Impact of Road Grade on Fuel Consumption: Potential Savings in Nablus, Palestine

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Abstract
The transportation sector contributes significantly to energy consumption with inherent consequences in terms of emission of local pollutants. This work aims to assess the impact of grades on vehicle fuel consumption and emissions in Nablus city. Traffic data in peak hour for thirteen representative segments was collected. Vissim was used to find the delay, fuel consumption, and emission for the current situation compared with no grade scenarios. The average fuel consumption was about 14.4 and 12.4 liters for the current conditions and assuming no grades, respectively. The average emissions (CO, NOx, and VOC) during the peak hours for the thirteen segments were about 264.1g, 51.4g, and 61.2g with grades, and 227.9g, 46.3g, and 52.8g assuming no grades. The maximum potential fuel savings was estimated in 2035 with about 9% by introducing hybrid and electric. The high potential fuel savings can encourage policymakers to adopt this policy in the future.

Keywords: Road Grade, Fuel Consumption, Emissions, Fuel Savings, Electric and Hybrid Vehicles

INTRODUCTION

Developing countries such as Palestine suffers from dramatical increasing in the toxic emissions resulting from the existing of huge fleet of private vehicles, Palestine has 435584 registered vehicles in 2021 based on the Ministry of Transportation data base (MoT, 2022), Nablus is selected to be the case study as it is the third city on the list after Ramallah and Hebron. Due to the complexity in Nablus geometric road features and at specific in grades with slopes up to 25% and the existing of about 23,685gasoline and diesel private vehicles at the end of 2021(MoT). The selected roads in Nablus (the case study) were carefully chosen as these roads are located in the western and middle parts of the city. From one side, the amount of traffic on these roads is the highest almost all the toady as these roads serves vital traffic generations such as universities, hospitals, municipal facilities, schools, etc. On the other hand, these roads are classified as arterials and have almost higher slopes (reach about 25%) which gives additional merit in terms of class and grade. This in turn will contribute to increasing the fuel consumption and accordingly will negatively impact the environment by producing toxic emissions. Accordingly, Nablus city was taken as a case study to investigate the relation between the type of vehicle in terms of fuel, traffic volume, and grades with the considerable quantities of transmitted emissions in the atmosphere such as Carbon dioxide CO_2 and nitrous dioxide NO_2 concentrations in the atmosphere which have increased significantly over the past century.

Based on the database from MoT, the number of hybrid and electric vehicles is Nablus city is still unpretentious. The introducing of electric and hybrid vehicles may influence the usage of existing vehicles. The usage of electric and hybrid vehiclesis compatible with Shin*etal.* 2012 who conducted a survey in South Korea considering the consumer preferences and usage of 250 households to analyze a future electric vehicles market. Moreover, the use of such vehicles has a good potential comparing with conventional ones due to; the dramatically increasing in fuel prices and governmental taxes and minimizing the CO_2 emissions.

In the transportation sector, it is important to deal with environmental issues and energy security in terms of energy consumption and greenhouse gas (GHG) emissions. In developing countries such as Palestine, the travel demands, and corresponding economic and logistics demands are continuing to rise. Accordingly, it is important to solve related problems by introducing and adopting new national policies and regulations consideringthe electric and hybrid vehicles promotion and fuel economy.Although the effect of decarbonization by the promotion of the electric and hybrid vehicles will take long-term, the local government should take effective mitigation measures to reduce the heavy vehicles GHG (Shin et al. 2012).The energy consumption of the electric vehicles usually depends on several factors among them road topography, traffic, driver behavior, temperature, time, distance, acceleration, etc. (De Cauwer*et al.* 2015). Manzie*et al.* 2007 declared that the increasing of oil prices requested the search for fuel efficient fleet like hybrid and electric vehicles. At the end 2021, the number of electric vehicles in Palestine (West Bank) is only 167 (1 in Nablus) and the hybrid is 699 (35 in Nablus) (MoT, 2022[1]).

Recently, due to projected shortage of crude oil and the urgent need of reducing greenhouse gas (GHG) emissions, more efforts and resources have been spent on developing a sustainable transportation system that can address the climate change challenge and reduce oil dependence (Hassouna and Al-Sahili, 2020).In 2018, the total amount of CO_2, CH_4, and N_2Oemissions produced by transportation sector was 2967.97, 1006.79, and 552.91thousand tons, namely about 65.6, 22.2, and 12.2 percent of the nationalCO_2 emissions, respectively (PCBS, 2021).

The high price of fuel is another problem that the transportation sector faces in Palestine. More specifically, the average gasoline price (per liter) in 2021 was about USD 1.80, while the world average price was about USD 1.21[PCBS Fuel Prices]. In other words, the average fuel price in Palestine is about 150% in relation to the world's average.

[1] Ministry of Transportation (MoT), 2022. Transportation annual statistical report 2021. Ramallah-Palestine.

Based on the EuropeanCommission in (2016), the Greenhouse Gases (GHG) emissions produced from transportation sectorin 2014 formed approximately 23% of the total emissions in the European Union (EU). In that year, highway vehicles accounted for 72.8% of all GHG transportation emissions, with about 53% of the CO_2 emissions attributed to inter-urban transportation. Road transportation was also the largest source of nitrogen oxides (NOx) emissions, accounting for 39% of total EU emissions, and was an important emission source (13%) of fine particulate matter less than or equal to 2.5 μm in diameter (PM2.5). Road transportation can also contribute significantly to the total emissions of other pollutants, such as sulfur oxides (SOx) and carbon monoxide (CO)of CO_2 (397 ppm) was approximately 40% higher than that estimated during the mid-1800s, with an average growth of2 ppm/year in the last ten years. Levels of methane (CH_4) and nitrous dioxide (NO_2) have also significantly increased (InternationalEnergy Agency, 2016).

