

Pros and Cons of Self Driving Vans - A Real Life Motorway Case Study Analysis from Great Britain

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Case Report

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Abstract

Given the speculations that autonomous vehicles are sure to take over the transport sectors in the near future, this study micro-simulates the impacts of automating the vehicle VAN using the micro-simulation software AIMSUN in a hypothetical condition. This study analyses the impacts of automation of vans in different levels of automation penetrations with heterogeneous traffic conditions on traffic parameters such as speed and different environmental factors and should only be considered as a case approach with minimal application in the real-world scenario. In this study, the impacts of automation of van in different road characteristics were also analyzed in detail. The study highlights that with an increase in van automation penetrations, traffic parameters speed is positively impacted while negative impacts on environmental conditions are observed. This is mostly because multiple analysis should have been carried out to have a complete understanding of the network.

Background

Traffic congestion has always been an area of rigorous concern for both urban planners and traffic engineers as the development of various infrastructural facilities gets adversely impacted by them. With the wide technological innovations and advancements occurring in the present-day field of automated vehicles, these concerns are sure to skyrocket soon (Johnson and Walker. (2016)). The General Motors and Radio Corporation of America Sarnoff Laboratory first carried out and initiated the idea of autonomous vehicles in the 1950s (Pendleton et al. 2017; Shladover 2018). Wadud et al. (Zia Wadud, Mackenzie, and Leiby. (2016)) and Flamig (Flämig. (2016)) reported that shortly, private methods of transportation and shared taxi services of transportation will see a major boost in the domain of Automated Driving Systems (ADS) which is going to transform the way people move on the road. The considered main advantage of autonomous vehicles is that they can be used both as a private and as a commercial (taxi) vehicle (Heinrichs. (2016); Collingwoos. (2017); Z Wadud. (2017); Anderson et al. (2014); Brown, Gonder, and Repac. (2014); Alessandrini et al. (2015); Levine and Boyles. (2015); Harper et al. (2016); Maurer et al. (2016); Zia Wadud, Mackenzie, and Leiby. (2016); Chan. (2017); Z Wadud. (2017); Taiebat et al. (2018); Khan et al. (2019)). Users with mobility limitations such as the children, sick, elderly, etc. (Pettigrew, Cronin, and Norman. (2019); Kovacs, McLeod, and Curtis.(2020)) are forecasted to be highly benefited by vehicle automation. In general, AVs are expected to be cheap, reliable, comfortable and bring about more normalized flows, steady speed outline, reduction in accidents caused by human negligence, more uniform travel behavior, reduced travel time, time use benefits, etc. (Fagnant and Kockelman. (2015); Ambühl, Ciari, and Menendez. (2016); Milakas, van Arem, and van Wee. (2017); Benenson et al. (2008a); Godoy et al. (2015); Paden et al. (2016)). But these benefits that are going to be introduced by the automation of freight vehicles are forecasted to bring about higher levels of traffic congestion especially with the current road infrastructure and their behavior with the existing conventional vehicles (Harper et al. (2016); Metz ID (2018)).

This study looks into the impact of highly automated (Appendix A) freight VANs on travel time/delay, speed, and environmental impacts on an already existing motorway in the UK. The different levels of automation penetration (25%, 50%, 75%, and 100%) for vans with heterogeneous traffic conditions having conventional cars, vans, and trucks (belonging to 3 different types) are addressed in this study. Thus, the impact of higher levels of van automation when in co-existence with the conventional vehicles are analyzed with the introduction of automation penetration in different penetrations.

This study aims to reduce the gap that currently exists in the body of literature that discusses the impacts of highly automated vans on real road network conditions. This study analyses the impacts of higher levels of automated vans on speed and environmental factors in motorway driving. Thus, in this study, the M62 motorway which has a substantially-high percentage of vehicle movements is selected to analyze the impacts of automated vans with heterogeneous mixed traffic conditions. The selected stretch of M62 features a comparably flat section with a considerable climb vehicle flows which is kept to the current road network conditions using the information obtained from Highways England. Vans were provided with automated capabilities and penetrated at 25%, 50%, 75%, and 100% automation in the microsimulation software AIMSUN.

1.2 Research Objectives

The main objective of this study is to analyze the various impacts that high levels of automated vans have on an already existing motorway. The various objectives include understanding the

- the impact of high-level van automation on overall traffic parameters such as speed and time
- impacts of high-level van automation on environmental emission factors (Using London Emission Model) with respect to Carbon-Dioxide (CO₂), Nitrogen Oxide (NO_x), Particulate Matter (PM), and Volatile Organic Compound (VOC).

Methods And Materials

2.1 Scope of the Study

Even though there exists a surplus body of literature corresponding to the impacts of automated cars and other private vehicles (typically of SAE Levels – 1 and 2), the body of literature incorporating the impacts of highly automated freight vehicles especially vans with mixed traffic conditions on a real road network conditions are limited. Thus, in this study, the M62 motorway which has a substantially-high percentage of freight movements is selected to analyze the impacts of automated vans with heterogeneous mixed traffic conditions on delay/travel time, traffic speed and environmental emission aspects. This

study focuses on reducing the above-mentioned gap in the literature by analyzing the impact of higher levels of automated vans with heterogeneous traffic conditions on an existing motorway traffic flow information obtained from Highways England by the method of micro-simulation modeling.

