International Journal of Scientific Engineering and Science
Volume 3, Issue 10, pp. 61-65, 2019. ISSN (Online): 2456-7361

Environmental Impact of Freight Transportation in Cd. Juarez region and Review of Aerodynamic Drag Reduction Devices for Heavy Trucks

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Abstract**—** *Nowadays studying the ways in which greenhouse gas emissions may be reduced from all sectors of human been activities, including the transportation sector, became extremely important. The purpose of this investigation is study environmental impact of freight transportation in cd. Juarez area and review of aerodynamic drag reduction devices for heavy trucks to better understand what technologies or practices can be applied to highway tractor and trailer combinations to reduce aerodynamic drag without negatively affecting the usefulness or profitability of the vehicles.*

Keywords**—** *Aerodynamics Drag, Drag Redaction Devices, Environmental impact, Heavy Tracks.*

I. Introduction

Aerodynamic drag is a dissipative, irreparable loss of energy and is one of the most important factors to reduce fuel consumption and emissions of heavy vehicles. Significant drag reduction can be achieved using modern and emerging technologies, but the uptake is generally slowly due to requirements from operators for the timely return of their investments. Typical evaluation strategies for developers and device manufacturers may be distorted rather than very representative in real conditions, which is one of the reasons why operators may be hesitant to new technologies. Therefore, industry needs guidance in selecting appropriate technologies that provide net benefits for lower fuel consumption and emissions.

Aerodynamics of road vehicles - a complex discipline and many specific topics beyond the scope of this research. However, some facts related to transportation Industries, especially for heavy trucks, are presented. The discipline of aerodynamics deals with the movement of air around and through the body and interactions associated with this relative movement between the air and the car system. The aerodynamic properties of a road vehicle include an impact on its performance, handling, safety, and comfort. In the context of this research, performance was a critical issue, and the influence of aerodynamic drag (load in accordance with the movement of the vehicle) and its effect on fuel consumption.

Fuel is consumed by a vehicle's engine when it is driving on a road with engine power output contributing to the five main factors listed in Table I. Depending on the duty cycle a vehicle (e.g. urban driving at low speed and a stop or highway traffic at a constant speed high speed), the contribution to fuel combustion of these five factors varies proportionally the other, as shown in table I. For example, in urban environments, power dissipates due to acceleration and deceleration of the vehicle; losses prevail while on the highway aerodynamic losses are dominant. Light hybrid vehicles with energy recovery systems are potentially a good solution to reduce fuel consumption in urban environments. For the environment in which most commercial goods are transported, whose aerodynamic losses disperse and cannot be recovered is the main source of energy and fuel consumption. Aerodynamic loss reduction is a significant area in which can improve fuel consumption.

TABLE I. Engine power balance for a fully loaded tractor-trailer (adapted from [1])

Source	Urban	Highway
Drivetrain	10-15%	5-10%
Inertia/braking/grade	35-50%	0-5%
Rolling Resistance	20-30%	30-40%
Auxiliary Loads	15-20%	2-10%
Aerodynamic Losses	10-25%	35-55%

The percentage contribution to fuel combustion for each of the five categories varies from vehicle to vehicle, and varies depending on the speed of the vehicle, since the effects of aerodynamics are not linear. The contribution to fuel combustion due to internal losses is usually modeled as constant, and part of the acceleration / deceleration / slope can be modeled by duty cycle.

Aerodynamic drag is a force that resists the movement of a body through a fluid. Aerodynamic drag varies with the square of the relative speed $U\infty$ between the vehicle and ambient air. When the vehicle moves in still air, doubling the speed of the vehicle about four times increases the aerodynamic drag. In the presence of earthly winds that not in accordance with the movement of the vehicle, transverse winds create a non-zero yaw angle of the wind relative to the direction of movement of the vehicle. For heavy trucks, the drag coefficient increases significantly with the yaw angle.