In the United States, emissions from transportation increased by approximately 17% from 1990 to 2014 (US EPA, 2016). The combustion of fossil fuels to transport people and goods is the second largest source of CO_2 emissions, accounting for about 31% of total US CO_2emissions in 2014. The largest sources were passenger cars (42.4%), medium- and heavy-duty trucks (23.1%), and light duty trucks (17.8%). The transportation sector is also responsible for 20% of CH_4 emissions and 41% of N_2O emissions from fossil fuel combustion.

LITERATURE REVIEW

Several studies have investigated the relation between vehicle route, driver behavior and traffic conditions on the emissions and fuel consumption such as De Vlieger et al. (2000) who tested a fleet of passenger cars in terms the effect of the vehicle route, driver behavior and traffic conditions on the emissions and fuel consumption. The authors revealed that the use of ring roads and motorways during rush hours is more environment-friendly comparing with short segments. Others analyzed and assessed the emissions resulting from cold start mainly in the urban areas and found increasing in emissions in local streets (Faria et al. 2018). Moreover, (Faria et al. 2018) also studied the percentage time spent on cold start considering the ambient temperature and the relation was inversely proportional.Demir et al. 2011 stated that the using appropriate emission models is expected to reduce the greenhouse gas. Moreover, the authors reviewed numerically different emission models related to the freight transportation.

Franco et al. 2013 examined and reviewed the advantages and disadvantages of the techniques such as chassis and engine dynamometer (PEMS) which is used to measure the road vehicle emissions in relation with development of emission factors. measurements, remote sensing, road tunnel studies and portable emission measurements systems.De Vlieger 1997 analyzed that effect of classification of road, driver behavior, and cold start on fuel consumption as well as NOx, CO, and HC emissions. The author concluded based on the performed test that in the real traffic conditions the low-emitting cars did not necessarily give low emissions.Wang et al. 2008 analyzed and developed the driving cycles characteristics for 11 Chinese cities. They used the car chasing technique to acquire the driving patterns of cars. The authors concluded the most important factors concerning significant differences in vehicle driving patterns. The concluded the importance of applying driving cycles considering real traffic situation in vehicle emission.

During the last two decades, several researchers investigated the implications and effects of the grades and road profile on fuel consumption and the transmitted emissions, especially in developed countries such EU and USAID. However, in developing countries such as Palestine, these studies are still recent and infancy.All studies indicated the directly proportional between the quantity of emissions and the slope of the road. Nablus city has a special condition as it has in general hilly and mountainous terrain. The following studies summarize the above-mentioned relation and implication throughout the world.

Cicero-Fernandez et al. 1997 assessed through their project the high emissions from driving patterns while driving on roads with zero to seven percentage grades along arterial roads and freeways. The results revealed that the percentage of carbon monoxide emissions is directly proportional to the grades.Wyatt et al. 2014 proposed that the developed emission model with LiDAR-GIS Road grade is considered a viable method for generating accurate emission estimates of real-world CO_2. Pelkmans and Debal, 2006 measured the emissions for two vehicles in grams per kilometer basis. The authors found that some of the emissions measured in the certification cycle differed dramatically from the real traffic emissions.Sentoff et al. 2015 suggested that incorporating and measuring real-world road grade is an important point. They also developed a typology for driving style to account for the estimated differences emissions due to driver variability.AlamHatzopoulou 2014 investigated the effect of network congestion, passenger load, roadway grade, and fuel type on transit bus emissions. They found that emissions are strongly affected by positive grades, type of fuel, increasing passenger load and congestion.Svenson and Fjeld 2016 quantified the effect of road curvature, gradient, and surface roughness for a 60-ton conventional logging truck.Safiarian and Mansourian 2020 studied the effect of road grade and surface on the fuel consumption for freeways in Tehran. They developed an equation measuring the fuel consumption as a function of road slope and in terms of international rough index.Faria et el. 2019 evaluated the effect of road type, fuel consumption and grade on driving aggressiveness by the using real world monitoring data. They studied 29 diesel and 17 gasoline light duty vehicles driven by 46 drivers. The authors found that the rates of fuel consumption increased by 255% with grades and aggressive driving behavior.

Boriboonsomsin and Barth 2009 assessed the impact of road grade on fuel consumption of light-duty vehicle using an analytical approach. The used uphill, downhill, and one flat roads. The results indicated that the road grade has significant effect on fuel consumption. They found that flat roads save about 15% to 20% fuel compared with graded ones.Gallus et al. 2017 studiedthe emissions resulted from different types of driving styles. They tested Gaseous emissions of two Diesel test vehicles (Euro-5 and Euro-6). Route. The authors found that CO2 (65-81%) and NOx (85-115%) emissions showed a good linear correlation with road grade (0-5%) for all urban, rural and motorway parts.Cicero-Fernandez et al. 1997 assessed driving patterns that promote high emissions while driving on roads with grade and facilitating the development of more accurate mobile source emission inventories. The authors found roads with 35-55 MPH speeds and grade more than 3% generated high rates of hydrocarbon emissions.Sentoff et al. 2015 used real-world vehicle operating mode data to measure road grade in order to correctly assign emission rates. The authors found that road grade should be taken into consideration in estimating emissions. Moreover, they declared that the amount of such emissions varied from driver to driver.

