AUT Journal of Civil Engineering

AUT J. Civil Eng., 4(2) (2020) 165-174
DOI: 10.22060/ajce.2019.15779.5551

Evaluating the effect of truck size on the amount of Air pollutants emission due to consumption fuel

A. Mansoori[1], Gh. Nabi Bid hendi[2,*], M.j. Amiri[2], H. Hoveidi[2]

[1] Graduate of PhD in Environmental Engineering Kish international Campus, University of Tehran, Kish, Iran
[2] School of Environment, College of Engineering, University of Tehran, Tehran, Iran

ABSTRACT: Easy access, door-to-door nature of service, and the existence of a sophisticated road network are the merits that guarantee the status of road transport as the dominant mode of transportation. However, the complete reliance of road transport on fossil fuels makes it a major source of emission and environmental damage. It is widely believed that the size of a freight truck has an impact on the emission generation, and when loaded to maximum capacity, larger trucks are more efficient than smaller ones. The present paper reexamined the effect of truck size on the fuel consumption and the resulting emission. The results show that, contrary to common belief, larger trucks are not more efficient and do not have a lower fuel consumption and emission per unit of net transported cargo. This misconception originates from the mistake of calculating the truck's maximum load capacity based on its axle capacities regardless of the maximum load that each axle can apply to the road pavement. When the axle capacity is greater than the equivalent capacity of the road, the difference will have a damaging impact on the road pavement. The magnitude of this damage will progressively increase with the degree of violation of standard equivalent 18-kip single-axle load criteria. This damage results in deformation and settlement in the surface pavement, which leads to reduced road safety and service level. Hence, the maximum load capacity of a truck is limited by the equivalent capacity of the road it traverses. From this perspective, the size of the truck does not have a significant impact on the amount of emission that will be produced for transporting a certain amount of cargo.

Review History:

Received: 2019-02-05
Revised: 2019-05-14
Accepted: 2019-07-02
Available Online: 2019-07-02

Keywords:

Transportation,
Emission,
Fuel consumption,
Truck size,
Equivalent load

INTRODUCTION

The transportation sector is one of the main causes of air pollution and climate change, and directly and indirectly affects the lives of many humans and animals. The direct environmental impacts of transportation include the pollution resulting from fuel consumption, environmental degradation due to the expansion of road infrastructure, and changes in the ground's reflection coefficient because of pavements such as concrete and asphalt. This sector also damages the environment indirectly through the pollution released during fuel production (from refineries) and during the production of infrastructure building materials (from cement factories, asphalt concrete production, bitumen refineries, etc.). Transportation accounts for 28% of total energy consumption in the United States (Wang and Rakha 2017) and about the same amount in Iran. (Sarabi 2011). Although there are several modes of transportation including road, rail, and marine, the dominant mode of transportation, which constitutes more than 80% of total demand, is the road transport (Hakimelahi, Rao et al. 2016). This noticeably higher demand for road transport can be attributed to factors such as convenient access, the existence of an already sophisticated road network, and door-to-door nature of this mode of transport. According to studies, road transport is the source of 20% of total greenhouse gas (GHG) emission in Europe (Zimmer and Koch 2017). Compared to other modes of transportation, road transport is the cause of more negative impacts including air pollution, accidents, noise, and climate change due to GHG emission (Newbery 1990, Parry 2007, Small, Verhoef et al. 2007) . The rate of emission generation due to road transport depends not only on the type of fuel but also other factors that influence the rate of fuel consumption, such as vehicle weight and geometric design of the road, particularly its longitudinal slope (Tavares, Zsigraiova et al. 2008). Another important factor is the engine technology. The higher is the engine's fuel consumption per kilowatt-hour of work, the lower is the fuel consumption and the consequent emission. Another important factor in regard to fuel consumption and emission is the shape and aerodynamic features of the vehicle. Research has shown that a 21% reduction in aerodynamic drag of trucks reduces their fuel consumption by 4 liters per 100 km (Chilbule, Upadhyay et al. 2014) . It has been shown that extensions such as trailer and side mirror and the gap between tractor and trailer may also affect the aerodynamic drag (Chowdhury, Loganathan et al. 2017, Salati, Schito et al. 2017) . Another factor involved in fuel consumption is the driving behavior (Walnum and Simonsen 2015), i.e. how

