit significant technical issues that could compromise operational safety. This observation indicates that the current framework of vehicle technical inspection procedures, although legally regulated and standardized, is not fully effective in identifying critical safety-related defects.

From the statistical data collected on 1033 vehicles inspected between October 2024 and September 2025, several key trends emerge. The mean vehicle age was 14.6 years, which is consistent with the aging vehicle fleet in Poland and significantly above the average for Western Europe. Mileage, averaging approximately 173,000 km, showed a strong correlation with the occurrence of certain technical defects, such as suspension looseness, oil leakage, and corrosion. Vehicles showing signs of corrosion were, on average, eight years older and had 100,000 km higher mileage than corrosion-free cars ($p < 0.0001$). Similarly, oil leaks and sweating were associated with both increased vehicle age and mileage, indicating that wear-related failures are a major factor influencing vehicle safety and environmental impact. Although the analysis is based on standard statistical methods, the strength of the study lies in the use of real-world inspection data, which enables direct verification of observed relationships.

The data also revealed statistically significant differences among vehicle brands in age, mileage, and braking performance. For example, although younger, Toyota vehicles demonstrated weaker braking forces than Volkswagen and Ford vehicles ($p < 0.05$). This may reflect variations in brake system maintenance practices or differences in design and component quality among brands. Brake test results are particularly relevant in this context, as they represent standardized, measurable parameters used in inspection procedures, enabling comparisons across vehicles and stations. Furthermore, the need for headlight adjustment was strongly associated with vehicle mileage rather than age, suggesting that lighting alignment degradation occurs primarily due to vibration and long-term use rather than material aging alone. These results collectively point to a clear link between vehicle wear and the frequency of defects detectable during periodic inspections. Although the analysis is based on standard statistical methods, the strength of the study lies in the use of real-world inspection data, which enables direct verification of observed relationships. These brand-related differences should be interpreted with caution and do not constitute an evaluation of manufacturer performance, but rather reflect the characteristics of the analyzed sample and real-world operating conditions.

However, the most critical insight emerges from the practical verification of a real vehicle case – a Volkswagen Golf V 1.4 TSI (2008) – which clearly demonstrates limitations that cannot be captured by statistical aggregation or theoretical modelling alone. The analysed vehicle had undergone several repairs approximately eight months prior to the inspection and had accumulated an additional 20,000 km during that period. Despite this, the technical evaluation revealed multiple irregularities that should have disqualified the car from being considered roadworthy. The examination of the timing drive system showed the use of non-original replacement parts of unverified quality, including the timing chain, guides, and sprockets. Moreover, key elements such as the variable valve timing gear and the oil pump drive gear remained original from 2008, despite being subject to wear beyond their design limits. The presence of worn chain guides and a scored chain tensioner piston indicated that the repair was not carried out in accordance with manufacturer recommendations. Such practices, unfortunately common in independent workshops, can lead to a substantial reduction in reliability and increase the risk of mechanical failure.

The inspection of the rear left wheel bearing further emphasized the limitations of current inspection procedures. The bearing displayed advanced fatigue damage and excessive longitudinal play, conditions that should have been easily detectable during a standard suspension and wheel test. The degraded lubricant consistency and the visible pitting of the rolling elements were indicative of prolonged use well beyond the expected exploitation life. These findings demonstrate that the defect was not a result of recent deterioration but of an earlier oversight during both repair and inspection processes. Some of the identified defects fall outside the scope of standard inspection procedures, which further highlights the inherent limitations of such systems. Operating a vehicle in such a condition poses a direct risk to road safety, as bearing failure can lead to wheel lock-up or loss of vehicle stability.

Equally concerning were the findings from the chassis geometry measurements. The alignment values significantly exceeded manufacturer tolerances prior to corrective adjustment, despite the vehicle's successful completion of its last technical inspection. Incorrect wheel geometry can lead to poor handling, uneven tire wear, and increased fuel consumption – all of which have safety and economic consequences. These deviations should have been detected during the official inspection, as the alignment reflects both the integrity of suspension components and the quality of any previous post-accident repairs. The inability of standard inspection stations to detect such issues suggests a need for stricter diagnostic procedures and better-trained inspectors.

Combining these practical results with the statistical analysis leads to several important implications. First, while the majority of inspected vehicles are nominally compliant with regulations, a non-negligible proportion still presents latent defects that directly affect safety. The 12.9% incidence of suspension looseness and the 7.6% rate of active oil leaks, for example, illustrate that mechanical wear and insufficient maintenance are widespread. Second, the high variability in defect detection among brands and stations confirms earlier studies showing that the human factor – diagnostic skill, diligence, and experience – remains a decisive element of inspection reliability [12]. Even though diagnostic equipment has become increasingly sophisticated, its effectiveness depends on the competence of the operator.