Prati et al. 2015 investigated the effect of road grade and slope variability on driving emissions by choosing two routes. The authors found that for uphill roads, emissions increased by 85% and 33% for CO_2 and NOx, respectively. However, they revealed the opposite trend was found for downhill, with NOx and CO_2 emissions decreasing by 60% and 45%, respectively.Brundell and Ericsson, 2005 discussed the variables that affect driving patterns in terms of environment effect considering street categorization.The results showed that the driving behavior is mainly affected by street and traffic environment.Ericsson 2001 investigated the properties of urban driving patterns which affect emissions and fuel consumption. The author estimated the fuel consumption and emissions using mechanistic emission model. He provided some recommendations concerning direct implications for environmental policy.Hallmark et al. 2002 proposed a new and better mitigation measures and strategies associated with elevated emissions to be implemented. The main two strategies were to reduce the stop time at traffic signals and vehicle speed and acceleration with higher emissions. Furthermore, the main statistical variable was the grade.

This study aims at investigating the impact of road grade on fuel consumption and emissions in terms of assessing potential savings in Nablus city. PTV Vissim will be used to simulate the amount of delay, fuel consumption and gas emissions (CO, NOx, and VOC). The authors will use different scenarios considering uphill and downhill grades as well as no grade case.

METHODOLOGY

Datasets

In this study, a large amount of data has been initially collected from several sources such as Ministry of Transport, Nablus Municipality, the Palestinian Central Bureau of Statistics (2021), in addition to field traffic volume data collected. The selection of roads in the study area was based on functional classification, importance, grading, serviceability, mobility, speed, etc. The main collected data was peak hour volume, vehicle classification in terms of private cars, taxies vehicles, and heavy duty, in addition to the grades of the targeted roads. Moreover, the data included the number of licensed vehicles in Nablus governorate up to end of 2021 in terms of type of fuel (gasoline and diesel), engine force, manufacturing date, etc.Table 1 shows the percentage of each type based on vehicle classification. Moreover, Figure 1 illustrates the targeted roads in the case study based on their ID.

Table 1: Percentage of vehicles based on their classifications

No.	Vehicle Class	Percentage
1	Private	65.51%
2	Taxi	27.26%
3	Heavy duty	7.23%
Total		100%

Figure 1. A map illustrated the targeted roads with ID

The classification of vehicles based on the type of fuel is illustrated in Table 2. From Table 2,it is clear that the majority of the registered vehicles use gasoline with about 58.60% followed by diesel with about (41.30%), and finally hybrid and electric vehicles with about (0.10%), These statistics indicate that the pollution and emissions are expected to be source of threat for public health and will badly impact the local national economy through the considerable quantities of fuel consumption. Furthermore, Figure 2 depicts these percentages graphically.

Table 2. Number and percentage of vehicles based on fuel type

	Gasoline			**Diesel**			**Hybrid**			**Electric**			**Total**
Vehicle Class	*Private*	*Taxi*	*Heavy duty*	*Private*	*Taxi*	*Heavy duty*	*Private*	*Taxi*	*Heavy duty*	*Private*	*Taxi*	*Heavy duty*	
Number	9,106	3,789	1,005	6,410	2,667	707	25	0	0	4	0	0	23,714
Subtotal	13,900			9,785			25			4			

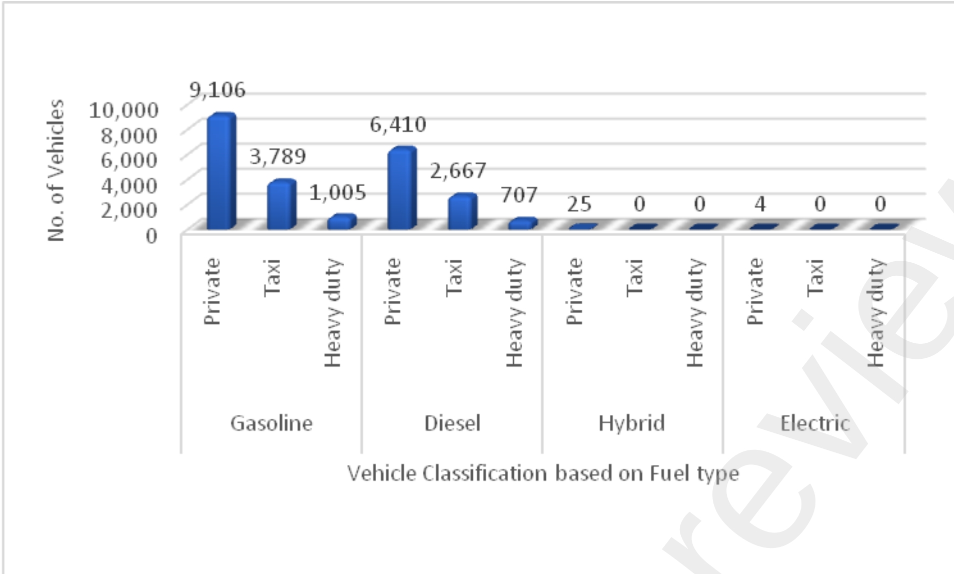

Figure 2. Number and percentage of registered vehicles based on fuel type.

The trend of number of vehicles based on fuel type (gasoline and diesel) from 1980 to 2020 is presented in Figure 3. It is clear that the number of both types is increasing dramatically which in turn will result in more emissions and pollutions.