*Corresponding author's email: mjamiri@ut.ac.ir

the driver accelerates and deaccelerates the vehicle (Díaz-Ramirez, Giraldo-Peralta et al. 2017). Since vehicle's contact with the road surface is via tier, which heavily influences the rolling resistance, improving the tier-road interactions may also reduce the fuel consumption and its environmental impacts (Ziyadi, Ozer et al. 2018). The proper choice of the route based on road geometry and traffic load can also reduce the amount of emission to be released during a travel. The routing schemes of many of the existing fleet management systems are based on travel distance minimization, which does not necessarily mean the minimization of fuel consumption or GHG emission especially when the route has traffic congestion or passes through sloping areas (Scora, Boriboonsomsin et al. 2015) . Hence, the problem of finding the route that minimizes the fleet's GHG emission, or the so-called green routing problem, has become a major subject of routing literature (Turkensteen 2017). Trucks, as critical components of road transport, are among the largest consumers of fuel and biggest sources of GHG emission (Scora, Boriboonsomsin et al. 2015). Thus, investigating the effects of these vehicles can benefit the efforts to address the environmental impacts of transport. In this study, we examine the effect of truck size on fuel consumption and the resulting GHG emission. Since all trucks are powered by diesel engines, we use the diesel engine and diesel fuel specifications provided by truck manufacturers to estimate the fuel consumption and GHG emission based on road slope, rolling resistance, wind speed, truck speed, and drag force. Since the objective is to assess the impact of truck size on fuel consumption and GHG emissions and other conditions should be uniform, the impacts of route properties and driver behavior are ignored. Considering that the fuel consumption of engine may slightly vary with the manufacturer, the research is focused on a single manufacturer to ensure a fair comparison. It should be noted that past studies on this subject have shown that, when fully loaded, larger trucks are more energy efficient than smaller trucks, and the larger is the truck size, the lower is the number of travels (McKinnon 2003, Odhams, Roebuck et al. 2010, Woodrooffe, Glaeser et al. 2010, Kim, Wiegmans et al. 2016).

MATERIALS & METHODS

According to Newton's laws, each action causes an equal reaction in the opposite direction. Accordingly, the thrust force needed for a truck to move forward can be determined by calculating the resistance forces that act against its movement. The performance of a road vehicle depends on the vehicle and environmental conditions. Here, the vehicle condition refers to the vehicle shape and extensions that affect its drag coefficient. The load size, type of tire, and vehicle speed are also important in this regard. The environmental conditions refer to the road slope and geometric design, pavement type and material, ambient temperature and pressure, and wind speed. The mentioned factors generate a series of forces and moments that need to be overcome by the engine's propulsion power. Equation 1 can be used to calculate the thrust force required for this task. This equation consists of three parts. The first part is the effective drag formula; the second part, which consists of two separate parts, calculates the rolling resistance due to tire-road contact; and the third part calculates the road slope, as the most important geometric characteristic of the road.

$$P_e = \frac{1}{2}\rho C_d A_f (V_r \mp V_w)^3 + mgV_r\left(f_r \mp \sin\propto\right) \quad (1)$$

Where:

ρ: Mass density of air (kg/cm^3), A_f :Vehicle's frontal projected area (m^2), V_r :Vehicle's relative speed (m/s), Cd : Aerodynamic resistance coefficient, W_w: Wind speed (m/s), m: Vehicle weight (kg), f_r: Rolling resistance coefficient, α: Road slope (degree) and g: Gravitational acceleration (m/s^2)

Ambient temperature and pressure of the area can also affect the magnitude of thrust force required for movement. In Equation 1, these parameters are included in the form of the mass density of air. Air density under various environmental conditions in terms of temperature, pressure, and humidity can be calculated using Equation 2. Since air density varies with temperatures and height, the drag force and consequently the required thrust force both vary with the vehicle location.

$$\rho = 1.225\left[\frac{P_r}{101.325}\right]\left[\frac{288.16}{273.16+T_r}\right] \quad (2)$$

Where:

P_r : Atmospheric pressure (in kilopascals) and T_r: Temperature (in degrees Celsius)

In Equation 1, the sign of V_w depends on the wind direction relative to the direction of movement; if the vehicle is moving against the wind, its speeds should be summed with the wind speed, otherwise, the wind speed should be deducted. Vehicle's frontal projected area can be calculated using Equation 3.

$$A_f = 0.80\, B \cdot H \quad (3)$$

Where:

B: Width of the vehicle body (in meters) and H: Height of the vehicle body (in meters)

Depending on the shape, extensions such as windshields can significantly alter the drag coefficient. In Fig. 1, these changes are plotted as a percentage of the drag coefficient of the original vehicle (Welfers, Ginsberg et al. 2011) . The values plotted in this figure are the results of wind tunnel experiments conducted on real size vehicles and downscaled models. These experimental results can be used to estimate the drag coefficient of an arbitrary vehicle. In this study, the drag coefficients are assumed to be the values given in Fig. 2 (Welfers, Ginsberg et al. 2011).

In Equation 1, $\sin\propto$ has a positive sign in uphill roads, where the road slope increases the required thrust force, and has a negative sign in downhill roads, where the gravity decreases the required thrust force. The rolling resistance coefficient f_r is a dimensionless number expressing the

Fig.1. effect of extensions on drag coefficient (Welfers, Ginsberg et al. 2011)