2.2 Study Area

Motorways are the network of trunk roads administrated by Highways England in the United Kingdom (ICE (2020)). For the purpose of this study, the stretch of M62 motorway situated to just further Junction 22 towards westbound of Leeds (Junction 28) & towards Manchester was selected. M62 is one of the main stretches of trunk roads in the UK linking wider European networks via Rotterdam and Dublin also covering other prominent urban areas in England such as the Hull, Leeds, Bradford, Manchester, and Liverpool.

Motorways with sections of entry and exit ramps of M606 and M621 motorways were merged with M62. The flat section which is 73m above sea level from Leeds to Brighouse (Junction 25) increases to 230m above sea level at Pennines (Junction 22). Hence the impact of automation on normal, congested, and up-hill stretches can be analyzed from this selected motorway without having the need to run multiple motorway simulations. The leftmost lane is considered to be the slow lane in the UK and that the highest elevation observed in the motorway of England (372m) is observed at the selected stretch at the east of Junction 22.

Figure 1 shows the chosen stretch of motorway M62 for simulation using the micro-simulation software Aimsun. The merging of motorways M606 and M621 into M62 is shown in Figure 1. The varying levels of congestion that can be observed in the selected stretch of motorway allow analyzing the impact of different levels of automation of different vehicles in traffic flow. The uphill stretch located near Junction 22 allows observing the impacts of speed, delay, and environmental emission behavior of automated vans in the uphill portions.

2.3 Simulation Setup

2.3.1 Simulating Vehicle Behavior

For the purpose of simulation, traffic flow data was collected. Micro-simulation software Aimsun version 8.3 was used for simulation of automated and non-automated vehicles in the motorway stretch M62 (Figure 1). Given that there is only less available literature that co-operates higher levels of automated vans with other types of conventional vehicles, vehicle types belonging to the classification of vans were assumed to be automated in existing mixed traffic conditions in our simulation.

The entire stretch of M62 given in figure 1 was simulated in the micro-simulation software Aimsun. Details of junctions, their exits, and entries, was incorporated in Aimsun while simulating the motorway characteristics. The merging of the M606 and M621 with M62 is shown in figure 1

The classes of vehicles used in the simulation were classified according to the vehicle length as per the motorway count measurement system which is given in Table 1. Even though we have three types of trucks (light, rigid and articulated) as given in Table 1, the impacts of automation of vans are assumed to penetrate at a similar rate for all the three groups together mentioned as Trucks in our study. Traffic flow is measured for this classification of vehicle classes and each class was given automation capability in different levels of penetration in the simulation.

Table 1: Vehicle Classification

Vehicle Classes	Vehicle Length
Cars	<=5.2m
Vans	>5.2m and <=6.6m
Light Commercial Vehicles (light trucks)	>6.6m and <=11.6m
Large trucks: they are split into 50% rigid and 50% articulated	>11.6m

Aimsun's default parameters were applied for simulating the standard (non-automated) vehicles. Some minor adjustments were made in order to reflect UK specification regulations and to calibrate against the mean speed of different classes of vehicles at individual sections of the motorway. The mean speed limit of automated vans was increased when compared to conventional vans since automated vehicles are predicted to have higher speed profiles.

The behavior of automated van for the purpose of micro-simulation of traffic flow along the motorway is modeled as follows:

- For an automated van, the reaction time is lesser than the human reaction time
- Speed distribution of automated van is more uniform since non – uniformity in human behavior can be overcome through the automation of vehicles
- Standard Speed limits given is 100% followed
- London Emission Model in the micro-simulation software Aimsun is used to analyze the environmental impacts of automation

2.4 Modelled Scenarios

2.4.1 Van Automation at Different Penetrations at a Time

Analysis of automation penetration was made for the group of scenarios where only the vehicle classification van was automated for different penetration levels at a single time.

Table 2: Modelled Scenarios – Van Vehicle Classification Automated

SI	Vehicle Classification	Percentage of Automation Penetration				
		0%	25%	50%	75%	100%
2.4.1	Only Van	√	√	√	√	√

Here the vehicle classification “Van” is automated at different penetrations (0%, 25%, 50%, 75%, 100%) while the other vehicle types “Car” and “Truck” are kept non-automated throughout the study. In the above-mentioned, 0% of automation penetration indicates the current real-life traffic demand on the motorway M62 network with 100% conventional vehicles. The results from 0% automation penetrations were used as a baseline to compare and understand the impacts that further levels of automation penetration have on traffic parameters and various environmental emission factors in our study. Similarly, 25% automation of vans indicates that out of the considered 100% conventional vans, 25% of the total vehicle type vans are converted to autonomous vehicles and given higher automation capabilities in simulation while the rest 75% of the vehicle type remains non-automated. Thus, in this particular scenario, various analysis such as effects on overall traffic parameter (speed), environmental emission analysis is carried out while the vehicle type cars are automated at different penetrations, while the impact of automation of vans on non-automated vehicles are also analyzed in detail.