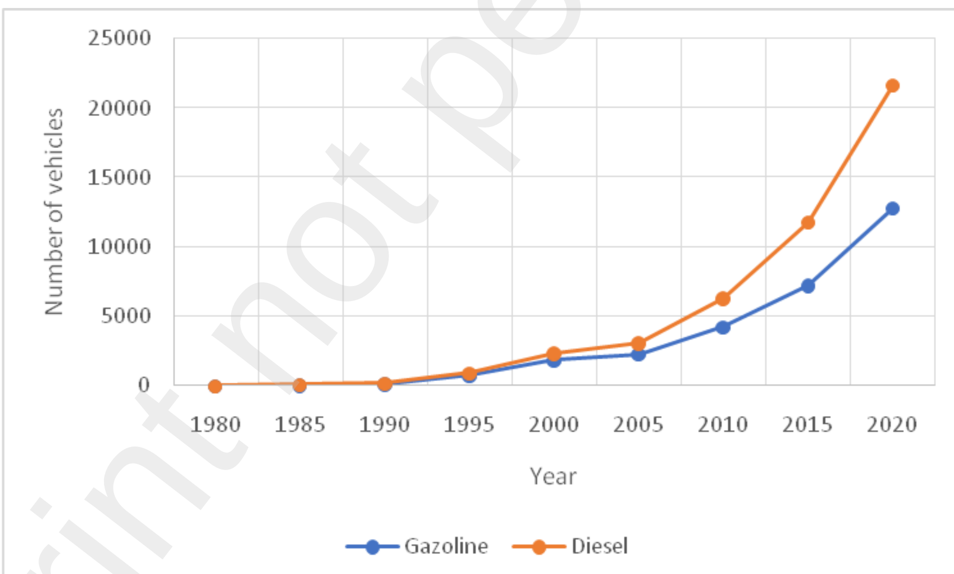

Figure 3. The trend of registered vehicles considering type of fuel

As stated before, the terrain of Nablus city can be described as hilly to mountainous. The grades reach about 25% in specific locations. Accordingly, the expected amount of fuel consumption and gas emissions is huge. The topography map of Nablus city is presented in Figure 4.

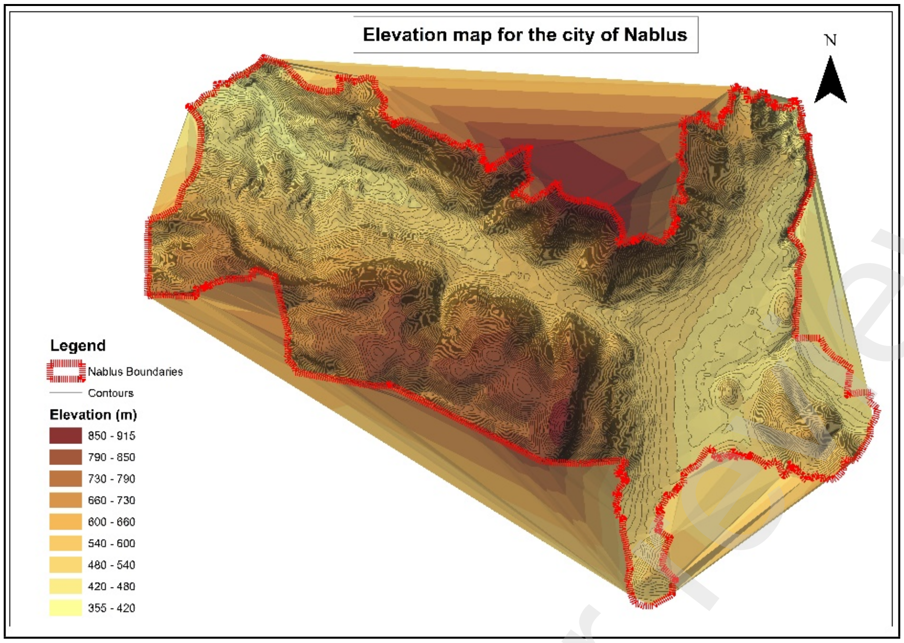

Figure 4. Topography map of Nablus city

Table 3 illustrates the collected traffic volumes on the target roads in Nablus city. Thirteen vital and important roads were selected with different grades and classifications. The traffic volumes were collected in the morning and afternoon for both uphill and downhill considering three main vehicle classes include private, taxi, and heavy duty. The length of segments was variable and measured grades were based on the change in slope.

Table 3. Summary of collected dataset

Street ID	Grade (%)	Length (km)	Time	Uphill			Downhill			Total
				Private	*Taxi*	*Heavy-duty*	*Private*	*Taxi*	*Heavy-duty*	
1	18	0.2	1-3PM	881	451	44	679	524	56	2635
2	16	0.1	1-3PM	704	262	59	565	207	52	1849
3	18	0.4	10-12AM	596	281	119	153	86	20	1255
4	21	0.4	10-12AM	556	266	117	141	80	22	1182
5	11	0.1	1-3PM	925	294	156	174	85	19	1653
6	19	0.2	1-3PM	265	56	32	241	53	28	675
7	20	0.2	7-9AM	235	79	24	223	61	32	654
8	11	0.1	1-3PM	276	67	29	271	62	18	723
9	12	0.3	7-9AM	273	89	16	266	116	13	773
10	8	0.2	8-10AM	53	9	2	62	13	1	140
11	7.5	0.1	1-3PM	141	28	20	120	17	3	329
12	13	0.3	8-10AM	678	507	22	831	391	38	2467
13	13	0.3	1-3PM	482	135	29	442	108	43	1239

The following steps illustrate the methodology followed by the researchers as presented in Figure 5.