The drag force on a vehicle can be calculated as follows:

$$FD = 0.5\ \rho\ (U\infty)2\ CD(\psi\infty)A \quad (1)$$

Where:

FD is the Drag force;

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Volume 3, Issue 10, pp. 61-65, 2019. ISSN (Online): 2456-7361

ρ is the density of the air;
U_∞ is the speed of the object, relative to the surrounding air;
ψ_∞ is the effective yaw-angle of the flow relative to the vehicle motion;
C_D is drag coefficient, which varies with yaw angle;
A is the projected front area of the vehicle.

In general, mechanical losses in the system linearly depend on the speed of the vehicle. At a speed of 53 km / h the power required to overcome mechanical resistance is approximately double that required for overcome aerodynamic drag. At a speed of 80 km / h, power is needed to overcome aerodynamic drag approximately equal to mechanical losses, and at higher speeds of the car aerodynamic losses dominate.

Table II illustrates the contribution to fuel consumption at various constant speeds (i.e., without acceleration), properly inflated tires, etc., and assuming that the internal power train losses can be modeled as a linear function of the vehicle speed.

TABLE II. Distribution of power consumption at different speeds of vehicle (adapted from [2]).

Vehicle Speed	Aerodynamic	Rolling & Accessories
32 km/h	28%	72%
53 km/h	33%	66%
64 km/h	36%	64%
80 km/h	50%	50%
96 km/h	62%	38%
105 km/h	67%	33%
113 km/h	70%	30%

Since aerodynamic drag is one of the sources of fuel consumption, it is important to understand its affects on total fuel consumption. At a speed of 80 km / h, a decrease in resistance of 20% will contribute to reduction in fuel consumption by about 10%. Consequently, reduction in fuel consumption will reduce contamination of the air by reducing the amount of pollutant elements, which is very stressful environmental, political and social factor everywhere, and especially for the Municipalities as Juarez, Mexico.

II. Environmental Impact Of Freight Transportation In Municipality Of Juarez

The Municipality of Juárez is in northern Mexico in the State of Chihuahua. The Municipality of Juárez occupies 1.4% of the territorial extension of the state, and is located 1,120 meters above the average sea level1. Demographically, Juarez is the most populous municipality in the state with 1,332,131 inhabitants (2010), or 38.8% of the population of the State of Chihuahua2. This results in a high economic activity for which it is necessary to supply the city with raw materials, food and consumables. In addition to its strategic geographical position adjacent to the State of Texas in the United States of America, Ciudad Juarez has positioned itself as one of the national border municipal entities, which has a high demand for the exchange of materials and goods, so the Cargo truck transit in this region of Paso del Norte is one of the main economic activities in the municipality.

According to the Technological Administration of Innovation and Research (RITA), in the years 2011 to 2013, they crossed an average of more than 725,000 cargo vehicles per year (to the north) through the two border crossings located in the urban spot of Ciudad Juárez (border crossing of Córdova - Las Américas and border crossing Zaragoza - Ysleta). Additionally, the number of crosses from the US and with destination to Mexico (which in the absence of official data) it is estimated that it ranges between 80% and 100% of travel cargo vehicles to the US from Mexico. Given these circumstances, it can be assumed that the number of border cargo crossings in both directions of more than 1,200,000 annually [1]. All this has caused the current situation in which cargo vehicles circulate without any control through the streets of the city, which in many cases are not prepared for the circulation of this type of transport. This translates into various negative impacts such as: (i) increased traffic jam; (ii) premature degradation of infrastructure, (iii) deterioration of air quality; (iv) increase of noise levels; among others.

Below, Figure 1 and Figure 2 shows the traffic types and volumes of cargo vehicles crossings to the US along the Córdoba-Las Americas and Zaragoza-Ysleta border.

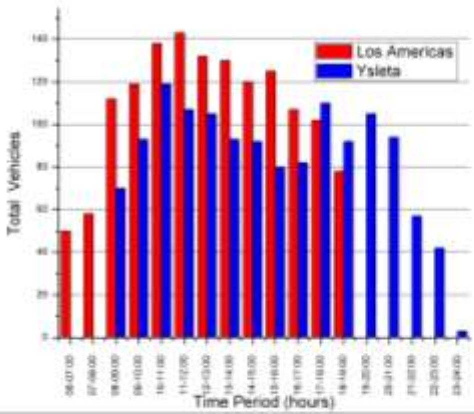

Fig. 1. Traffic of Cargo Vehicles using Córdova - Las Américas and Zaragoza - Ysleta de México bridges to the US.