The findings of the present study align with earlier international observations [3], which reported that while periodic inspections reduce the number of defective vehicles, they do not necessarily translate into a direct reduction in accident rates. This paradox may be explained by compensatory driver behavior and the fact that certain defects remain undetected during standard inspections. The detailed case analysis conducted in this research further supports the conclusion that the official inspection procedures are insufficiently sensitive to detect many safety-critical issues, particularly those related to wear-induced degradation or improper repairs.

Another crucial aspect revealed by this study concerns the quality of automotive repairs and the responsibility of workshops. The use of non-genuine components of uncertain origin, as observed in the analyzed vehicle, compromises both performance and safety. Although legal mechanisms such as warranty and consumer protection regulations exist, they are often ineffective in practice, especially when technical expertise is required to establish fault. Therefore, there is a pressing need for a system that ensures greater accountability for repair quality and for integrating workshop data into the official vehicle inspection database.

While advanced diagnostic methods may improve defect detection, their implementation is associated with increased costs, longer inspection times, and the need for specialized training. Moreover, their effectiveness depends strongly on proper execution and interpretation by inspectors. Therefore, improving inspection quality through better supervision, standardized procedures, and sufficient inspection time may be equally important as introducing new technologies.

Finally, the results highlight the need to enhance both procedural and technological aspects of vehicle inspections. Integrating advanced diagnostic methods, such as vibration analysis or on-board sensor data interpretation, could significantly improve defect detection rates. Additionally, a comprehensive training and certification program for inspectors, emphasizing both theoretical knowledge and practical experience, is essential to reduce the influence of the human factor. This perspective is consistent with findings reported in the literature and institutional analyses, which identify insufficient supervision and variability in inspection quality as key limitations of current systems [9, 20, 22, 24]. Given the rapid technological evolution of vehicles – including hybrid and electric powertrains – periodic inspection systems must adapt accordingly to maintain their relevance and effectiveness.

In summary, this study confirms that the technical condition of passenger cars in western Poland remains a significant factor influencing road safety. The results emphasize the importance of continuous improvement of inspection procedures, higher competence standards for inspectors, and stricter quality control in automotive repairs. The combination of statistical evidence and practical diagnostics clearly demonstrates that a valid inspection certificate does not always guarantee actual vehicle safety. Addressing these shortcomings is vital to reducing the risk of accidents and ensuring the long-term reliability of vehicles operating on public roads.

5. Limitations and future work

The present study, while comprehensive in scope, has several limitations that should be acknowledged. First, the data were obtained from a single regional inspection station network in western Poland, which may not fully represent the national vehicle population or inspection practices in other regions. Additionally, although over 1000 vehicles were analyzed statistically, the practical verification involved only one detailed technical case study, limiting the generalizability of the specific mechanical findings. The study also relied on periodic inspection data that do not capture intermediate maintenance or repair activities performed between inspections. Future research should therefore include a broader geographic sample and employ longitudinal monitoring of selected vehicles to observe defect development over time. Expanding the analysis to include vehicle types such as light commercial vehicles, hybrids, and electric cars would also provide valuable insights into evolving maintenance challenges. Furthermore, integrating advanced diagnostic tools – for example, non-invasive vibration analysis, thermal imaging, or OBD-based fault pattern recognition – could significantly enhance defect-detection sensitivity and support the development of an improved, data-driven framework for vehicle safety inspection.

6. Conclusions

The study revealed that the actual technical condition of many passenger cars in western Poland does not fully correspond to their official inspection results. Statistical analysis of over one thousand vehicles showed that defects such as corrosion, suspension looseness, and oil leakage are significantly related to vehicle age and mileage. The detailed inspection of a Volkswagen Golf V confirmed that even vehicles with valid inspection certificates may exhibit serious faults, including worn components, incorrect chassis geometry, and non-original parts of uncertain quality. The study provides practical, evidence-based insight into the real effectiveness of vehicle inspection systems, complementing existing model-based approaches. This study contributes to the field by providing empirical, evidence-based insight into the real effectiveness of vehicle inspection systems and highlighting their practical limitations.

7. Practical implications

The results can support policymakers, inspection authorities, and vehicle service organizations in developing more effective inspection standards and training programs for automotive diagnosticians, ultimately contributing to higher safety and technical reliability on public roads.

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