- Data collection. The qualitative data was collected from the field and represented by the traffic volume counts and the calculated peak hour volumes. The second type of data was the quantitative. The main sources of such data werethe Ministry of Transport (MoT), Palestinian Center Bureau of Statistics (PCBS), Nablus municipality, Ministry of Local Government (MoLG), and topography and grades utilizing GIS.
- Data Analysis. The main two components which were addressed are fuel consumption and gas emissions (CO_2,NOx, and VOC) in the targeted roads considering both uphill and downhill grades.
- Results. Developing and validation the model which describes the amountof emissions and fuel consumptions. In addition to the developing what if analysis (scenarios) in the case of using electric or hybrid vehicles considering level, uphill, and downhill grades.
- Conclusions and recommendations and perspectives for future development.

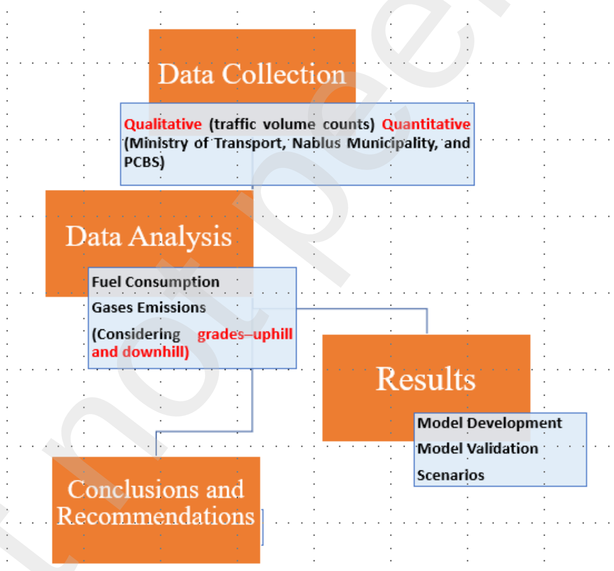

Figure 5. Research methodology

Simulation

PTV Vissim is a widely usedmicroscopic simulation program for modeling multimodal transport operations and belongs to the Vision Traffic Suite software. Vissimprovides the best conditions for engineers totest various traffic scenarios realistically and accurately before implantation. Vissim is now being used worldwide by the public sector, consulting firms, and researchers in universities(Ramadhan, 2019;Stevanovic, 2009; Park, 2003; Ziemska, 2021; Alshayeb, 2021; Zhao, 2021).Vissim has various features, such as traffic flow modeling, vehicle delay analysis, vehicle queue length analysis, multiclass vehicle simulation, fueland emissions analysis, as well as including the effect of geometric road parameters including grades.There have been many studies that usedVissim to simulatetraffic conditions of real scenarios for fuel consumption and emissionsincluding (Ziemska, 2021; Alshayeb, 2021; Zhao, 2021).Vissim allows for considering mutual interactions generated by groups of traffic users moving on the sameroad network, which is essential in our study. Vissimis based on theWiedemann model as a car-following model.Thevehicle following another vehicle reaches its maximum speed then it slows down and accelerates to keep a safe distance from the vehicle in front of it (Ziemska, 2021).In this study,Vissim was used to build a series of simulations for the 13 streets that are part of the study considering two scenarios:using their real grades, and assuming no grades. During these simulations of the two scenarios, we reported the results of delay, fuel consumption, emissions of CO, NOx, and VOC for the traffic passing througheach of the 13 streets. For each street, we reported the results considering the uphill and downhill and using the traffic counts for each of them, which was collected as shown in Table 2. In order to implementthe model, the following steps were made:

- The roads with the grades and lengths weremapped;
- We added vehicle counts on an hourly basis based on data in Table 2;
- The different classes of vehicles were added based on Table 1;
- Allowable speeds on individual sections were assigned and speed zones were created for areas, where it is believed that vehicles are not supposed to exceed lower speeds than the allowable; and
- Measurement points for fuel consumption, emissions, and delay were added.

Based on five simulation runs, the results were averaged. The model made is considered to reflect the existing state of the study area.

RESULTS AND ANALYSIS

The simulation results are presented based on the analysis of delay, fuel consumption, and emissions ofthe thirteen segments with their grades and assuming no grades. For each segment, we reported the results for the downhill lane, uphill land, and the total impact on the segment. The analysis of nodes on Vissim allowed us to obtain data on the emission generation of CO, NOx, VOC by vehicles as well as fuel consumption on the microscopic level. Figure 1 shows the location of the analyzed segments in the network, each one is labeled from 1 to 13. First, the impact of the road grads on delay, fuel consumption, andemission in the city is presented. The analysis showed data on the current state (with grades) and is compared with the assumed state (no grades). In the end, potential savings in fuel consumption and emission is presented if hybrid and electric vehicles were adopted as a policy by the policymakers in the coming years.

In the results of the microsimulation model, it can be seen that the resultsdiffer depending on the segment. It depends on the traffic volume, the queue, the road grade, percentage of heavy-duty vehicles, and the length of the segment.Although it is obvious that results in uphill are usually greater from results in downhills, the amount of difference also depends on the previously mentioned factors. A statisticalStudent's t-test was performed to assess the significance of the differences between grades and no-graderesults. In all cases, we found that the p-value is less than 0.001 revealing that results with grades have a significantly higher delays, fuel savings, and emissions than the no-grade results.

Delay is considered a significant factor in determining the level of service at the segments as well as a parameter that can be used in the optimization of traffic signal timings for nearby signalized intersections. Figure 6 shows the impact of road grades on the delay at the segments. We found that the average delay for the 13 segments is about 35.5 sec for the current state and about 27.9 sec assuming no road grades in the segments. In the case of segment12, the maximum value of the delay was found to reach about 85.0 sec during the two-hour under study.