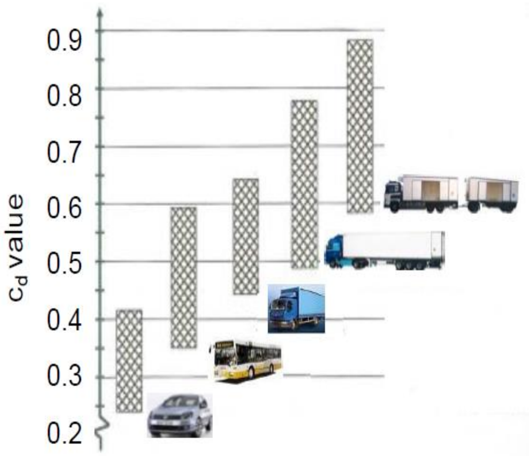

Fig.2. Drag coefficient of different vehicles (Welfers, Ginsberg et al. 2011)

complex interactions of the tire with the road surface. The factors affecting the roll resistance are tire temperature, tire pressure or load, vehicle speed, tire material and design, and tire slip. Given the complexity of relations between the mentioned factors, several researchers have attempted to provide a formulation for calculating the rolling resistance. In this study, we use the formula proposed by the University of Michigan Transportation Research Institute for estimating the rolling resistance of radial and bias-ply tires for heavy-duty trucks.

$$f_r = \left(0.0041 + 0.000041\frac{V}{1.60934}\right)C_h \; Radial\,Tire \tag{4}$$

$$f_r = \left(0.0066 + 0.000046\frac{V}{1.60934}\right)C_h \quad Bias\,Tire \tag{5}$$

Where:

V: Speed (Km/hr) and C_h : Road surface coefficient

The rolling resistance is lowest when the road surface has a dry, hard and smooth surface and can be twice as much when the road surface is worn. In wet surfaces, the low temperature decreases the tire flexibility, thus increasing the rolling resistance.

Since the specific fuel consumption depends on the engine RPM, it is calculated using Equation 6. Engine RPM is one of the factors that depend on driver's acceleration and deceleration behavior. Since the comparisons of this study are focused on truck size, and driver conditions are assumed to be uniform, we use the optimal engine RPM, i.e. the RPM at which fuel consumption is minimum.

$$n = \frac{30 \cdot I_D \cdot I \,.\, v}{\pi \cdot R} \tag{6}$$

Where:

Table 1. Road surface coefficient C_h (Gillespie 1997)

Road surface	C_h
smooth concrete	1
worn concrete, brick, stone, and cold mix asphalt	1.2
hot mix asphalt	1.5

n: Angular speed of the engine (in revolutions per minute), ID: Differential ratio, I: Gear ratio and v: Vehicle speed (m/s)

A portion of the thrust force obtained from Equation1 will be consumed by the engine's internal mechanisms (to generate heat and overcome friction). Therefore, Equation 7 can be used to calculate the required thrust force based on the engine efficiency.

$$P = \frac{P_e}{\eta} \tag{7}$$

Where:

η: Efficiency of the diesel engine (varies between 0.80 and 0.90)

The engine power and RPM to be used for fuel consumption calculation can be obtained using the algorithm given in Fig. 3.

After obtaining the required engine power and RPM from the algorithm Fig. 3, Equation 8 can be used to calculate the fuel consumption (or emission) based on the specific fuel consumption (or emission). Since U_S (the specific fuel consumption or emission) is constant and, as indicated in Equation 8, fuel consumption and emission both depend on the required thrust force, any result deduced from the comparison of thrust force can be extended to the fuel consumption and emission.

$$F_C = \frac{L}{V} \cdot P \cdot U_S \tag{8}$$

Where:

F_C: Fuel consumption or emission pollutant (in grams), V:

