

Article

Analysis of the Relationship between Fuel Prices and Vehicle Numbers in Urban Road Networks

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Abstract: The article presents an analysis of the relationship between the price of fuel and diesel oil and traffic intensity in the city. First, an analysis of fuel prices was prepared over fourteen months and the number of passenger cars and trucks per day was examined at the same time. From the results obtained, the highest, lowest, and average values were obtained. On this basis, it was noticed that when the price of fuel was the highest, there were fewer passenger cars, but when the price dropped, the number of vehicles increased. Another conclusion from the analysis is that when the price of fuel dropped even more than the average, there were no more cars. Based on the analysis, it was noticed that the number of vehicles may vary by up to 8000 passenger vehicles per day within one intersection. Then, a microsimulation model was performed in the PTV Vissim program to check the amount of pollution generated by vehicles in three variants: the highest, lowest, and average traffic intensities. The results show that the average daily CO pollution at the moment of the lowest traffic intensity is 15,000 g lower than the average, so the high price of fuel causes much less pollution for the consumer.

Keywords: sustainable transport; fuel consumption; fuel pricing; transport microsimulation; transport modeling for a cleaner environment



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1. Introduction

Road transportation constitutes an integral facet of urban existence, wielding an indelible impact across myriad spheres encompassing architectural paradigms, spatial delineations, economic dynamics, and societal interactions. The intricate labyrinth of connections posits formidable challenges to traffic management hubs and municipal administrations alike. The ramifications of transportation on multifarious facets of existence and ensuing repercussions have been subject to exhaustive scrutiny. Foremost among the scrutinized domains is the nexus between vehicular traffic and the natural milieu [1–5]. Emissions emanating from vehicular propulsion mechanisms, comprising noxious compounds such as nitrogen oxides and particulate matter, engender atmospheric contamination within urban environs, precipitating deleterious health consequences for denizens. Presently, burgeoning scholarly interest is being accorded to electric vehicular modalities and their concomitant impacts on traffic dynamics and urban pollution indices [6–8]. Factors subjected to meticulous analysis encompass not only emissions [4,7,9] but also acoustic pollution [10,11]. Noise pollution has emerged as a principal concern for denizens inhabiting sprawling metropolises, primarily stemming from the escalating vehicular flux and the pronounced presence of freight carriers. Concomitantly, research endeavors are underway to optimize urban spatial configurations and vehicular fluxes [12–15] with the overarching objective of fostering pedestrian-centric urban landscapes whilst mitigating automobile-centric predilections. Concurrent scrutiny is being directed toward assessing the influence of pedestrian influxes on traffic signal operability and intersection throughput capacities [16]. The prevailing trend underscores an ethos predicated upon endowing cities with a pedestrian- and cyclist-centric ethos, thereby precipitating the emergence of

“15-minute cities” [17] wherein denizens evince a proclivity towards eschewing vehicular conveyance in favor of pedestrian mobility. Notwithstanding the attendant challenges, efficacious road transportation serves as the linchpin undergirding the economic fecundity of urban conurbations, endowing residents with mobility, facilitating access to gainful employment opportunities and essential amenities, and playing an instrumental role in fostering seamless integration between urban hinterlands and their environs. Thus, the imperative of road transportation within urban precincts necessitates a holistic paradigm, underscored by integrated management stratagems and the cognizance of sustainable developmental imperatives, with a view towards ameliorating adverse repercussions and harnessing its latent potential to engender an idyllic milieu conducive to enhanced quality of life for denizens. The gamut of engineering precepts underpinning traffic dynamics naturally converges with economic paradigms [18–20] both at micro and macro levels. The crux of this discourse resides in elucidating whether the fuel tariffs borne by urban denizens for their vehicular pursuits exert a discernible impact on vehicular density within urban agglomerations and, by extension, on pollution indices. Is there a price threshold that would occasion a diminution in urban pollution levels? Alternatively, might a reduction in fuel tariffs precipitate an uptick in vehicular proliferation within urban locales? Could tariff regulations proffer a viable panacea for assuaging congestion and curtailing environmental pollution emanating from vehicular emissions? The city of Gdynia shall serve as a crucible for this analytical inquiry, given its implementation of a sophisticated traffic control infrastructure facilitating vehicular enumeration and categorization.

2. Materials and Methods

The article draws upon data derived from the Intelligent Traffic Management System, which is equipped with the Balance and Epics traffic control algorithms. Vehicle flow data were juxtaposed across three distinct intersections, denoted for analytical purposes as J1 (54.485163, 18.545723), J2 (54.538551, 18.471236), and J3 (54.532893, 18.488710), all situated within the confines of Gdynia (Figure 1).