Results And Discussion

3.1 Introduction

The simulation results for the different scenarios are presented for smaller stretches of the motorway between two junctions in order to understand and identify the different vehicle behaviors and environmental impacts along different stretches. Stretch 27 - 26 (J27 - J26) is the heavily congested stretch, 26 - 25 (J26 - J25) is the moderately congested stretch, stretch 24 – 23 (J24 - J23) is the uphill stretch, and stretch 23 - 22 (J23 -J22) is the mild uphill stretch. Inferences on the impact of automation in different road geometry (uphill or not), traffic conditions (congested or not), and environmental factors were made without having the need to run different simulations for understanding the impact of automation in different road network characteristics.

3.2 General Analysis

The mean speed represented below in the figures is the average speeds of the vehicles that are taken into consideration for the simulation. Environmental emission factors such as Carbon-Dioxide (CO₂), Nitrogen Oxide (NO_x), Particulate Matter (PM), and Volatile Organic Compounds (VOC) was analyzed along the stretch of motorway. To determine and examine the different emission factors along the considered stretches, London Emission Model in the micro-simulation software Aimsun was used. With the increase in penetration of automated vehicles, hints of certain trends for the emission factors for different stretches of the motorway with almost similar property could be observed. For each scenario, it can be observed that the greatest emissions along M62 happen at the most congested stretch i.e. J27 – J26 as expected. Stretch 27 - 26 (J27 - J26) is the highly congested stretch due to the merging of M621 into M62 and stretch 26 - 25 (J26 - J25) is the moderately congested stretch due to the merging of M606 into M62, stretch 24 - 23 (J24 - J23) is the uphill stretch and stretch 23 - 22 (J23-J22) is the mild uphill stretch.

3.2.1 Analysis of Higher Level of Van Automation

Mean Speed.

Figure 2 represents the impact of different levels of automation penetration of vehicle type van on traffic speed on the motorway M62. The other vehicle types cars and trucks are kept non-automated throughout the stretch on M62. From the different subfigures shown in fig 2, improvements in mean speed for the vehicle type van can be observed as the automation penetration increase i.e. as more and more vans are automated, the mean speeds of vehicle type van also increase. Noticeably, as more and more vans are automated, it can be observed that the mean speed of non-automated vehicles also positively being impacted by the increase in automation penetration, although this increase is negligible. Overall, van vehicle automation improves the travel speed of vehicle type van and does not have any adverse impacts on the speeds of other vehicles.

With respect to the increase in automation penetration, there is some observational hint of non-linearity in the improvements in the mean speed of vans. In normal conditions, it can be observed that the improvements at higher automation penetration are greater than the speed increases at lower automation penetration. In congested situations, as in J27 - J26 and J26 - J25 (Figures 2a and 2b), this non-linearity becomes more prominent at an earlier level of penetration.

From fig 2, it can be noted that the largest benefits in terms of greater mean speeds are observed in congested situations (fig 3b). The congested stretch J27 – J26 falls just after the merging of the two motorways M621 and M606 with the M62. An increase of 14.7% in mean speed of vehicle type van is observed when all of them become automated compared to none of them being automated i.e. 0% automation. Noticeably, this substantial increase in mean speed of vans also improves the mean speed of cars and trucks in congested stretches by 16.8% and 13.2% respectively. It can be noted that just for congested stretches, the vehicle type cars are more benefitted with respect to mean speed when vans are automated. This might be possibly due to the less amount of conflicts between the vehicles due to automation and the higher amount of the vehicle type car along the stretch. Since the stretch J27 – J26 lies between 2 other motorways merging at both ends (M621 and M601), this stretch also has substantial weaving traffic. In comparison, only less than 4% improvement for cars and trucks with respect to mean speed can be observed along the normal stretches of the considered motorway whereas a minimum of 7% increase in mean speeds for the vehicle type vans is observed along the stretch of the motorway. From fig 2e and 2f it can be observed that even along uphill stretches the mean speed of the vehicle type van gets benefited without any negative impact on the mean speed of other non-automated vehicle types.

Environmental Emission

Figure 3,4, 5, 6 represents the total emission concentration of the stretches when vans are automated on the simulated stretch M62. From stretches, where possible, inferences on the impact of automation with respect to environmental emission in different road geometry (uphill or not) and traffic conditions (congested or not) were made.

For different stretches of the motorway with almost similar property, hints of certain trends for the emission factors could be observed along with the penetration of automated vans. For congested, normal, and uphill stretches along with the motorway, it can be observed that 100% penetration of automated vans emitted the greatest emission and controversially, 0% penetration of automated vans emitted the least emission for congested, uphill and normal stretches. This might be possible because of the share of the percentage of vehicle mix of vans in the traffic demand. Due to fewer percentage of vehicle type van along the motorway, automation of vans might create road traffic confusions to conventional vehicles resulting in more frequent accelerations, decelerations and braking, resulting in more emission of environmental factors. It can be observed that the greatest emission along M62 happens at the most congested stretch i.e. J27 – J26 as expected. The general trend observed for environmental emission along van automation penetration is mentioned in Table 3.