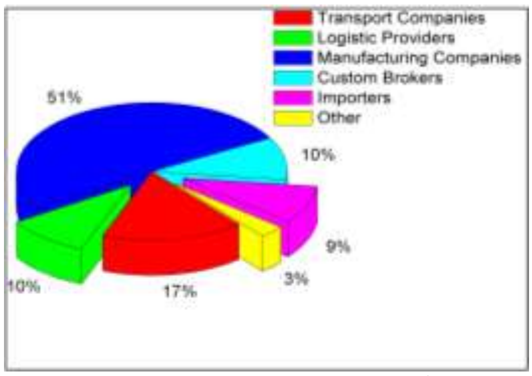

Fig. 2. Entity that Determines the Cross-Border Route of Freight Transport.

Geographical location of intersections traffic lights on primary roads of Ciudad Juárez shown on Figure 3, and Heavy trucks border crossing statistics (1995-2018), and expectation (2019-2030) presented on Figure 4 below.

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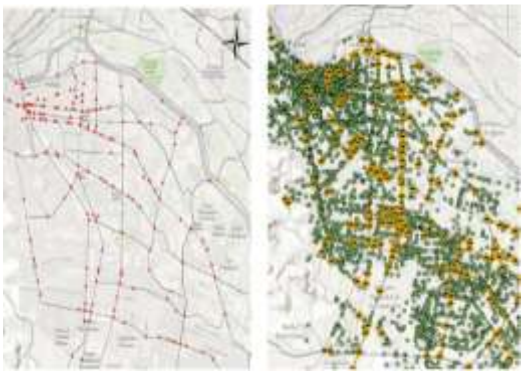
Fig. 3. Geographical location of intersection traffic lights (Red) on primary roads in Ciudad Juarez and an Accident Locations (Cars – green, Heavy Tracks – yellow).

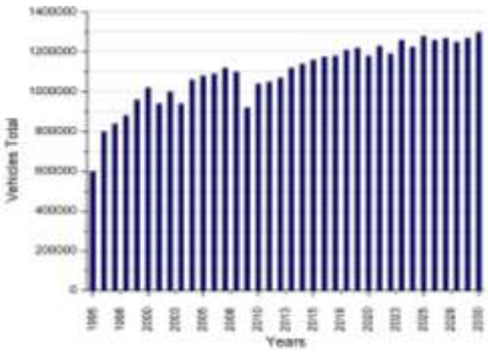

Fig.4. Heavy trucks border crossing statistics (1995-2018), and expecting (2019-2030) (Data from [1]).

Ciudad Juarez is the 3rd most polluted city in the country, and heavy trucks are responsible for 80% of emissions to the environment. As a key part of the analysis carried out the emissions of freight transport were estimated, and the year 2015 was determined as a baseline.

The results are shown below on Fig. 5, where six atmospheric pollutants were estimated for this purpose: volatile organic compounds (VOCs), carbon monoxide (CO), nitrogen oxides (NOx), carbon dioxide (CO_2), sulfur dioxide (SO_2) and particles smaller than 10 microns (PM10). All estimate was completed for the time 2015 to 2030 and considering the changes in the vehicle fleet and the environmental conditions prospected.

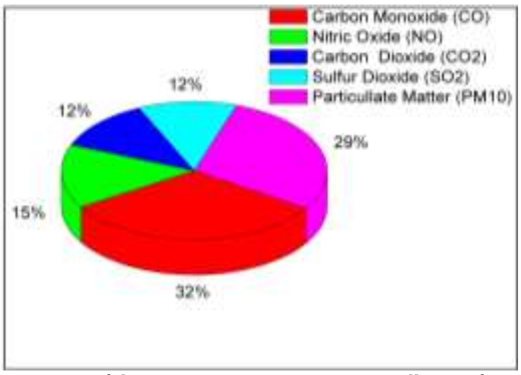

Fig 5. Variations of the contaminating environment pollutants from heavy trucks in Juarez area.