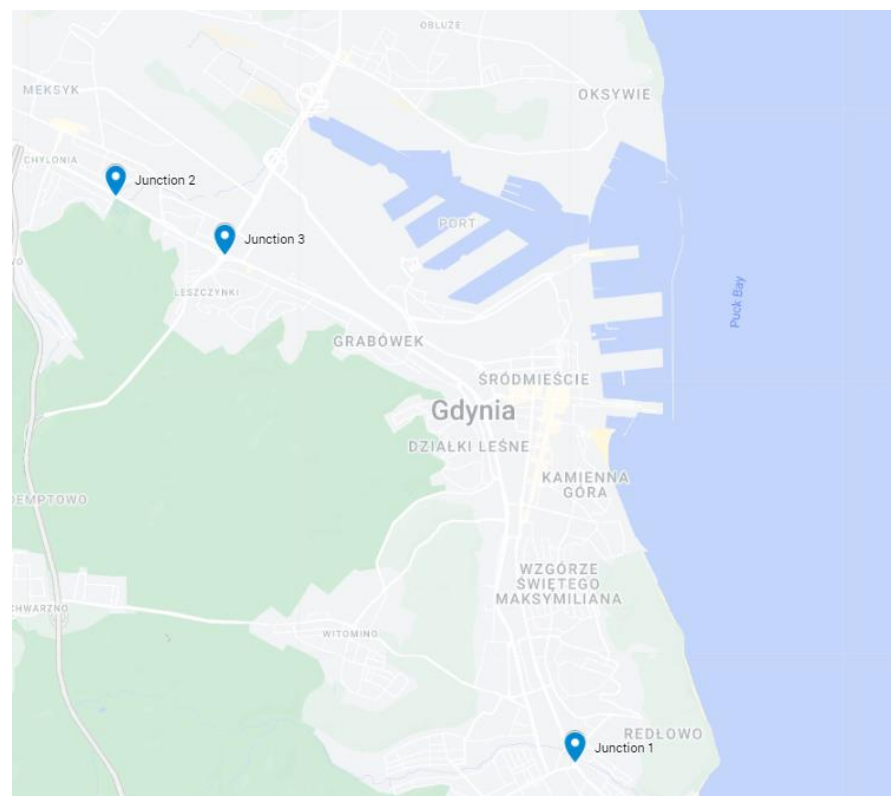


Figure 1. Marked: Junction 1, Junction 2, Junction 3 on the map of the city of Gdynia.

Gdynia, as a port city, experiences an augmented influx of commercial vehicular traffic due to the strategic centrality of its port. The temporal span of vehicular flow analysis extended from 2 November 2022 to 4 January 2024, thereby encapsulating 14 months. Exclusion criteria were applied to data stemming from Saturdays, Sundays, Mondays, and Fridays, given the irregularity in traffic patterns during these periods, as well as public holidays. Furthermore, a categorical distinction was made between passenger and commercial vehicles.

An additional pivotal dataset requisite for comprehensive analysis pertains to the daily fuel costs. Fuel cost was researched by several scientists [21–23] trying to answer the question of how fuel price influences people’s lives. Historical fuel pricing data for the aforementioned period (2 November 2022 to 4 January 2024) were collated from the online platform www.bankier.pl, with the dataset being current as of 5 May 2024 [24]. This time period was chosen for many reasons: one of them is that the period is after the COVID-19 pandemic, when road traffic has returned to pre-pandemic times. Another reason is the availability of measurement data. The most important factor is the selection of the period when the inflation level in Poland was rising, which affected the real value of money. Of course, the selection of an even longer measurement period could affect the results but the pandemic period affects the number of vehicles in the network, which would result in unreliable results. The analysis delineated two primary fuel types prevalent within the region, namely E95 and diesel (ON). The pricing data were denominated in the local currency, Polish zloty (PLN), per liter, with conversion approximations to EUR 0.23 (€) or USD 0.25 (\$) per PLN. In 2023, the statutory minimum monthly wage in Poland stood at PLN 3490 gross, translating to approximately PLN 2710 net. Hence, with an averred fuel price of PLN 6.50 per liter, it is discerned that one could procure approximately 415 L of fuel at the minimum wage level.

The volatility of fuel prices is evident in Figure 2. The highest diesel (ON) prices were recorded in December 2022, reaching nearly PLN 8 per liter, while the lowest price of PLN 6 occurred in October 2023. Meanwhile, the price of E95 gasoline fluctuated around PLN 6.50 but also decreased to PLN 6 during the period of October 2023. A difference in fuel prices of PLN 2, in the case of the minimum wage, allows for the purchase of only 338 L, whereas compared to the lowest fuel price during the study period, it allows for the purchase of up to 450 L, resulting in a difference of approximately 110 L of fuel.

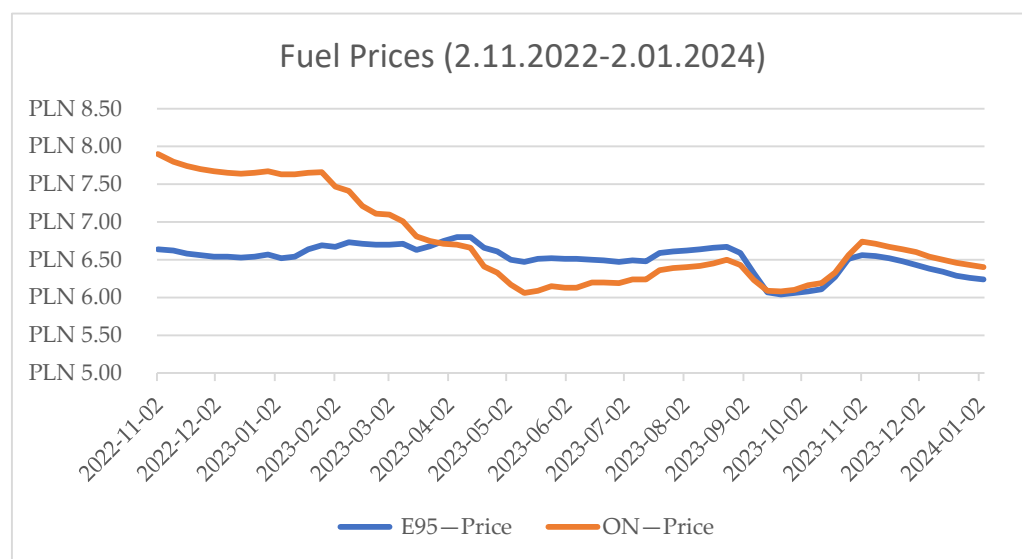


Figure 2. Fuel prices through the 14 months of analysis.