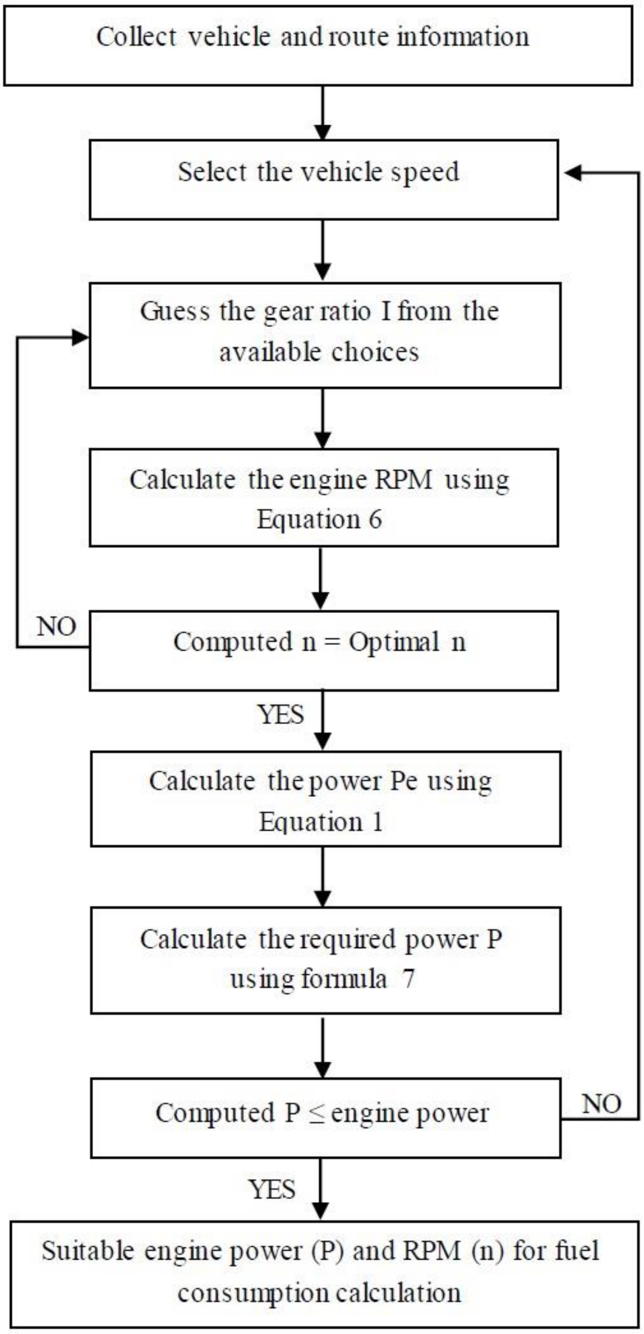

Fig.3. algorithm of calculation of required engine power and RPM

Speed (km/hr), L: Route length (km), P: Output power (kw) and U_s : Specific fuel consumption or emission pollutant (in grams per kilowatt-hour).

RESULTS & DISCUSSION

To compare the impact of truck size on the GHG emission due to fuel consumption, we examined five commonly used trucks with different load capacities. Considering the comparative nature of this research, all trucks were selected from the same company. Calculations were performed based on two scenarios for vehicles speeds of 0-100 km/h. Since the purpose of the study is to compare the impact of truck size on fuel consumption and emission, all calculations were performed with other route and environmental conditions including wind speed, altitude, temperature, surface type, and slope considered constant. The drag coefficients of trucks were computed based on the experimental (wind tunnel) results available in the literature and the standard specifications of the vehicles. The weights of trucks were calculated in two scenarios using the specifications provided by the Benz company (Table 2). The differential and gear ratios were obtained from the catalogs provided by the selected manufacturer (Table 3). Table 4 shows the allowed emission of the engine according to the engine emission standard.

Table 2. Specifications of freight trucks (Mercedes-benz 2018)

Description	Truck	Truck	Truck	Truck	2-axle tractor
	11 tons	12.5 tons	18 tons	34 tons	60 tons
Engine power (Kw)	130	130	205	235	425
Engine type	OM904LA	OM 904 LA	OM 906 LA	OM 501 LA	OM 502 LA
Number of cylinders	4	4	6	6	6
Engine technology	EURO 3	EURO 3	EURO 3	EURO 3	EURO 3
Truck weight*	4.1	4.85	5.3	10.39	20.8
Front axle capacity	4	4.7	7	8	8
Rear axle capacity	7.1	7.7	11	26	26
Trailer axle capacity	0	0	0	0	26
Total axle load capacity	11.1	12.4	18	34	60
Number of axles	2	2	2	3	5
Total road load capacity	11.1	12.4	15.2	24.4	40.8
Net axial load	7	7.55	12.7	23.61	39.2
Net road load	7	7.55	9.9	14.01	20
Width	2.05	2.1	2.36	2.5	2.5
Cab height	2.35	2.9	2.77	3.31	3.31
Height of cargo compartment	3	3	3.5	4	4
Drag coefficient	0.6	0.6	0.65	0.65	0.705

*includes the weight of chassis, cargo compartment, and empty container (when used as trailer)

Table 3. Specifications of the gearbox of freight trucks (Mercedes-benz 2018)

Description		Truck	Truck	Truck	Truck	2-axle tractor
		11 tons	12.5 tons	18 tons	34 tons	60 tons
Differential ratio		3.909	4.3	3.583	4.333	4.143
Gear ratio	1	6.291	9.2	9.478	14.93	14.93
Gear ratio	2	3.475	5.23	6.635	9.02	9.02
Gear ratio	3	2.095	3.15	4.821	7.03	7.03
Gear ratio	4	1.383	2.03	3.667	5.45	5.45
Gear ratio	5	1	1.37	2.585	4.4	4.4
Gear ratio	6	0.786	1	1.81	3.41	3.41
Gear ratio	7			1.315	2.65	2.65
Gear ratio	8			1	2.05	2.05
Gear ratio	9			0.75	1.6	1.6
Gear ratio	10				1.24	1.24
Gear ratio	11				1	1
Gear ratio	12				0.78	0.78

Table 4. Emission of diesel engines based on EURO technology

Norme antipollution (g/kw.hr)	Euro 3	Euro 4	Euro 5
Oxyde d'azote	5.00	3.50	2.00
Monoxyde de carbone	2.10	1.50	1.50
Hydrocarbures	0.66	0.46	0.46
Particules	0.10	0.02	0.02

Table 5. equivalent load for road pavement design according to ASHTO (Yoder and Witczak 1975)