Variation of the pollutants with respect to the base year shows that the contribution is increased by more than 30%, only in the case of SO_2, CO_2 and NOx is smaller and ranges between 10% and 15%, freight transport reflects an important contribution situation, compared to private cars that, although they contribute, is not representative to consider within the study.

III. Heavy Tracks Drag Reduction Devices

Today, there are many devices to reduce the air drag of heavy trucks and technologies in use and in development. Many of them have been extensively studied, with the performance benefits well documented in the research press. They include roof deflectors, cab side extensions, tail trailers and trailer side skirts. There are four following key areas for aerodynamic improvement of tractor-trailers under the highway conditions:

- Tractor streamlining;
- Air flow control around the gap of the tractor and trailer;
- Airflow control under the trailer;
- Airflow control at the rear of the trailer.

With the status of some current and emerging technologies, it is predicted that aerodynamic handling these key areas can lead to lower fuel consumption under the highway conditions of the order of 15% in the period from 2015 to 2020 [2].

The drag reduction technologies can be divided into two main categories; those mounted on the tractor and those mounted on the trailer. As stated Leuschen, Cooper [3] et al., there are three to four times as many trailers in operation, as there are tractors. Like the vast majority of additional drag reduction devices usually installed on a trailer, the industry is reluctant to use these devices, as there is a clear distinction between tractor owners / operators and trailer owners. With trailer manufacturers, as a rule, are also not operators, and in general the cost of devices with a gap increases trailer purchase costs, there is little motivation on the part of trailer manufacturers for adoption these devices. The payback period of attachments will be much shorter for devices on a trailer, which will affect the speed of implementation of such technologies in transport industry. Therefore, tractor devices and technologies are likely to be adopted earlier.

When evaluating potential fuel economy on trailers, it's important to understand the context in which any measurements or evaluations have been made. Results, especially those based on road tests may be biased depending on conditions the vehicle and the environment in which they were tested.

Most of the previous research has been done on a very specific or small set of tractor trailers combinations. Since many of today's tractors can pull loads of many types of trailers that themselves have significantly varying aerodynamic properties, it's worth it study of the effect of the most common commercially available resistance reduction devices on various tractor-trailer combinations. In particular, there have been few studies of possible negative effects that may occur due to cab roof fairings and side extensions when used with certain combinations of trailers. [4] Most recent

International Journal of Scientific Engineering and Science
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second-generation research technologies typically perform drag reduction or fuel economy assessments using streamlined form of a new generation tractor. Truckers often prefer older boxing style tractors with many appendages, lights and without air deflectors. Also, worth a rating effects of some newer technologies that may not significantly affect the appearance vehicle on these classic style tractors.

As noted above, four critical areas are identified for applying resistance reduction technologies. Initially, a general list of concepts was developed based on several references [2], [5-14] that identify technologies and devices that can be the potential for reducing the drag of a tractor with a trailer is estimated.

A. Tractor streamlining

Tractor optimization has been a driving force in the development of tractors by manufacturers for the past three decades. The fuel crisis of the 1970s contributed to the development and subsequent market launch of tractors in the 1980s and 1990s. Despite demand from older drivers for classic tractors with square caps, flat bumpers and large external appendages such as air filters and exhaust pipes, all manufacturers have models of aerial tractors that have been designed with fuel economy in mind. Models of tractors provide a decrease in aerodynamic drag, compared with the classic style, by about 30% [5]. Rounding the front surfaces, using roof air deflectors and the use of fairings above the fuel tanks between the steering axle and driving bridges mainly achieve this improvement.

Current efforts to gradually reduce tractor resistance are directed to bumper sections, the underbody and gap between tractor and trailer.

B. Air flow control around the gap of the tractor and trailer

The area immediately behind the tractor and in front of the trailer is defined as a gap between tractor and trailer. The flow behavior in this gap area directly affects pressure on the rear of the cab and the front of the trailer, both of which is large surfaces perpendicular to the movement of the vehicle and therefore contribute significantly to the overall drag onto the vehicle. With prevailing winds on the truck tractor at inclined angles, the transverse flow through the gap changes the pressure in the cab and trailer faces leading to an increase in the overall resistance of the car [46]. This is the dominant region for which an assessment of wind resistance is required to determine the benefits of drag reducing devices.