The environmental pollution analysis adopted a micro-scale traffic modeling approach utilizing the PTV Vissim 24 tool. Building a microsimulation model in PTV Vissim involves

a number of subsequent necessary steps. A schematic sequence diagram is presented in Figure 3. Due to the single-intersection model, static route options were used. Traffic volume was added to the model at hourly intervals around the clock, starting at 0:00. Vehicle volume was divided into passenger vehicles and trucks. Additionally, public transport vehicles were added to the model—buses and trolleybuses running according to the timetable. Pedestrians and a signaling program consistent with the schedule applicable on weekdays were also added to the model. The elucidation of the modeling methodology and requisite procedural steps is expounded upon within article [25]. Traffic volume data, derived from three distinct scenarios—minimal, maximal, and mean—were harnessed to devise a model applicable to Intersection J3.

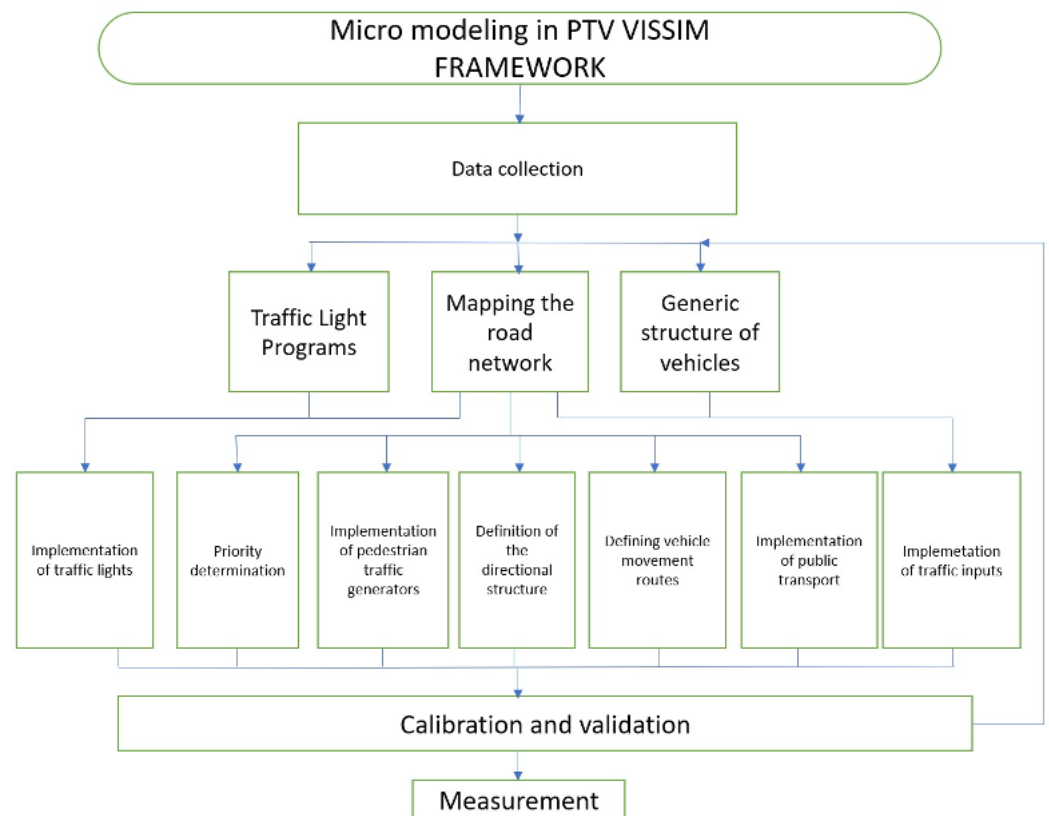


Figure 3. PTV Vissim methodology—framework [22].

These empirical inputs facilitated an evaluative examination of atmospheric pollution levels consequent to vehicular fuel combustion. Below in Table 1, the data aggregated according to the variants are presented.

Table 1. Cars and HGVs volume per day—Junction 3.

Vehicle Type	Inlet Name	V1 [v/Day]	V2 [v/Day]	V3 [v/Day]
Car	N	12,116	10,845	10,701
Car	S	4248	3429	3062
Car	E	23,467	14,236	18,252
Car	W	17,227	9776	13,278
HGV	N	983	864	726
HGV	S	342	289	207
HGV	E	1120	1240	965
HGV	W	1148	475	744

3. Results

3.1. Cars

After analyzing the data collected from the induction loops at intersections, several fundamental dependencies regarding vehicle flow throughout the day should be noted. At Intersection J1, the highest number of vehicles was recorded on 7 June 2023, at 48,096, while the lowest was on 26 January 2023, at 38,736. The average number of vehicles observed was approximately 43,792. At Intersection J2, the highest number of vehicles was recorded on 24 August 2023, at 34,564, while the lowest was on 25 January 2023, at 28,308. The average number of vehicles observed was approximately 31,292. At Intersection J3, the highest number of vehicles was recorded on 28 December 2023, at 58,098, while the lowest was on 26 January 2023, at 39,067. The average number of vehicles observed was approximately 52,810. The detailed results are presented in Figure 4, where the graph illustrates the history of changes in diesel and E95 gasoline prices concerning the daily volume of passenger vehicles.