Axle Load	Structural Number , SN					
(Kips)	1	2	3	4	5	6
2	0.0004	0.0004	0.0003	0.0002	0.0002	0.0002
4	0.003	0.004	0.004	0.004	0.003	0.002
6	0.01	0.02	0.02	0.01	0.01	0.01
8	0.03	0.05	0.05	0.04	0.03	0.03
10	0.08	0.10	0.12	0.10	0.09	0.08
12	0.17	0.20	0.23	0.21	0.19	0.18
14	0.33	0.36	0.40	0.39	0.36	0.34
16	0.59	0.61	0.65	0.65	0.62	0.61
18	1.00	1.00	1.00	1.00	1.00	1.00
20	2.61	1.57	1.49	1.47	1.51	1.55
22	2.48	2.38	2.17	2.09	2.18	2.30
24	3.69	3.49	3.09	2.89	3.03	3.27
26	5.33	4.99	4.31	3.91	4.09	4.48
28	7.49	6.98	5.90	5.21	5.39	5.98
30	10.31	9.55	7.94	6.83	6.97	7.79
32	13.90	12.82	10.52	8.85	8.88	9.95
34	18.41	16.94	13.74	11.34	11.18	12.51
36	24.02	22.04	17.73	14.38	13.93	15.50
38	30.90	28.30	22.61	18.06	17.20	18.98
40	39.26	35.89	28.51	22.50	21.08	23.04

To compare the impact of truck sizes on fuel consumption and emission, it is necessary to determine the maximum load capacity of the truck. This capacity can be determined in two scenarios. The first scenario is to use the load capacity of each axle based on the specifications given by the manufacturer. This capacity is the sum of capacities given for front, rear, and trailer axles in Table 2. In this table, this capacity is also given as the total axle load capacity. The second scenario is to use the capacity of the road pavement. During the design of load-bearing capacity of road pavements, it is required that the load applied by a single axle of vehicle do not exceed the equivalent of 18 kiloponds. The reason for this limitation is shown in Table 5. As shown in Table 5, the damage caused by the equivalent 18-kip single-axle load corresponds to a structural number (SN) of 1, and the loads greater than this amount have progressively greater damaging impacts on the road. But note that, for example, the rear axle of the 18-ton truck described in Table 2, which has a capacity of 11 tons (24.25 kip), will inflict 3 times more damage to the road pavement than the equivalent 18-kip load. Therefore, since the load-bearing designs of road pavements are based on this equivalent load, the loads exceeding the equivalent 18-kip single-axle load are not permissible. Another important point in this regard is the maximum axle load capacity instructed by the manufacturer. For example, in the 18-ton truck of Table 2, the front axle has a maximum capacity of 7 tons (15.73 kip), which means it cannot safely bear the equivalent 18-kip load. Thus, manufacturer's safety instructions may also limit the amount of load that can be applied on each axle. As a result, in the second way of calculating the maximum load, one must use the axle capacity or the road's equivalent capacity, whichever is the lowest. In Table 2, the latter capacity is given as the total road load.

The summarized results of the thrust force calculations based on the first method for the speeds of 0-100 km/h are presented in Table 6 and plotted in Fig. 4. These results are

Table 6. Output power at different speeds (in kilowatts) - the first calculation method

Truck size	Speed (km/hr)										
	0	10	20	30	40	50	60	70	80	90	100
11 tons	0	2	5	8	13	19	26	35	47	60	76
12.5 tons	0	2	6	9	14	21	29	38	50	65	82
18 tons	0	4	8	14	21	30	41	55	72	93	117
34 tons	0	7	15	25	36	51	69	90	115	144	179
60 tons	0	12	26	42	61	84	110	140	176	217	263

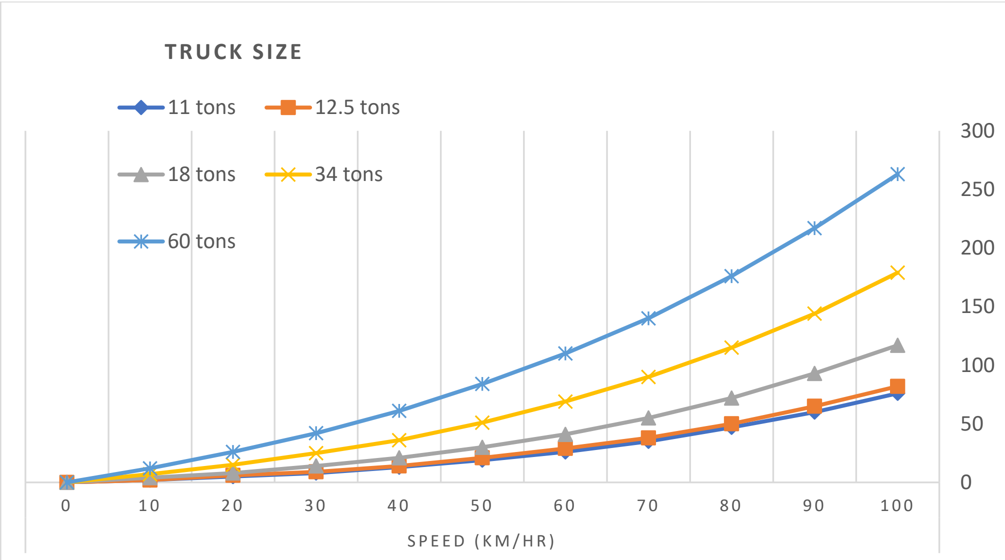

Fig.4. Power required at different speeds (in kilowatts) - the first calculation method