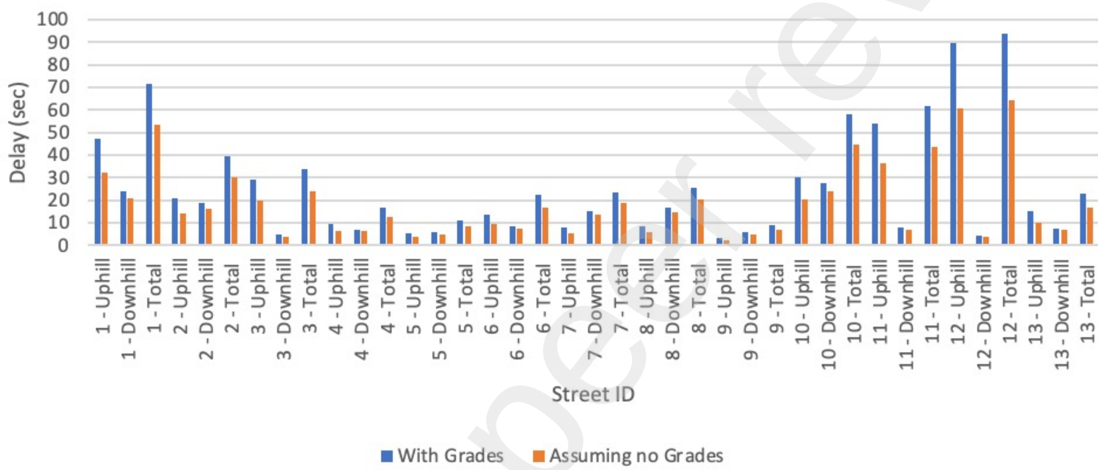

Figure 6. Delay at each segment with grades and assuming no grades.

The effect of road grade on fuel consumption was evaluated for the segments during the two-hour under study. Figure 7 shows the fuel consumption and the reduction percent at each segment with grades and assuming no grades.We found that the averagefuel consumption was about 14.4 Liters and 12.4 Liters for the current segment state and assuming no grades, respectively. We also found that the average reduction in fuel consumption considering no road grades is about 19%.However, the maximum value for fuel consumption was in case of segment 1 with about 33.3 Liters. The highest reduction percentage was in case of uphill section in segment 12 with about 37%, if no grade is assumed. We further investigated the relationship between road grades and reduction in fuel consumption. We found that there is a seemingly a linear relationship, where reduction in fuel consumption increased when road grades increased as presented in Figure 8. We found that there is a relatively strong relationship ($R^2$is estimatedabout 0.89) and equation (1) represents the relationship as follows:

$$Reduction\ Percent\ =\ 0.019\ Road\ Grade -\ 0.061 \quad (1)$$

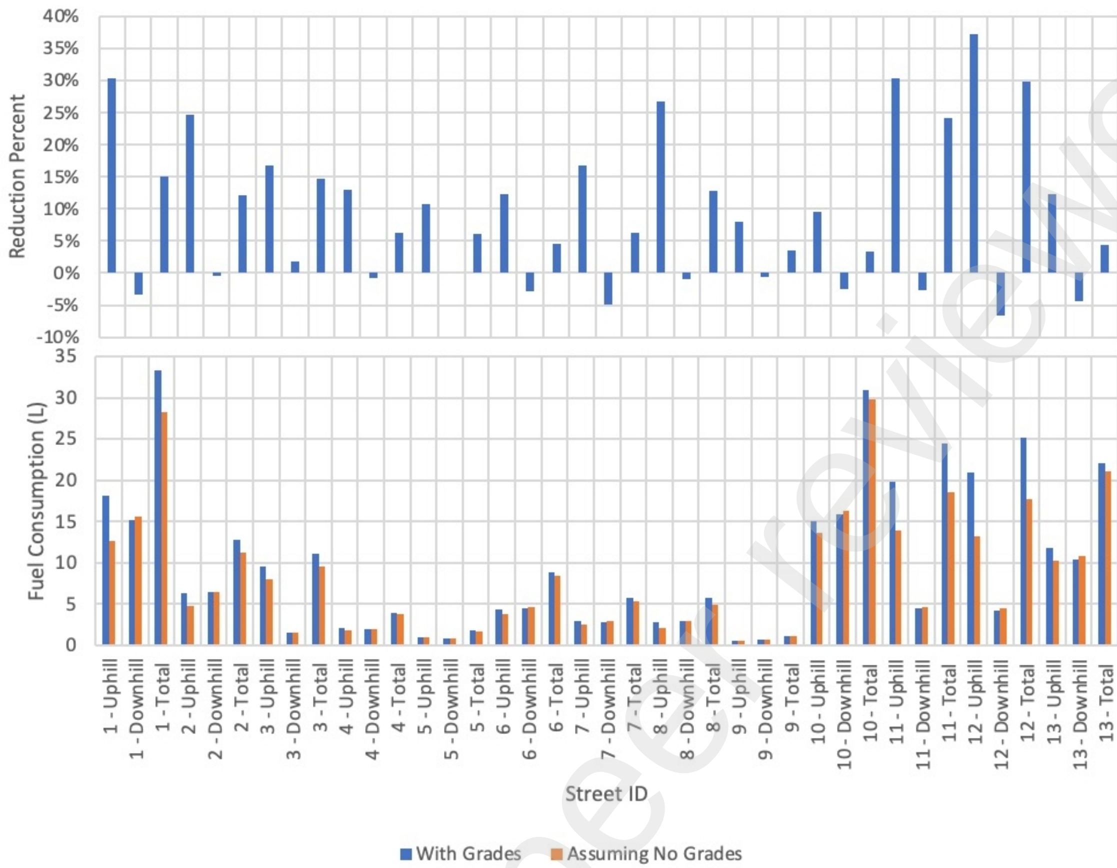

Figure 7. Fuel consumption and reduction percent at each segment with grades and assuming no grades.