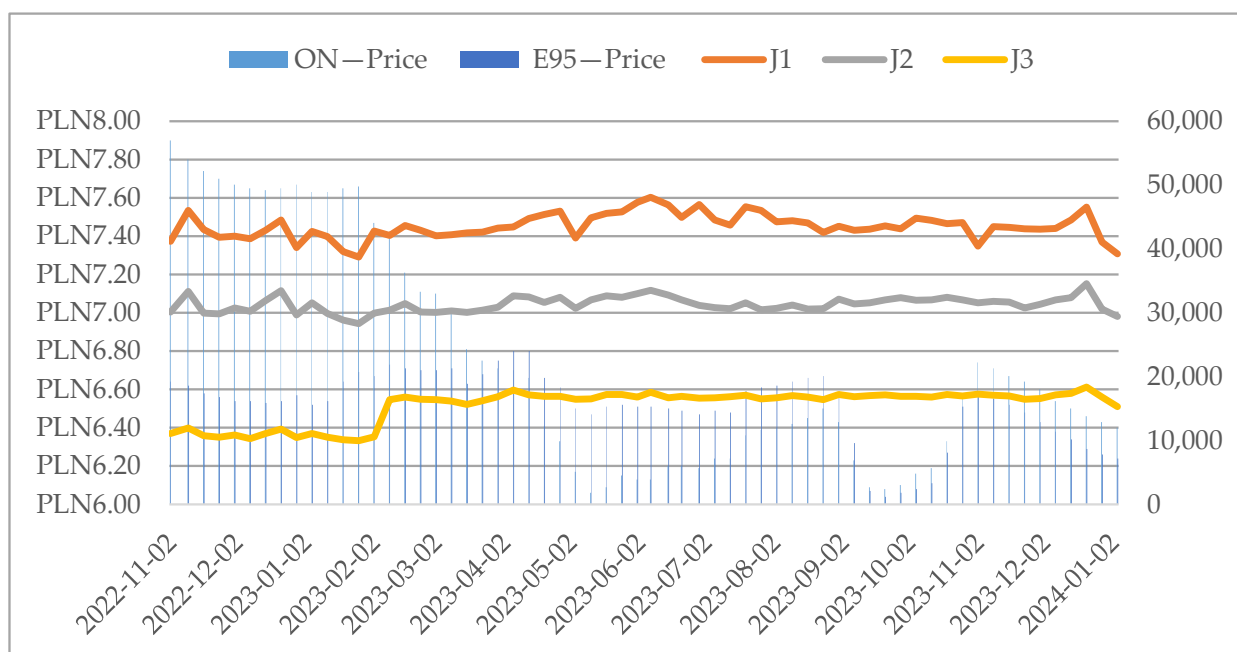


Figure 4. Comparison of the price of fuel and car volume.

3.2. Heavy Goods Vehicles (HGVs)

In the analysis of heavy-duty vehicles, only diesel prices were considered because it is the most prevalent fuel for such vehicles. At Intersection J1, the highest number of Heavy Goods Vehicles (HGVs) was recorded on 2 November 2022, with 3101 vehicles. The lowest number of HGVs was observed on 28 December 2023, with 2859 vehicles. At Intersection J2, the highest number of HGVs was recorded on 8 December 2022, with 2219 vehicles. The lowest number of HGVs was observed on 29 December 2022, with 1491 vehicles. At Intersection J3, the highest number of HGVs was recorded on 6 July 2023, with 3802 vehicles. The lowest number of HGVs was observed on 28 December 2023, with 2769 vehicles. The average count of HGVs observed at Intersection J1 over the analyzed period is approximately 3038 vehicles. For Intersection J2, the average HGV count is around 1709 vehicles. At Intersection J3, the average count of HGV during the same period is approximately 3315 vehicles. The detailed results are presented in Figure 5, where the graph illustrates the history of changes in diesel prices concerning the daily volume of HGVs. It can be observed that in no case does the diesel price affect changes in the flow intensity of Heavy Goods Vehicles.