Table 3: Emission trends along the stretch when vehicle type VANs are automated

Stretch	Decreasing level of emission (London Emission model) with respect to the level of VAN automation penetration				
Characteristic	Decreasing Level of Emission				
Congested Stretch	100%	75%	25%	50%	0%
	(Greatest)				(Lowest)
Uphill Stretch	100%	75%	25%	50%	0%
(Stretch with slope)	(Greatest)				(Lowest)
Flat Stretch	100%	75%	25%	50%	0%
	(Greatest)				(Lowest)

From the above analysis, the stretch with the maximum congestion (J26- J27) was observed to be the stretch that emits the greatest emission along the motorway and non-uniformity in emission analysis in almost all kinds of stretches were observed. This study highlights that the automation of vans increases the mean speed of travel taken to traverse different stretches of the motorway as observed from section 3.2.1. However, the environmental emission analysis indicates a significant rise in emission values for almost all of the considered scenarios. A possible conclusion about the negative impacts of emitted environmental emission factors is that as lower levels of automated vans are introduced into the existing heterogeneous traffic demand, initial confusions in mixed traffic behaviors within vehicles are developed. This confusion in traffic behavior are developed as a result of the difference between the reaction time, speed profile and speed acceptance characteristics of autonomous and non-autonomous vehicles along with the motorway. This results in non-uniform traffic flows. These initial levels of confusions are expected to reach greater levels as the total percentage of automated vans reaches greater occupancy levels in the motorway, as there still exist a prominent amount of conventional trucks and private cars compared to automated vans in the motorway traffic. This can lead to an increase in difference of vehicle behavior resulting in more amount of frequent accelerations and braking. These conflicts are identified by the non-

uniformity in the emission levels represented through figures 3,4,5 & 6 The study highlights that when all of the vehicles along the motorway are automated, such conflicts will be reduced and benefits for environmental emissions can be observed in a significant amount which is represented in figure 6.

When all the vehicles are automated, it can be noted that for the total stretch from Junction 22 to Junction 28 for a distance of approx. 37 km along M62, 100% automation of vehicles (total emissions of all vehicle type considered together) gives the least value of emission for all the considered environmental factors.

Conclusion

4.1 Summary

Micro-

simulation software Aimsun was used for the simulation purpose of various modeled scenarios described in this research. This study has shown that speed is

4.1.1 Traffic Parameter Analysis

- Traffic flow was found to improve with the increase in levels of van automation. Automation of vans in different penetrations along with the motorway ber
- No negative impacts on the mean speed was observed from the different levels of
- Congested stretch and Up-hill stretches are the most benefited from vehicle automation concerning speed and time..

4.1.2 Environmental Emission Analysis

- This study highlight that introducing higher levels of van automation into existing heterogenous motorway traffic leads to increase in vehicle emission. This study hypothesizes that this is probably because multiple analysis and simulations shuld be conducted inorder to get a proper average result.
- The study hypothesizes that the complete benefits of autonomous vehicles can only be observed after every vehicle class are automated with higher levels of autonomous capabilities.
- Carbon-dioxide emission appears to be the most significant environmental emission factor and Particulate Matter the least. Thus, stating that, negative impacts of environmental emissions through van automation can possibly lead to increase in global warming by significant amounts.
- It was observed that greater slope results in greater emission values of environmental factors irrespective of the length of the considered stretch. (It was observed that the stretch with the greatest slope (J24 – J23) of length 2250m (approx.) emits higher values of emission factors than the stretch with mild slope (J23 – J22) of 11200m (approx.). Suggesting that the rate of the slope of the considered stretch can lead to higher negative impacts on emission factors rather than the length of the stretch).
- Particulate Matter emissions are observed to be the highest in congested stretches suggesting that major portions of the Particulate Matter emissions occur from frequent tyre and brake wears resulting from the non-uniform flow of traffic (leading to frequent acceleration and braking) and not just from vehicle exhausts.

Thus, from the overall analysis of the microsimulation conducted along motorway M62, it can be concluded that higher level van automation favors different traffic parameters along the motorway in a positive manner. Importantly, the conclusions that no negative impacts have been analysed on the traffic parameters for automation of vehicles in any of the simulated scenarios and that individual automation of vehicles benefits speed with negative impacts on the environmental emission factors are of significant importance.

4.2 Research Limitations and Future Research Recommendations

- Demand- For the purpose of this study, a conscious decision was made to not include any potential demand implications of any vehicle class automation that might occur due to the relative changes in the price of automated vehicle transport. How the demand of autonomous vehicles might impact the total traffic flow of road networks are still under studies, thus these changes that might occur in traffic demand due to automation can be included in the future works once everything is precise and clear.
- Van Automation – only van was assumed to be automated with higher levels of capabilities. Different impact analyses with other vehicle types can be worked in future and the results found could be compared.
- Single Motorway - This study analyzes the impact of vehicle automation in motorway M62 in the UK with different road characteristics between junctions, more motorways can be simulated in the future and the results found could be compared.
- Emission- London Emission Model was used to analyze the environmental impacts of vehicle automation along the motorway, in the future more environmental model analysis could be carried forward with multiple simulations. The emission analysis carried in this study analyzes the total emission impacts from all vehicle classes along the considered motorway. If needed individual vehicle emission analysis from the same motorway could be done in the future.