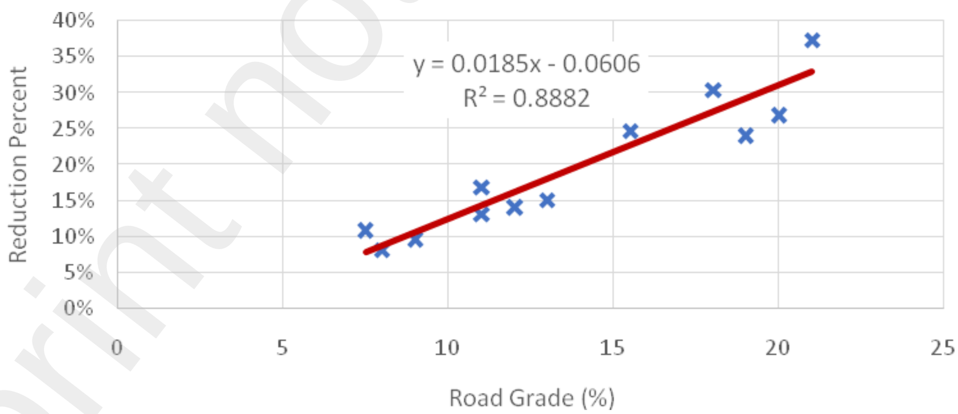

Figure 8. Relationship between reduction percent and road grade.

The effect of road grade on emissions including CO, NOx, and VOC were evaluated for the segments during the two-hour under study. Figure 9 shows the three types of emissions at each segment with grades and assuming no grades. We found that the average emissions for the 13 segments are about 264.1g, 51.4g, and 61.2g with grads; and

227.9g, 46.3g, and 52.8g assuming no grades for CO, NOx, and VOC, respectively. In case of segment 1, it has the highest emissions with about 611.5g, 119.0g, and 141.7g for CO, NOx, and VOC, respectively during the two-hour study.

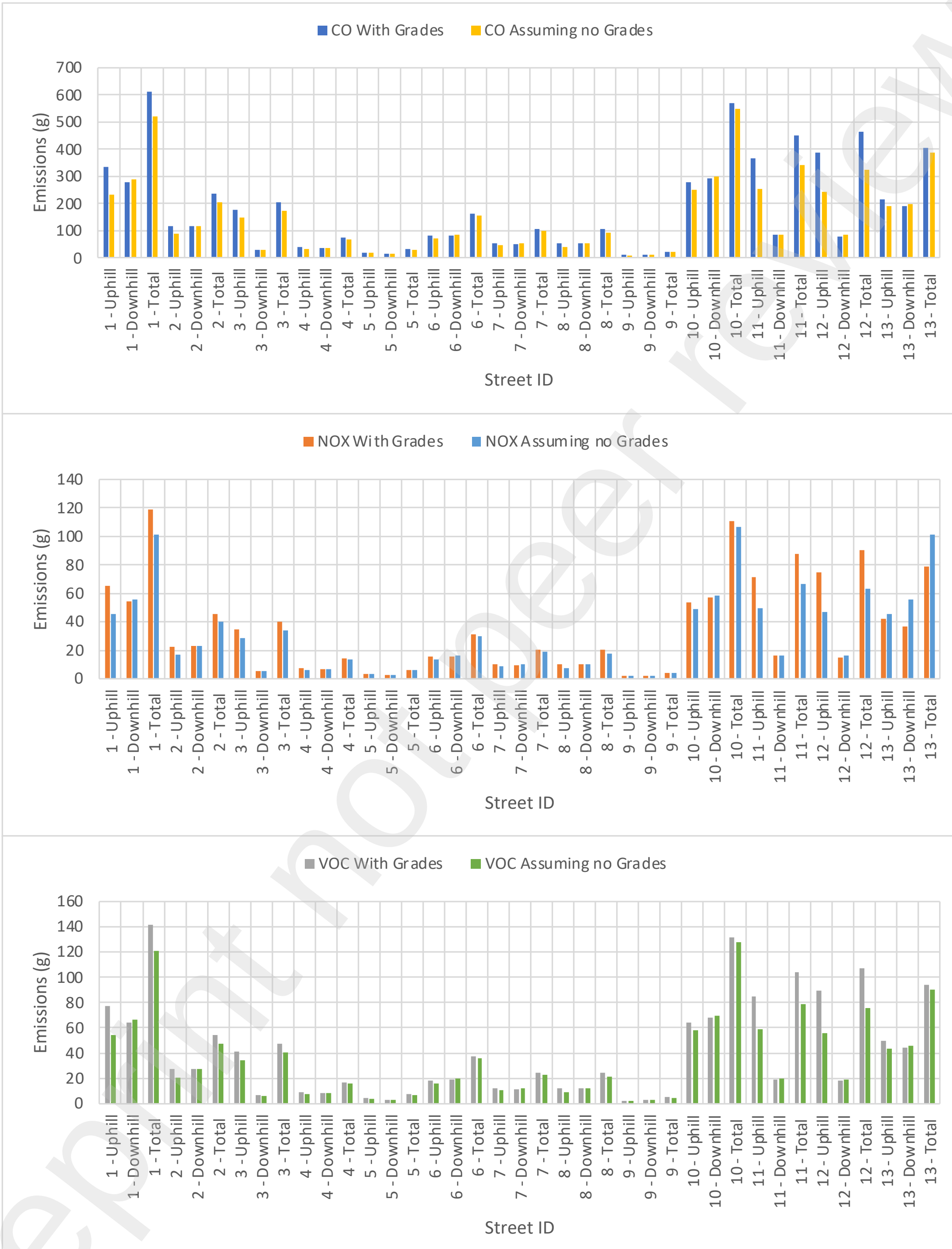

Figure 9. Emissions at each segment with grades and assuming no grades.