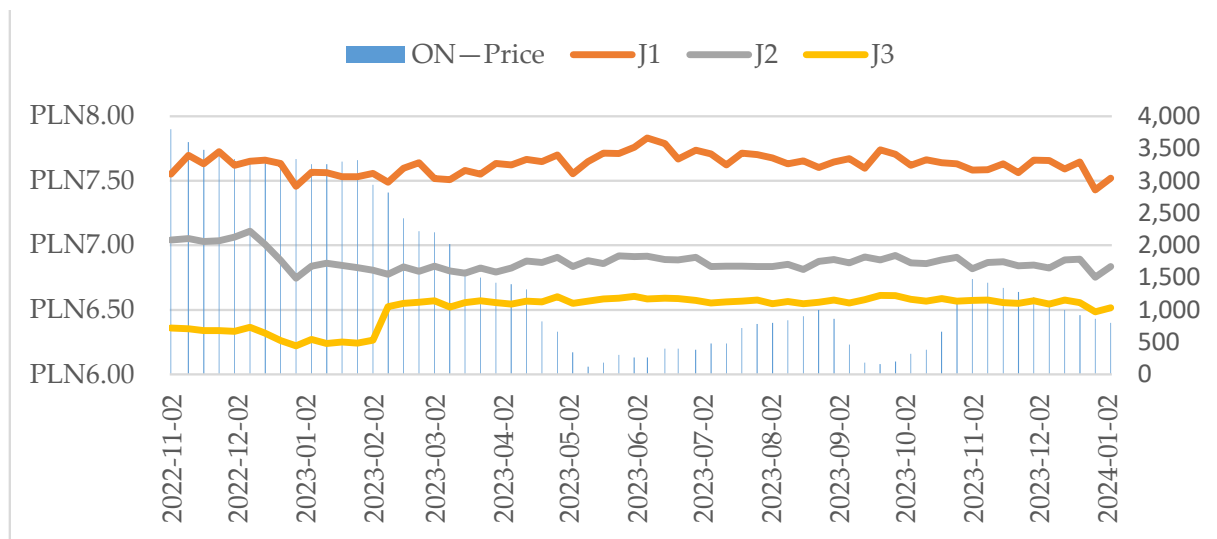


Figure 5. Comparison of the price of fuel and HGV volume.

3.3. Microsimulation Analysis

Due to the diverse results of the previous stage of analysis, the microsimulation in PTV Vissim [26–28] will be based on the example of Intersection J3. The model includes three variants: with maximum intensity as indicated in the previous stage of analysis, minimum vehicle intensity, and average intensity from the entire study period. The model was validated and calibrated using *GEH* statistics (1) where *M* is the traffic volume from the model and *C* is the traffic volume from the real measurements on-site. The purpose of validation and calibration using the *GEH* statistic method is to ensure that the value measured from the model does not deviate significantly from the actual intensity measured. For this purpose, an appropriate mathematical equation is used. The result of this equation cannot exceed values above 5 so that the values measured from the model are suitable for making measurements.

$$GEH = \sqrt{\frac{2(M - C)^2}{M + C}} \quad (1)$$

Figure 6 shows the results of calibration, as is shown every period and every inlet has a *GEH* statistic under 5.

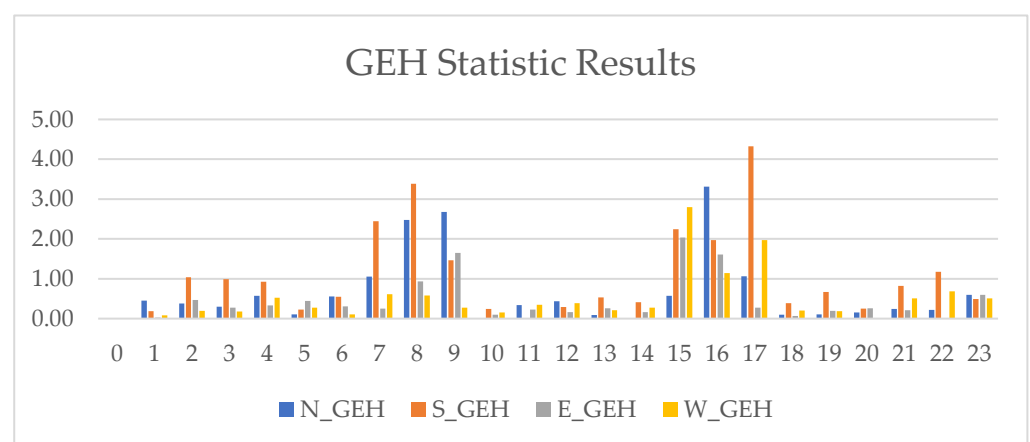


Figure 6. GEH Statistic—validation results.

The view of the modeled Intersection J3 is shown in Figure 7.

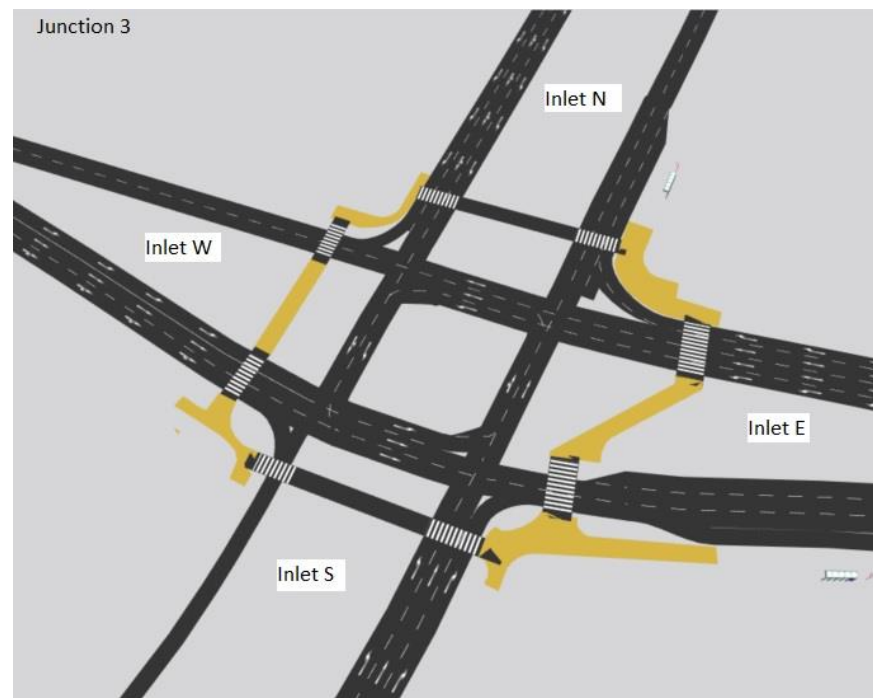


Figure 7. Modeled Intersection J3.