Declarations

Data Availability Statement

Some or all data, models, or code generated or used during the study are proprietary or confidential in nature and may only be provided with restrictions

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Figures

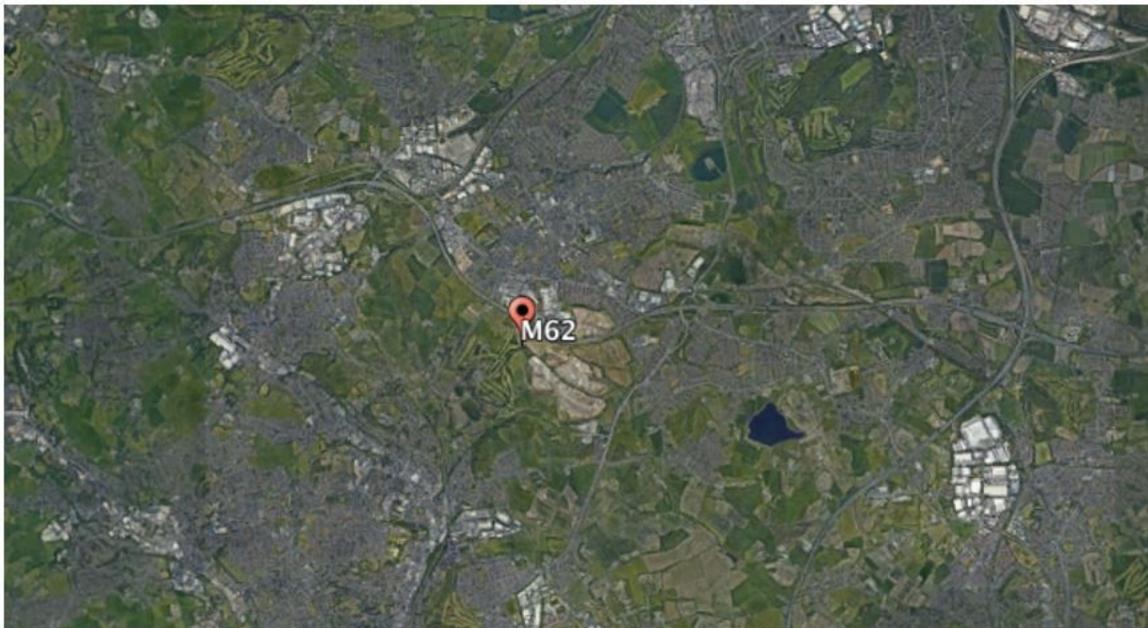


Figure 1

M62 Motorway (Study Area) Note: *Source - From Micro-simulation conducted in AIMSUN by the author