Potential fuel consumption savings were assessed by assuming a scenario, where thepolicymakers adopt introducing and incentivizing the use of hybrid and electric vehicles. The current transportation situation inthe City of Nablus is still mainly based on the use of conventional vehicles powered solely by an Internal Combustion Engines (ICE) that use gasoline (about 58.60%)or diesel (about 41.30%). There are several reasons for this trend including the lack of governmental tax incentives for electric/hybrid vehicles, absence of real investment in the needed infrastructure, as well as due to unpredictable political conditions. We assumed that if the government incentivized the public to replace ICE vehicles with hybrid and electric ones, the distribution of vehicles in the city by type will pick up the global trend between 2023 to 2035(Hassouna and Al-Sahili, 2020), which is also the case in nearby countries including Jordan (Shalalfeh, 2021).

The fuel consumption for the 13 representative road segments allowed estimating the potential savings in fuel consumption from 2023 to 2035. Figure 10 showsEVs and hybrid assumed trends in Nablus and potential saving in fuel consumption. We extracted the trends based on several reports and references including (Chen, 2022; Tung, 2020; MacDonald, 2016; BloombergNEF, 2021; Kapustin, 2020).On average, a 5.0% reduction on fuel consumption may be achieved every year. This percentage increases when considering that moreEV and hybrid vehicles will be used and when it is used on gentler road grades. It must be noticed that the maximum potential fuel savings will occur in 2035 with about 9.0%. Introducing EVs and hybrid vehicles leads to fuel consumption savings as well as to avoiding emissions. A potential reduction on fuel consumption may also be translated in avoided CO, NOx, and VOC emissions per year in the City of Nablus.From these results one may conclude thatthe high potential fuel savings found each year by introducing and incentivizing EVs and hybrid vehicles is indicative of the importance of directing the policymakers' attention towards adopting this policy in the near future.

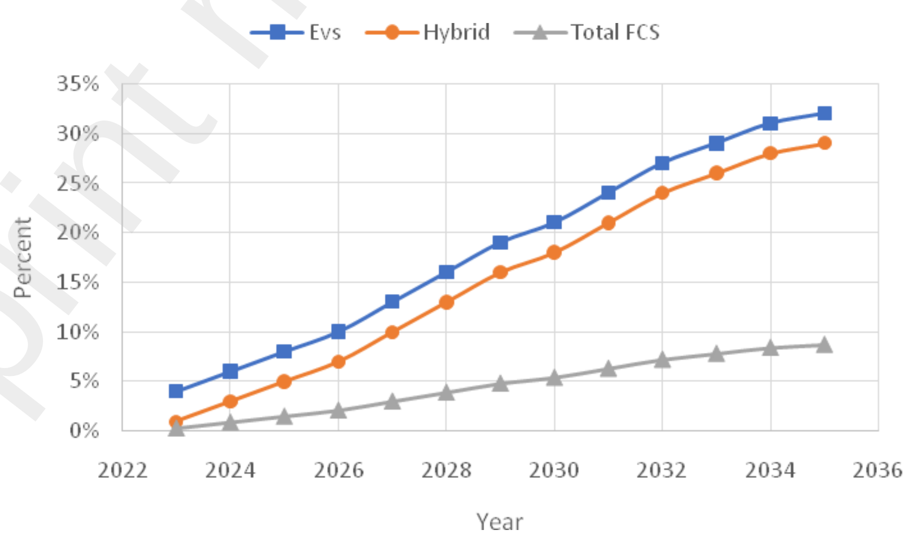

Figure 10. EVs and hybrid assumed trends in Nablus and potential saving in fuel consumption.

CONCLUSION

This study investigated the impact of delay, fuel consumption, and emissions in terms of CO, NOx, and VOC using Vissimsimulation for thirteen segments in Nablus city. The percentage of heavy-duty vehicles, queue, peak hour traffic volumes, length of uphill and downhill segments, grades, and fuel type (gasoline, diesel, hybrid, and electric) were used in the simulation process. Results revealed that the amount of delay, emissions, and fuel savings were directly proportional with increasing road grades. The average delay for the thirteen segments was about 35.5 sec considering current situation and 27.9 sec assuming no road grades. Regarding the average fuel consumption, 14.4 liters and 12.4 liters for the current conditions and assuming no grades, respectively. The average reduction in fuel consumption considering no grades was about 19%. However, the highest reduction percentage was in case of uphill section with about 37% which was illustrated by the strong correlation ($R^2 = 0.89$) as shown in equation (1).The average emissions (CO, NOx, and VOC) during the peak hours for the thirteen segments were about 264.1g, 51.4g, and 61.2g with grades, and 227.9g, 46.3g, and 52.8g, respectively assuming no grades.

The potential fuel consumption savings were assessed for the period from 2023 to 2035 by assuming a scenario where the policy makers adopt introducing and incentivizing the use of hybrid and electric vehicles. On average, a 5% of fuel reduction is expected to be achieved every year. The maximum potential fuel savings is expected in 2035 with about 9% by introducing hybrid and electric vehicles which in turn will contribute to minimize the gas emissions (CO, NOx, and VOC) in Nablus city.Finally, based on these results,we conclude that the high potential fuel savings found each year by introducing and incentivizing hybrid and electric vehicles is an indicator of the importance of directing policy makers attention towards adopting this policy in the near future.

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