Table 7. Power required at different speeds (in kilowatts) per unit of net transported cargo - the first calculation method

Truck size	Speed (km/hr)										
	0	10	20	30	40	50	60	70	80	90	100
11 tons	0	0.3	0.7	1.2	1.9	2.7	3.7	5.1	6.7	8.6	10.9
12.5 tons	0	0.3	0.7	1.2	1.9	2.7	3.8	5.1	6.7	8.6	10.8
18 tons	0	0.3	0.6	1.1	1.6	2.3	3.2	4.3	5.7	7.3	9.2
34 tons	0	0.3	0.6	1	1.5	2.2	2.9	3.8	4.9	6.1	7.6
60 tons	0	0.3	0.7	1.1	1.6	2.1	2.8	3.6	4.5	5.5	6.7

based on the truck weight obtained from the Total axle load capacity given in Table 2.

The calculated power will be consumed to overcome the resistance forces resulting from the total weight of the truck. However, the purpose of transport is to move the cargo. while it is true that the truck weight is also a part of the transported mass, the efficiency of different trucks must be assessed based on the net weight of transported cargo. Hence, the power requirement values listed in Table 6 were divided by the Net axial load given in Table 2. The results obtained accordingly are presented in Table 7 and Fig. 5.

As illustrated in Fig. 5, according to the calculations performed based on the net load using the first method, the larger is the truck, the lower is the power consumption, and thus the lower is the fuel consumption and emission. In other words, the results obtained by this method of calculation support the idea that bigger trucks are more efficient and less polluting than smaller ones.

As explained earlier, the second scenario is to calculate the maximum capacity by using the equivalent 18-kip load or the manufacturer recommended permissible axle load, whichever is the lowest. The results obtained in this scenario for speeds of 0-100 km/h are presented in Table 8 and Fig. 6. These results were calculated based on the truck weight

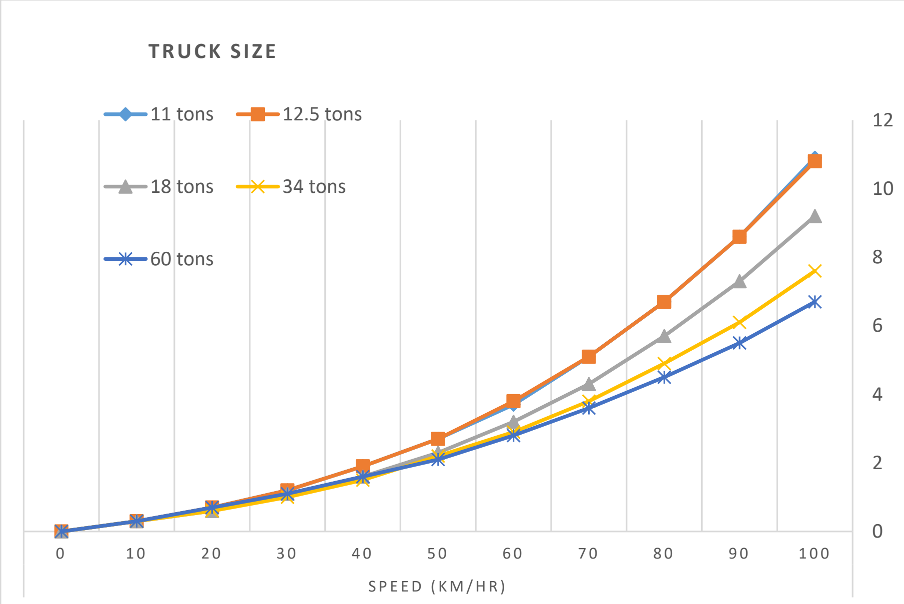

Fig.5. Power required at different speeds (in kilowatts) per unit of net transported cargo - the first calculation method

Table 8. Power required at different speeds (in kilowatts) - the second calculation method

Truck size	Speed (km/hr)										
	0	10	20	30	40	50	60	70	80	90	100
11 tons	0	2	5	8	13	19	26	35	47	60	76
12.5 tons	0	2	6	9	14	21	29	38	50	65	82
18 tons	0	3	7	12	18	26	37	50	66	85	108
34 tons	0	5	11	18	28	39	54	72	93	119	150
60 tons	0	8	18	29	43	60	80	105	133	167	205