To minimize the effect of gap on drag, a complete seal of the clearance will eliminate contribution under crosswind condition. However, due to operational requirements minimum clearance between the gaps is required, so that the tractor can turn relative to the trailer to facilitate maneuvering at loading and unloading facilities. Typical tractor trailers gaps are in range of about 1.0 meters (40 inches).

It was shown that the gap begins to have a significant effect on the resistance of the track once it is greater than about 0.45 m, with the drag increases by about 2% for every 0.25 m of increased gap beyond approximately 0.75 m. Study by Landman et al. [47] suggested that with the complete elimination of the gap issue, savings will be about 6%.

for a typical tractor-trailer. This will be approximately 3% improvement in fuel consumption at 98 km / h (60 mph), as shown in Figure 6.

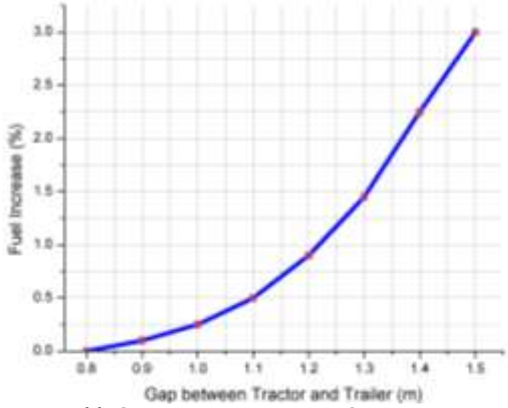

Fig. 6. Increase of fuel consumption *versus Gap* between Tractor and Trailer (Data from 15).

There are two main types of devices designed to reduce drag in the gap between tractor and trailer. These are tractor side extensions and devices in the gaps.

Side extensions mounted on the tractor extend the rear edge of the cab to prevent flow air to the gap area. The gap splitter (large vertical plate) is a technique often used for trailers. A tractor mounted gap splitter will behave similarly while minimizing implementation costs.

The final technique on the tractor to reduce the drag associated with the gap is to reduce distance between the rear of the tractor and the front of the trailer. This method is limited by the need of the operator to maintain a sufficient turning radius for loading and unloading on constrained areas of the dock or negotiate difficult turns to the right.

C. Airflow control under the trailer

Like the gap between the tractor and the trailer, an open area under the trailer provides greater drag resistance under crosswind condition. General approach to minimize the drag associated with this region to prevent air from entering. Mercedes recently introduced a concept trailer, which is reported to provide an 18% reduction in drag for full European combination tractor with trailer [50]. Trailer uses air dams, trim panels, side skirts, boat fairings and tail to reduce overall vehicle air drag. The concept is a complete package and does not consist of separate addition components.

D. Airflow control at the rear of the trailer

The trailer base is one of the largest sources of drag for tractor trailers. Low pressure on

face of the trailer due to aerodynamic wake, combined with high pressure on the front surface the tractor causes a pressure differential which generates a force in the downwind direction.

This pressure difference from front to back is the main source of drag for most heavy vehicles. An increase the base pressure will reduce this differential and decrease vehicle net air resistance. Thus, many drag reduction technologies for the trailer are aimed at increasing this backpressure.

IV. Conclusion

Since aerodynamic drag is one of the sources of fuel consumption, it is important to understand its affects on total fuel consumption. At a speed of 80 km / h, a decrease in resistance of 20% will contribute to reduction in fuel consumption by about 10%. Consequently, reduction in fuel consumption will reduce contamination of the air by reducing the amount of pollutant elements, which is very stressful environmental, political and social factors.

It was shown that the gap between tractor and trailer begins to have a significant effect on the resistance of the vehicle after it greater than about 0.45 m, while the resistance increases by about 2% for every 0.25 m a gap beyond approximately 0.75 m. Studies have shown that, completely addressing the gap problem saves about 6% on a conventional tractor with a trailer. This will be a roughly 3% improvement in fuel consumption at 98 km / h (60 mph).