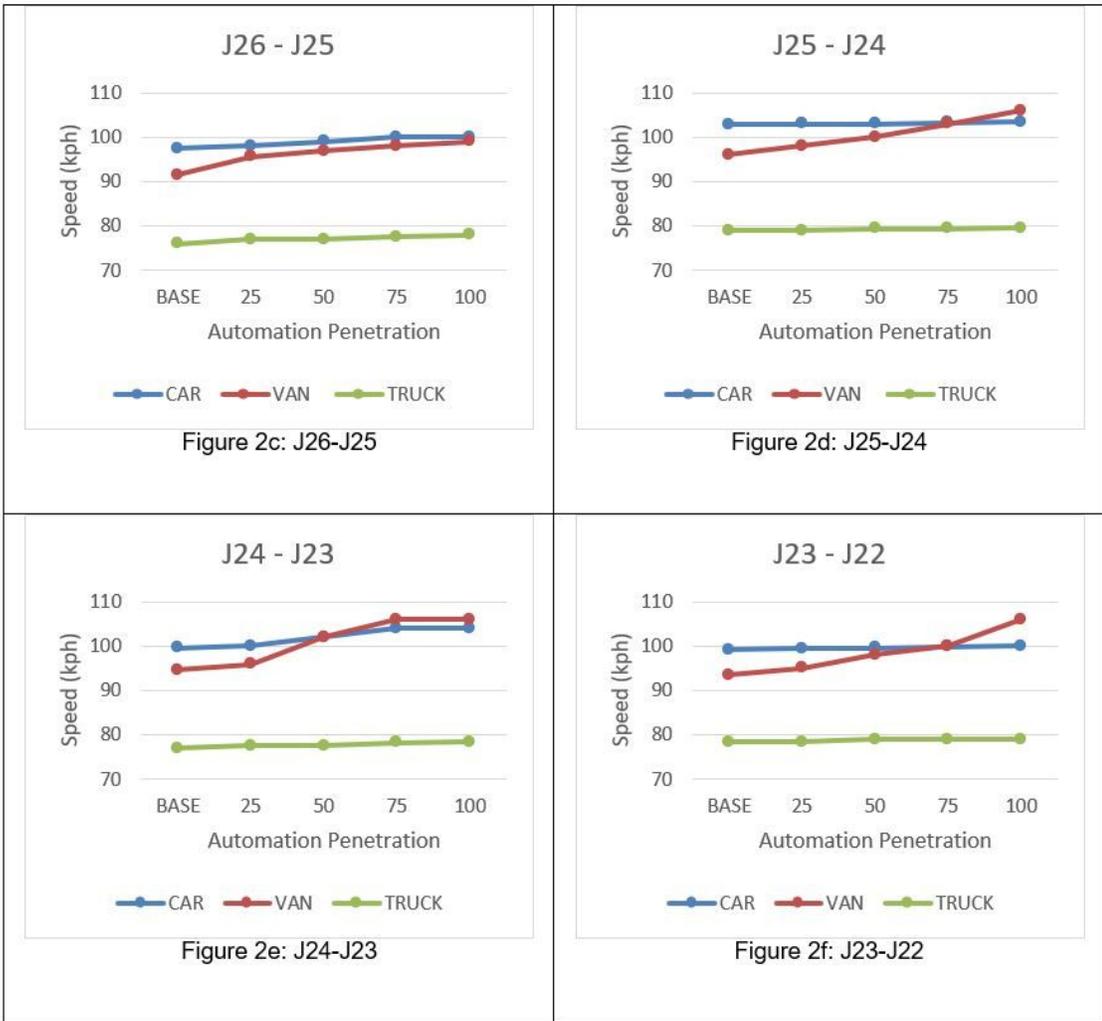


Figure 2

Effects of VAN automation on mean speed of different vehicle types along M62

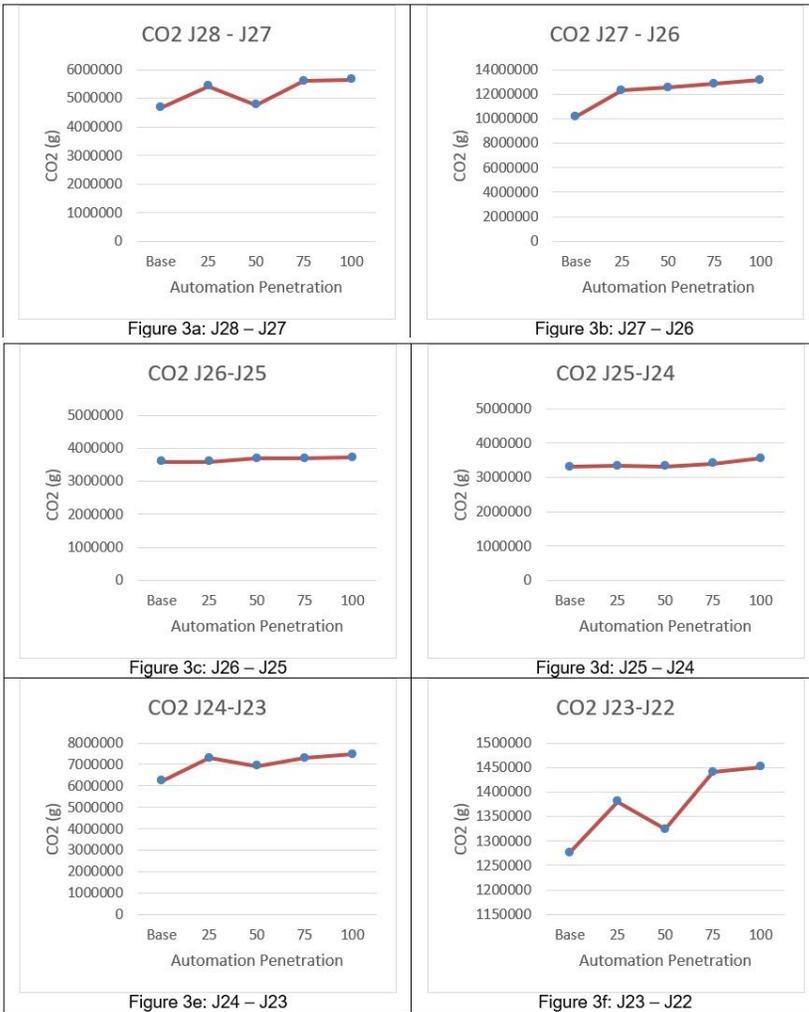


Figure 3

Effects of VAN automation on total carbon-dioxide emission along M62

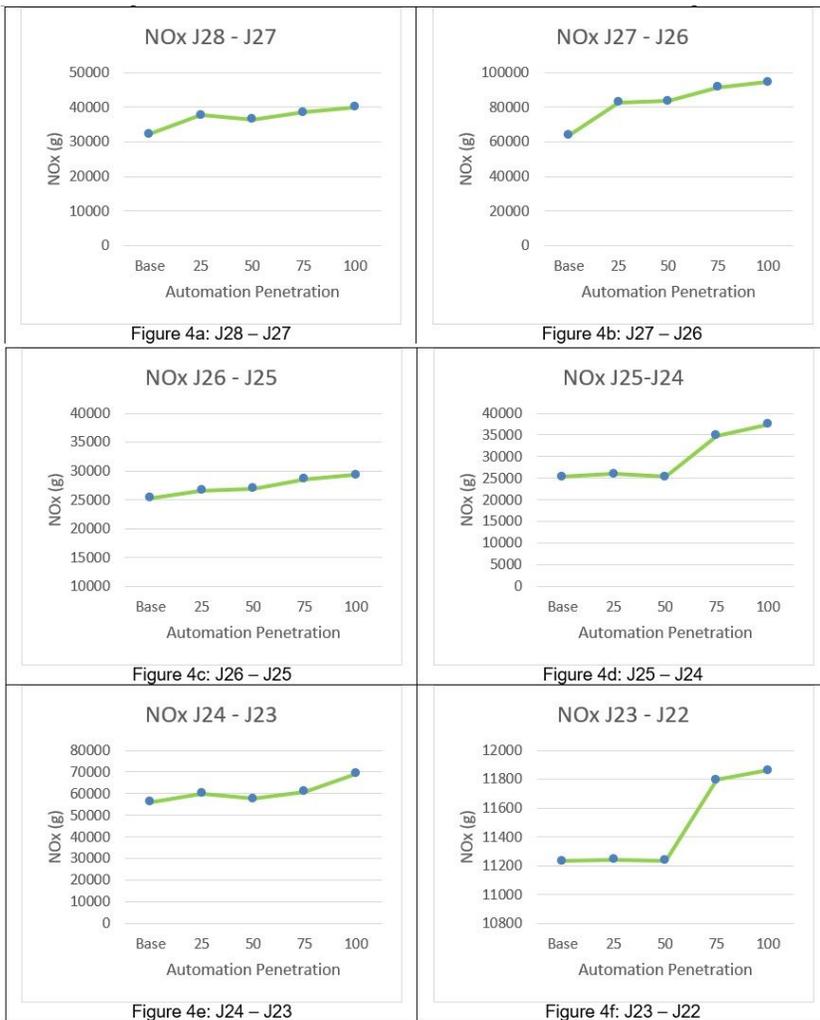