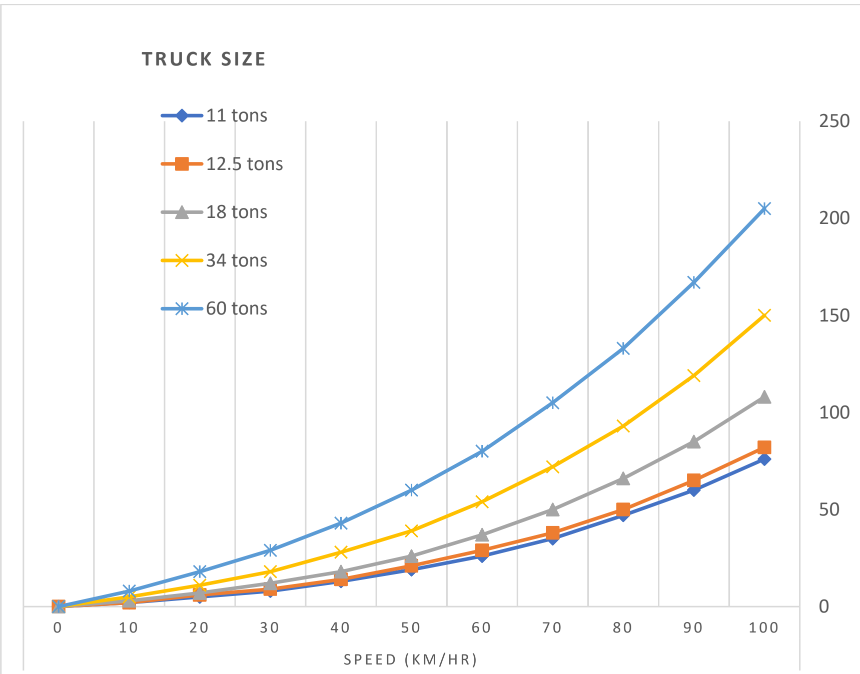

Fig.6. Power required at different speeds (in kilowatts) - the second calculation method

Table 9. Power required at different speeds (in kilowatts) per unit of net transported cargo - the second calculation method

Truck size	Speed (km/hr)										
	0	10	20	30	40	50	60	70	80	90	100
11 tons	0	0.3	0.7	1.2	1.9	2.7	3.7	5.1	6.7	8.6	10.9
12.5 tons	0	0.3	0.7	1.2	1.9	2.7	3.8	5.1	6.7	8.6	10.8
18 tons	0	0.3	0.7	1.2	1.8	2.7	3.8	5.1	6.7	8.6	10.9
34 tons	0	0.3	0.8	1.3	1.8	2.8	3.8	5.1	6.7	8.5	10.8
60 tons	0	0.3	0.8	1.3	1.8	2.8	3.8	5.1	6.7	8.5	10.8

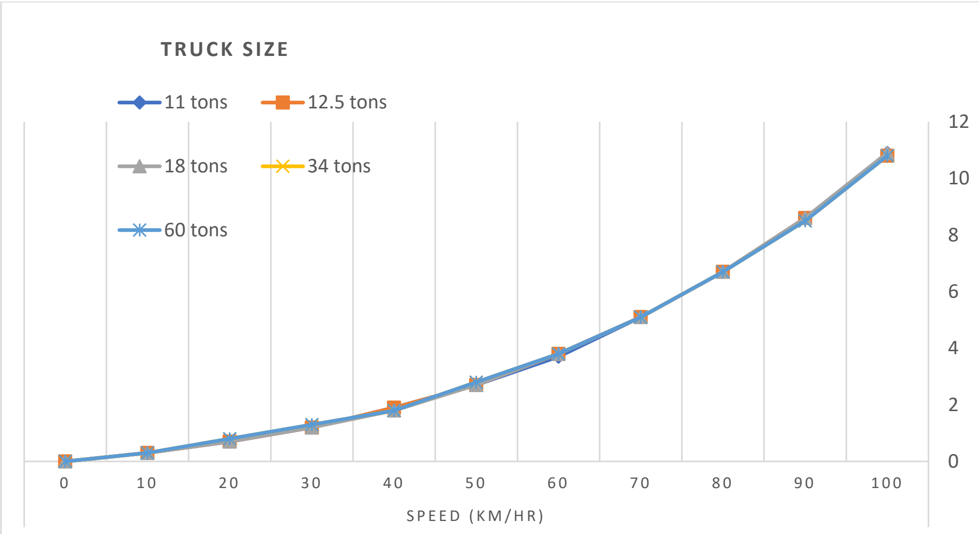

Fig.7. Power required at different speeds (in kilowatts) per unit of net transported cargo - the second calculation method

resulting from the Total axle load capacity given in Table 2.

Again, since the efficiency of trucks must be assessed based on the net weight of transported cargo, the power values given in Table 8 were divided by the Net road load given in Table 2 to obtain the results presented in Table 9 and Fig. 7.

As shown in Fig. 7, based on the second calculation method, the power requirement, fuel consumption, and emission do not significantly change with speed, especially at the speeds of 75-85 km (the average speed of trucks on the road). These results thus indicate that the truck size does not have an impact on the fuel that will be consumed and the emission that will be released to transport a certain amount of cargo.