The difference in fuel consumption is significant, especially during the afternoon peak traffic hours. Comparing the highest traffic intensity with the average, the greatest difference is observed during the morning peak period. Therefore, residents living near the intersection, in the case of the highest traffic intensity (variant 1), will be exposed to nearly 600,000 g of CO, over 100,000 g of NO_x, and VOC daily. The detailed distribution of fuel combustion at Intersection J3 is presented in Figure 8.

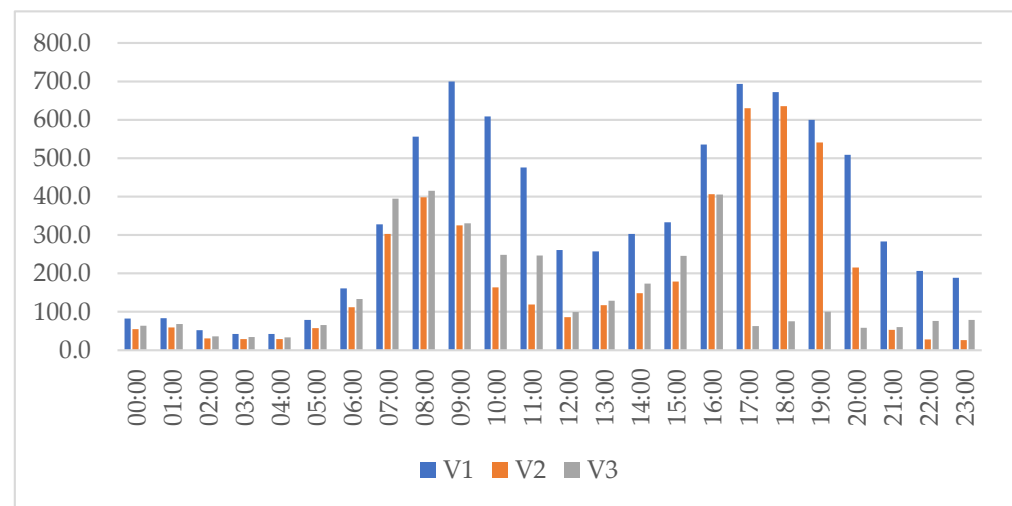


Figure 8. Fuel consumption comparison in liters.

The analysis of air pollutants generated by passenger and freight vehicles at the analyzed intersection on a typical, i.e., average traffic, day yielded the following results: nearly 300,000 g of CO, 57,500 g of NO_x, and 68,500 g of VOC. A detailed analysis is presented in Figure 9.

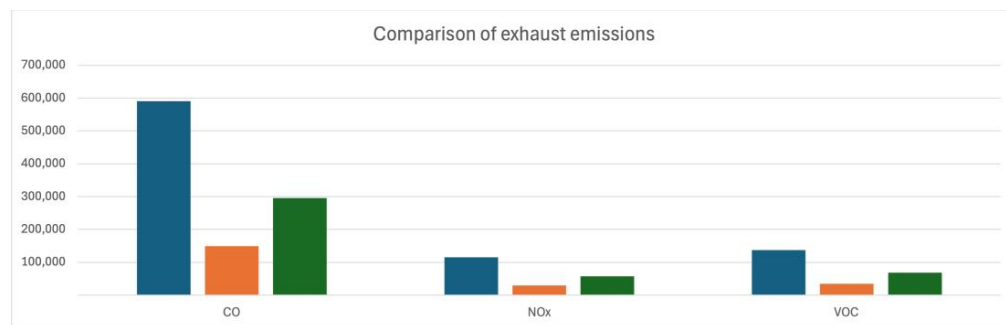


Figure 9. Comparison of exhaust emissions (blue: V1; orange: V2; green: V3).

4. Discussion

It should be noted that generally, nobody refuels their car every day, so depending on the frequency of driving and the length of the routes, a particular car will have to be refueled sooner or later. The most significant changes are observed at Intersection 3, where the number of cars was lowest during the period when diesel fuel was most expensive. It can be concluded that the factor of high fuel prices may have led to a restriction on the use of private cars and prompted drivers to seek alternatives. However, the reduction in fuel prices did not result in an increase in the number of vehicles on the road at any of the three analyzed intersections. The intersection connects various movements from the city districts and also provides a connection to the roads leading to the port. Often, people traveling from the northern parts of the city or the outskirts have no alternative in the form of public transport, especially since, for example, the fast urban railway does not reach there. The remaining intersections are in close proximity to public transport, so travelers have an alternative way to travel. This may be the direct reason that the fuel price did not significantly affect the results. It should also be noted that the price reduction did not last long, so it was not a factor in starting to use the car for an unusually large number of trips, other than those recorded on average. Controlling the number of vehicles through price is possible; according to the analysis, high prices lead to a decrease in vehicles on the road network. An important factor is considering people living outside the city center, e.g., in rural areas, who are forced to travel by private transport due to transportation exclusion [29,30]. These individuals, compelled to use their own cars due to the lack of alternative forms of travel such as public transportation, will be most affected by a situation where fuel prices are drastically high.