Figure 4

Effects of VAN automation on total Nitrogen-Oxide emission along M62

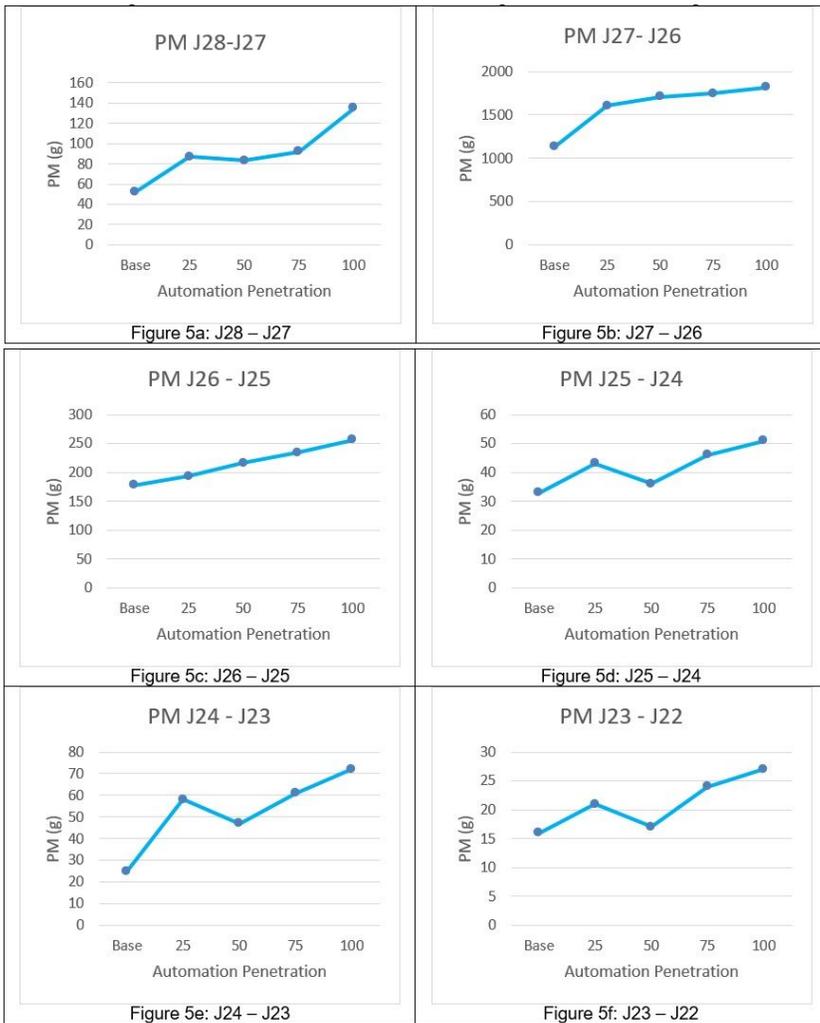


Figure 5

Effects of VAN automation on total Particulate Matter emission along M62

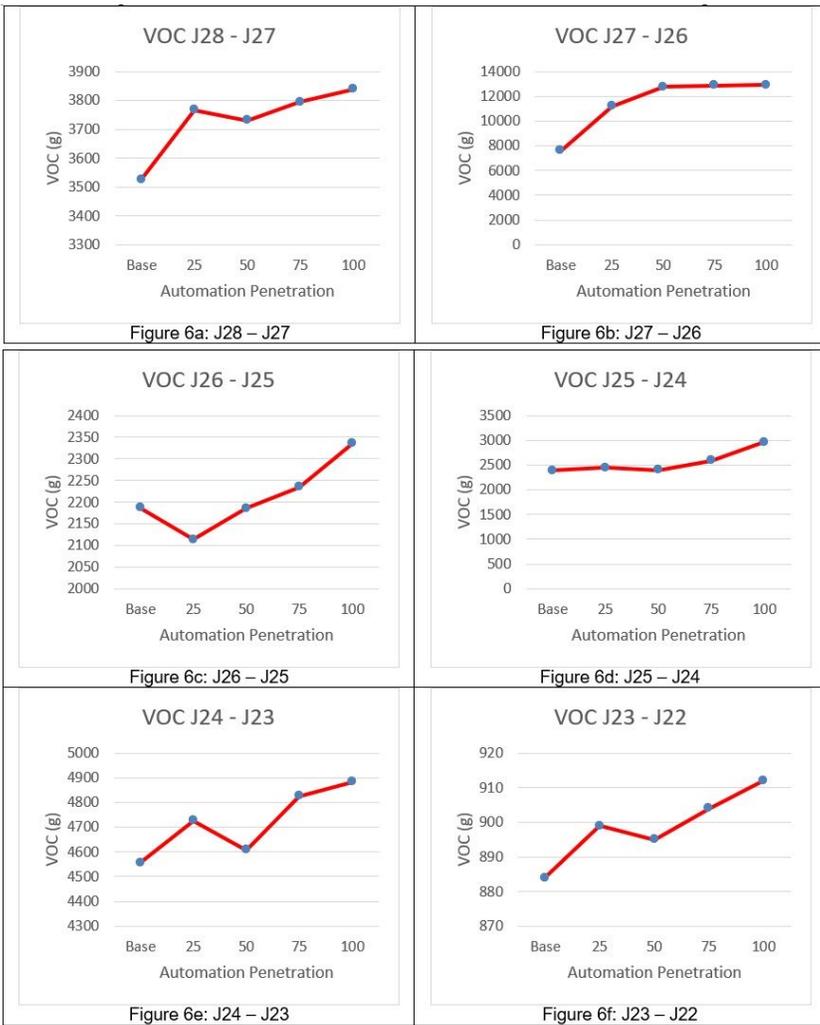


Figure 6