Side skirts are used to prevent air from entering the area under the trailer. In recent years, these have been widely adopted and are commonly seen on many trailers. The reduction of fuel consumption on the order of 3-7% has been reported.

It was also shown that the side underbody boxes reduces drag by 10-15% and can be used to store equipment that is usually attached to the outside of the tractor or bottom of the trailer. Boxes under the bottom can also be used instead of traditional side guards. However, they increase the weight of the trailer and can also affect the angle of break over as trailers drive through railroad tracks and other obstacles.

Aero-tractor models provide reduction aerodynamic drag, compared with the classic style, on about 30%. This is achieved mainly due to rounding of the front surfaces, using roof air deflectors and the use of fuel tank fairings between the steering axle and driving bridges.

References

[1] Technological Administration of Innovation and Research (RITA) https://www.transportation.gov/research-technology

[2] National Academy of Sciences (NAS). 2010. Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles. Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles. The National Academic Press.

[3] J. Leuschen and K.R. Cooper, Full-Scale Wind Tunnel Tests of Production and Prototype, Second-Generation Aerodynamic Drag-Reducing Devices for Tractor-Trailers, 06CV-222, SAE International, 2006.

[4] H. Martini, B. Bergqvist, L. Hjelm and L. Löfdahl, Aerodynamic Effects of Roof Deflector and Cab Side Extenders for Truck-Trailer Combinations, 2011-01-2284, SAE International, 2011.

[5] Cooper, K. R. 2004. Commercial Vehicle Aerodynamic Drag Reduction: Historical Perspectives as a Guide. In The Aerodynamics of Heavy Vehicles: Trucks, Buses, and Trains (McCallen, R., Browand, F., and Ross, J., eds.) pp. 9-28, Springer, New York.

[6] Leuschen, J., Cooper, K. R. 2006. Full-Scale Wind Tunnel Tests of Production and Prototype, Second-Generation Aerodynamic Drag-Reducing Devices for Tractor-Trailers. SAE Paper No. 2006-01-3456.

[7] Leuschen, J., Cooper, K. R. 2006. Summary of Full-Scale Wind Tunnel Tests of Aerodynamic Drag-Reducing Devices for Tractor-Trailers. Lake Tahoe.

[8] Salari, K. 2011. DOE's Effort to Reduce Truck Aerodynamic Drag through JointExperiments and Computations - DOE Annual Merit Review, Project ID # VSS006 May 9-13, 2011 (Presentation). Document found at http://www1.eere.energy.gov/vehiclesandfuels/pdfs/merit_review_2011/veh_sys_sim/vss006_salari_2011_o.pdf. Accessed January 2012.

[9] Platform for Aerodynamic Road Transport, found at http://www.part20.eu/en/ Accessed January 2012.

[10] Salari, K. Ortega, J. 2010. Aerodynamic Design Criteria for Class 8 Heavy Vehicles Trailer Base Devices to Attain Optimum Performance. Lawrence Livermore National Laboratory Report No. LLNL-TR-464265.

[11] Patten, J; Poole G; Mayda, W; Trailer Boat Tail Aerodynamic and Collision Study; NRC-CSTT; CSTT-HVC-TR-169; March 2010.

[12] Sinha, S. K. 2008. Improving Fuel Efficiency of Tractor Trailer Trucks with Deturbulator Aero-Drag Reduction. SAE Paper No. 2008-01-2602.

[13] Landman, D., Wood, R., Seay, W., Bledsoe, J. 2009. Understanding Practical Limits to Heavy Truck Drag Reduction. SAE Paper No. 2009-01-2890.

[14] System Drag Reduction (SDR). Road Tech for Saving and Ecology. Document found at http://sdr-sys.com/archivos/Presentation.SDR-2010-2011.pdf Accessed

[15] L. Hjelm and B. Bergqvist, European Truck Aerodynamics – A Comparison Between Conventional and CoE Truck Aerodynamics and a Look into Future Trends and Possibilities, The Aerodynamics of Heavy Vehicles II: Trucks, Buses, and Trains, Volume 41, 2009.