The analysis of the number of trucks pertains to a different sector of the economy than individual transport. Freight transport, especially in a port city, will always take place. The fuel cost will be borne by the transport company, which will include this cost in the cost of its service. Ultimately, the service requester for road transport will pay more. However, at this point, other alternatives may also prove attractive, such as transporting goods by rail. Transport companies will seek savings themselves to make their business profitable. It should also be noted that the number of trucks in a port city is directly dependent on the volume of cargo handling in the port. Drivers carrying, for example, a container that needs to be loaded onto a specific ship must appear at the container terminal on a specific day, which may also define the number of vehicles on the road network. The results clearly show that at Intersection 1, the number of trucks increased when the diesel price stabilized in the range of PLN 6 to PLN 6.50. December 2022 and December 2023 are months when drivers typically take longer vacations and make fewer trips. However, the difference between the highest and lowest results is about 900 trucks per day in the urban network. In the analyzed case of Intersection 2, there is no difference in the number of trucks in the urban network throughout the analyzed year of 2023. An interesting observation is that the highest number of vehicles was when the diesel price was also the highest. In the case of Intersection J3, the values also fluctuated around 3500 trucks per day, so they were not dependent on fuel price.

The study of pollution, even at just the average traffic intensity, revealed the extent to which residents are exposed to environmental pollution generated by vehicles, nearly 300,000 g of CO, 57,500 g of NO_x, and 68,500 g of VOC. In the case of minimal traffic intensity, the differences are significant.

5. Conclusions

The conclusion of the research on the impact of the price of fuel or diesel oil on road traffic on the urban road network is as follows: the high price of fuel reduces the number of vehicles on the road network. However, the low price of fuel does not increase the number of vehicles in the network. The reference to low/high prices should be considered in matters of minimum or average wages in a given research area. The phenomenon of high fuel prices compared to the earnings of the local community can be a tool to reduce the number of vehicles in the network and, thus, reduce the pollution caused by transport. The high price of fuel in relation to truck traffic is now more of a business issue due to the calculation of the fuel price as a service cost. Environmental pollution related to road transport is the subject of many studies and considerations by local authorities. The analysis shows that a higher fuel price can reduce the pollution generated by vehicles by up to half. Increased car traffic is something that all major cities struggle with. The conclusion of the study is how important a role public transport plays. Namely, when the price of fuel is too high for an average resident, he or she is forced to travel by public transport; however, if it were not necessary and a lucrative alternative to passenger cars was used, lower results in air pollution with exhaust fumes could be obtained and the price of fuel could remain unchanged. Therefore, the prices of transport services for truck transport could not be increased.

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Data Availability Statement: Restrictions apply to the datasets.

Conflicts of Interest: The author declares no conflicts of interest.

Abbreviation

CO	Carbon monoxide
E	East
GEH	Formula used in traffic modeling to compare two sets of traffic volumes
HGV	Heavy goods vehicle
J1	Junction 1
J2	Junction 2
J3	Junction 3
N	North
NO _x	Nitric oxide
ON	Diesel
PLN	Polish zloty
S	South
USD	United States dollar
V1	Version 1
V2	Version 2
V3	Version 3
VOC	Volatile Organic Compound
W	West

References

1. Ou, Y.; West, J.J.; Smith, S.J.; Nolte, C.G.; Loughlin, D.H. Air pollution control strategies directly limiting national health damages in the US. *Nat. Commun.* **2020**, *11*, 957. [[CrossRef](#)]
2. Ravi, S.S.; Osipov, S.; Turner, J.W.G. Impact of Modern Vehicular Technologies and Emission Regulations on Improving Global Air Quality. *Atmosphere* **2023**, *14*, 1164. [[CrossRef](#)]