Effects of VAN automation on total VOC emission along M62

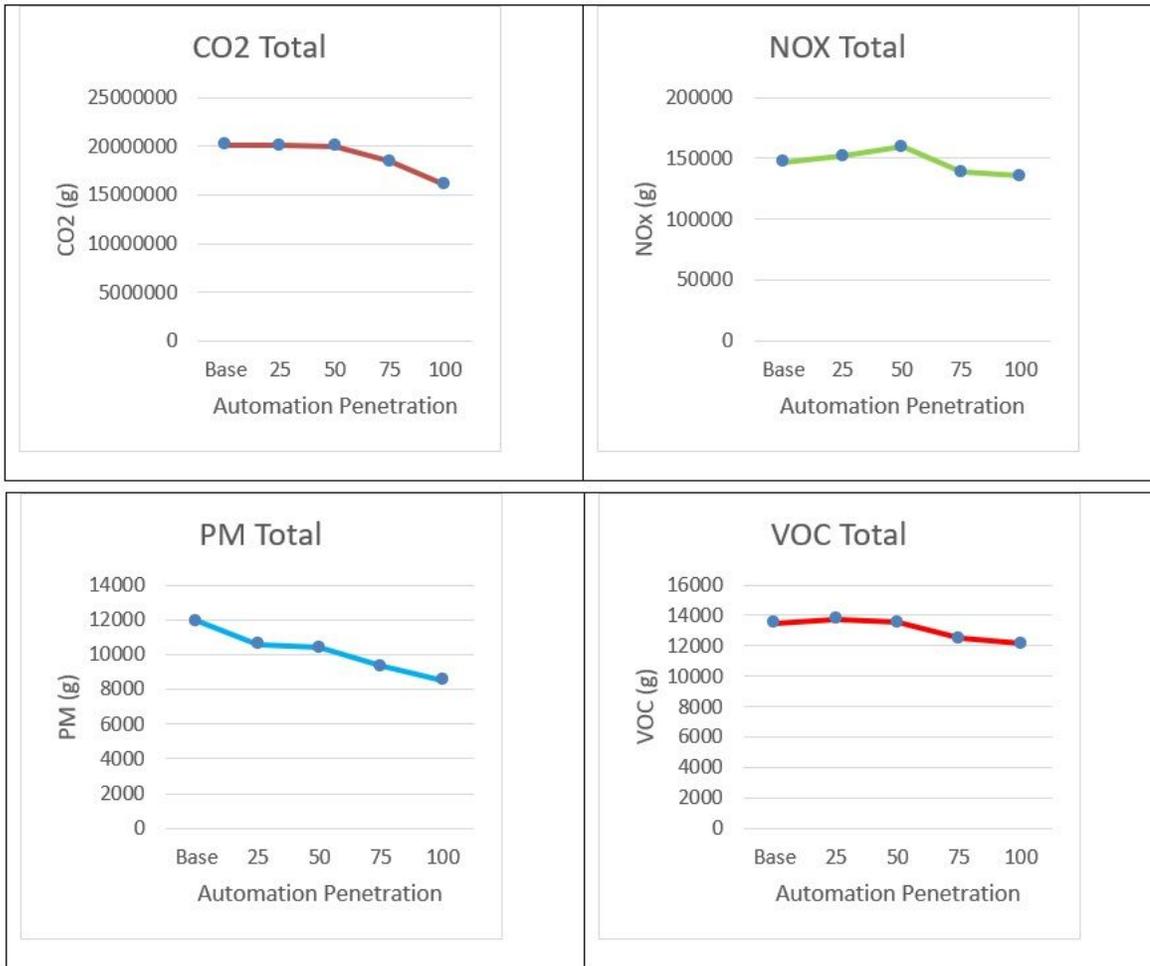


Figure 7

Effects of ALL vehicle automation on Environmental Emission Factors for the motorway M62 (J22 – J28)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [AppendixA.docx](#)