CONCLUSIONS

Our inquiry revealed that the maximum amount of cargo that can be loaded on a truck must be lower than two thresholds: the maximum load that can be carried by the truck axles and the maximum load capacity of the road pavement. Naturally, safety requirements of road pavement and vehicle require us to use whichever of the above thresholds that is the lowest, and this means ignoring either of these thresholds can result in safety risks due to the disintegration of the road structure or the failure of truck axles. In other words, the maximum allowable load of a truck is either its axle load capacity or the equivalent 18-kip load of the road it traverses, whichever is lowest. Since many national codes have forbidden the violation of equivalent 18-kip load criterion, it would be a mistake to use the method described in scenario 1 to calculate the fuel consumption and emission of freight trucks. After using the second calculation method (scenario 2) for this purpose, it was found that, as shown in Fig. 7, irrespective of speed, truck size does not affect the fuel consumption and emission generation per unit of net transported cargo. Nevertheless, larger trucks can still decrease the traffic and thus reduce the number of road accidents.

ACKNOWLEDGMENTS

The authors would like to thank the anonymous reviewers and the guest editor for their comments that improved the manuscript.

REFERENCES

Chilbule, C., et al. (2014). "Analyzing the profile modification of truck-trailer to prune the aerodynamic drag and its repercussion on fuel consumption." Procedia Engineering **97**: 1208-1219.

Chowdhury, H., et al. (2017). "Effect of Various Deflectors on Drag Reduction for Trucks." Energy Procedia **110**: 561-566.

Díaz-Ramirez, J., et al. (2017). "Eco-driving key factors that influence fuel

consumption in heavy-truck fleets: A Colombian case." Transportation Research Part D: Transport and Environment **56**: 258-270.
Gillespie, T. D. (1997). "Vehicle Dynamics." Warren dale.
Hakimelahi, A., et al. (2016). "Fuel Consumption Monitoring for Travel Demand Modeling." Transportation Research Procedia **17**(Supplement C): 703-712.
Kim, N. S., et al. (2016). "Potential CO2 savings by increasing truck size: A Korean case study." KSCE Journal of Civil Engineering **20**(3): 997.
McKinnon, A. (2003). Logistics and the Environment, chapter published in Henscher, DA & Button, KJ (eds), Handbook of Transport and the Environment, Handbooks in Transport, Elsevier Ltd, Oxford, UK.
Mercedes-benz (2018). "ACTROS - Specifications." from http://buchhammer-handel.com/image/data/Mercedes%20ACTROS%20-%20Specifications.pdf.
Newbery, D. M. (1990). "Pricing and congestion: economic principles relevant to pricing roads." Oxford review of economic policy **6**(2): 22-38.
Odhams, A., et al. (2010). "Factors influencing the energy consumption of road freight transport." Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science **224**(9): 1995-2010.
Parry, I. W. (2007). "Are the costs of reducing greenhouse gases from passenger vehicles negative?" Journal of Urban Economics **62**(2): 273-293.
Salati, L., et al. (2017). "Wind tunnel experiment on a heavy truck equipped with front-rear trailer device." Journal of Wind Engineering and Industrial Aerodynamics **171**: 101-109.
Sarabi, E. R. (2011). "An analysis to energy consumption rate in road transportation sector of Iran and introduction policies of fuel consumption management in recent years." Procedia Engineering **21**(Supplement C): 989-996.
Scora, G., et al. (2015). "Value of eco-friendly route choice for heavy-duty trucks." Research in Transportation Economics **52**: 3-14.
Small, K. A., et al. (2007). The economics of urban transportation, Routledge.
Tavares, G., et al. (2008). "A case study of fuel savings through optimisation of MSW transportation routes." Management of Environmental Quality: An International Journal **19**(4): 444-454.
Turkensteen, M. (2017). "The accuracy of carbon emission and fuel consumption computations in green vehicle routing." European Journal of Operational Research **262**(2): 647-659.
Walnum, H. J. and M. Simonsen (2015). "Does driving behavior matter? An analysis of fuel consumption data from heavy-duty trucks." Transportation Research Part D: Transport and Environment **36**: 107-120.
Wang, J. and H. A. Rakha (2017). "Fuel consumption model for heavy duty diesel trucks: Model development and testing." Transportation Research Part D: Transport and Environment **55**: 127-141.
Welfers, T., et al. (2011). Design of a Tractor for Optimised Safety and Fuel Consumption.
Woodrooffe, J., et al. (2010). "Truck productivity, efficiency, energy use, and carbon dioxide output: benchmarking of international performance." Transportation Research Record: Journal of the Transportation Research Board(2162): 63-72.
Yoder, E. J. and M. W. Witczak (1975). Principles of pavement design, John Wiley & Sons.
Zimmer, A. and N. Koch (2017). "Fuel consumption dynamics in Europe: Tax reform implications for air pollution and carbon emissions." Transportation Research Part A: Policy and Practice **106**(Supplement C): 22-50.
Ziyadi, M., et al. (2018). "Vehicle energy consumption and an environmental impact calculation model for the transportation infrastructure systems." Journal of Cleaner Production **174**: 424-436.

HOW TO CITE THIS ARTICLE

A. Mansoori , Gh. Nabi Bid hendi, M.j. Amiri, H. Hoveidi, Evaluating the effect of truck size on the amount of Air pollutants emission due to consumption fuel, AUT J. Civil Eng., 4(2) (2020) 165-174.

DOI: 10.22060/ajce.2019.15779.5551