3. Fenger, J. Urban air quality. *Atmos. Environ.* **1999**, *33*, 4877–4900. [\[CrossRef\]](#)
4. Zhang, X.; Wang, Q.; Qin, W.; Guo, L. Sustainable Policy Evaluation of Vehicle Exhaust Control—Empirical Data from China’s Air Pollution Control. *Sustainability* **2019**, *12*, 125. [\[CrossRef\]](#)
5. Ziemska, M. Exhaust Emissions and Fuel Consumption Analysis on the Example of an Increasing Number of HGVs in the Port City. *Sustainability* **2021**, *13*, 7428. [\[CrossRef\]](#)
6. Lee, S.; Oh, J.; Kim, M.; Lim, M.; Yun, K.; Yun, H.; Kim, C.; Lee, J. A Study on Reducing Traffic Congestion in the Roadside Unit for Autonomous Vehicles Using BSM and PVD. *World Electr. Veh. J.* **2024**, *15*, 117. [\[CrossRef\]](#)
7. Wang, Q.; Delucchi, M.A.; Sperling, D. Emission Impacts of Electric Vehicles. *J. Od Air Waste Manag. Assoc.* **1990**, *40*, 1275–1284. [\[CrossRef\]](#)
8. Jacyna, M.; Żochowska, R.; Sobota, A.; Wasiak, M. Scenario Analyses of Exhaust Emissions Reduction through the Introduction of Electric Vehicles into the City. *Energies* **2021**, *14*, 2030. [\[CrossRef\]](#)
9. Marino, C.; Nucara, A.; Panzera, M.F.; Pietrafesa, M. Assessment of the Road Traffic Air Pollution in Urban Contexts: A Statistical Approach. *Sustainability* **2022**, *14*, 4127. [\[CrossRef\]](#)
10. Jacyna, M.; Wasiak, M.; Lewczuk, K.; Karoń, G. Noise and environmental pollution from transport: Decisive problems in developing ecologically efficient transport systems. *J. Vibroeng.* **2017**, *19*, 5639–5655. [\[CrossRef\]](#)
11. Münzel, T.; Sørensen, M.; Daiber, A. Transportation noise pollution and cardiovascular disease. *Nat. Rev. Cardiol.* **2021**, *18*, 619–636. [\[CrossRef\]](#)
12. Zheng, P.; Li, Y.; Lin, M.; Hu, Y.; Zheng, P.; Li, Y.; Lin, M.; Hu, Y. Urban Traffic Flow Prediction Based on Spatio-Temporal Convolution Networks. *J. Comput. Commun.* **2023**, *11*, 15–23. [\[CrossRef\]](#)
13. Yulianto, B. Traffic Management and Engineering Analysis of the Manahan Flyover Area by Using Traffic Micro-Simulation VISSIM. *IOP Conf. Ser. Mater. Sci. Eng.* **2020**, *852*, 12005. [\[CrossRef\]](#)
14. Lochrane, T.W.P.; Al-Deek, H.; Dailey, D.J.; Krause, C. Modeling driver behavior in work and nonwork zones: Multidimensional psychophysical car-following framework. *Transp. Res. Rec.* **2015**, *2490*, 116–126. [\[CrossRef\]](#)
15. Nævestad, T.-O.; Sagberg, F.; Levlin, G.; Bjørnskau, T. Competence, equipment and behavioural adaptation on Norwegian winter roads: A comparison of foreign and Norwegian HGV drivers. *Transp. Res. Part F Traffic Psychol. Behav.* **2021**, *77*, 257–273. [\[CrossRef\]](#)
16. Ziemska-osuch, M.; Osuch, D. Analysis of the Capacity of Intersections with Fixed-time Signalling Depending on the Duration of the Green Phase for Pedestrians. *TransNav, Int. J. Mar. Navig. Saf. od Sea Transp.* **2024**, *18*, 323–327. [\[CrossRef\]](#)
17. Khavarian-Garmsir, A.R.; Sharifi, A.; Sadeghi, A. The 15-minute city: Urban planning and design efforts toward creating sustainable neighborhoods. *Cities* **2023**, *132*, 104101. [\[CrossRef\]](#)
18. Glaeser, E.L.; Ponzetto, G.A.M. The political economy of transportation investment. *Econ. Transp.* **2018**, *13*, 4–26. [\[CrossRef\]](#)
19. Rondinelli, D.; Berry, M. Multimodal transportation, logistics, and the environment: Managing interactions in a global economy. *Eur. Manag. J.* **2000**, *18*, 398–410. [\[CrossRef\]](#)
20. Gauthier, H.L. Transportation and the Growth of the São Paulo Economy. In *Transport and Development*; Palgrave: London, UK, 1973; pp. 167–189. [\[CrossRef\]](#)
21. Suleymanli, J.; Mammadov, I.; Ahmadov, F.; Ali, T.; Nithya Priya, D. Impact of increasing fuel prices on consumers. *Int. J. Energy Econ. Policy* **2022**, *12*, 405–411.
22. Sidebottom, A.; Agar, I.; Kurland, J. Do increases in the price of fuel increase levels of fuel theft? Evidence from England and Wales. *Crime Sci.* **2023**, *12*, 7. [\[CrossRef\]](#)
23. Zakaria, H.; Rohani, M. Road Users in Rural Areas Mobility: Impact from Fuel Price. *Recent Trends Civ. Eng. Built Environ.* **2023**, *4*, 143–151.
24. Euro 95 (Polska). Available online: <https://www.bankier.pl/gospodarka/wskazniki-makroekonomiczne/eu-95-pol> (accessed on 18 June 2024).
25. Ziemska-Osuch, M.; Osuch, D. Modeling the Assessment of Intersections with Traffic Lights and the Significance Level of the Number of Pedestrians in Microsimulation Models Based on the PTV Vissim Tool. *Sustainability* **2022**, *14*, 8945. [\[CrossRef\]](#)
26. Fellendorf, M. VISSIM: A microscopic Simulation Tool to Evaluate Actuated Signal Control including Bus Priority. In *64th Institute of Transportation Engineers Annual Meeting*; Springer: Berlin/Heidelberg, Germany, 1994.
27. Liang, Q.; Wan, Q.; Bai, L.; Yu, H.; Lv, L.; Li, D. Sensitivity of Simulated Conflicts to VISSIM Driver Behavior Parameter Modification. In *Green, Smart and Connected Transportation Systems*; Springer: Singapore, 2020; pp. 113–122, ISBN 978-981-15-0643-7.
28. Gunarathne, D.; Amarasingha, N.; Wickramasinghe, V. Traffic Signal Controller Optimization Through VISSIM to Minimize Traffic Congestion, CO and NOx Emissions, and Fuel Consumption. *Sci. Eng. Technol.* **2023**, *3*, 9–21. [\[CrossRef\]](#)
29. Lucas, K. A new evolution for transport-related social exclusion research? *J. Transp. Geogr.* **2019**, *81*, 102529. [\[CrossRef\]](#)
30. Lucas, K. Transport and social exclusion: Where are we now? *Transp. Policy* **2012**, *20*, 105–113. [\[CrossRef\]](#)

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