ERASMUS UNIVERSITEIT ROTTERDAM
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Human factor in fuel consumption of trucks

Master Thesis

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Abstract

This paper is focused on the analysis of human factor in fuel consumption of trucks. The effects of drivers and other factors are studied on a specific trucking and logistics company from Slovakia. To assess the differences among the variables affecting fuel consumption a Structural Equation Modelling function is applied to analyse the model of the relationships among variables. The model differentiates between direct drivers' effects and indirect drivers' effects which comprise of idling time, cruise control use, high RPM, high speed and average speed.

The model results proved the drivers' effects to be significant in respect to fuel consumption. The potential improvement in fuel consumption varies among the indirect effects. The highest potential improvement in fuel consumption due to the highest spread in the effects among the drivers was found to be in idling time followed by high RPM, cruise control use and high speed respectively.

Key words:

Human factor, fuel consumption, drivers' effects, diesel, trucks, factors of consumption, road transport, Structural Equation Modelling, operating costs

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1 Introduction

1.1 Background

Demand for transport is a derived demand, what makes it hard to stimulate revenues from transport, thus low costs play a crucial role in profitability of transport companies. In the road haulage, the cost of diesel consumed by trucks is the major part of the truck operation costs. According to Freight Transport Association (2012), the fuel may represents up to 40% of total operating costs of the trucking companies. Therefore, a decrease in its consumption may result in higher profits of in the road haulage sector, which is one of the least profitable sectors among the transport industry. Given that fuel represents a significant proportion of the costs, one of the biggest issues that trucking companies face is the question of improving fuel consumption.

Several studies have been executed on the factors of fuel consumption - factors indirectly affecting profitability. Generally, the factors can be divided into 3 groups: First of all, the uncontrollable factors, such as the quality and slope of the road, regulations, restrictions and weather conditions, etc. Secondly, the factors affected by company operational decisions, such as the truck technical specifications, maintenance, type of freight, etc. And last but not least, the factors directly or indirectly influenced by the driver depending on his skills, concentration and patience which are crucial while driving. These factors and the way of driving vary among the drivers, which suggests different fuel consumption of different drivers. According to Deierlein (2001), the drivers, by controlling the idle time, speed, brake usage, acceleration, coasting style, accessory use, shifting style and other determinants can significantly influence the amount of fuel consumed.

This study attempts to address this matter and to fill in the research gap in quantitative research of the human factor on the consumption of heavy trucks. For that reason, this paper will research the drivers' behaviour effect on the fuel consumption. The research question will be answered through a case study of a Slovak trucking and logistics company PEVAS SK, a.s. and it will shed new light on the matter of fuel economy.

1.2 Research Question

The main focus of this master thesis is the analysis of the variations among drivers' fuel consumption and factors influencing fuel consumption. The analysis will indicate how much the drivers' effect differ throughout several factors and whether these variations among drivers are significant. The analysis in this master thesis will be focused on the effects of human driving behaviour through several factors with influence on the fuel consumption of trucks and on other factors that influence fuel consumption and consequently the costs and profitability of the company. The purpose of this thesis is to answer the questions:

"What role does the driver's behaviour play in the fuel consumption of a road transport company?"

"Which factors influenced by the driver have the highest potential in improving the fuel economy?"

The answers to the research questions will be crucial for the company PEVAS SK, a.s. and its cost minimization. Nevertheless, the effect of human factor on the consumption is interesting not only for any truck operating companies and their expense minimization, but as well for governments and society as a whole with regards to emission elimination.

1.3 Research Approach

In order to understand the role of fuel consumption in the profitability of road haulage companies the theory behind the costs structure in road transport will be studied in available literature. The aim of looking at the operating costs of road freight transport in particular and its profitability is to illuminate the importance of fuel consumption. Consequently, the theory behind the fuel consumption and the factors affecting it according to the literature will be assessed with the aim of realizing how the drivers affect the consumption and what the potential results are. This will provide us with a theoretical framework which will be further used in building model of relevant variables and relationships. They will be tested through quantitative analysis of the dataset provided by the company PEVAS SK. The effects of the variables in the model consistent with literature, company experience and logical reasoning will be identified through structural equation modelling (SEM) function in Stata 12. This multi equation model will be a function of endogenous and exogenous variables with their effects on the consumption as well as on each other in order to show the direct and/or indirect effects of the variables and drivers. Finally, with the purpose of answering the research question, in this confirmatory analysis, the direct, indirect and total effects on the fuel consumption and their distribution among drivers will be examined in detail. This will help to answer the research questions.

1.4 Outline

The next chapter (Chapter 2) will be dedicated to the description of Share of Fuel in Operating Costs of road haulage companies in order to point out its role in profitability. The following Chapter 3 will deal with Factors Influencing the Fuel Consumption as well as the potential effects of drivers on the fuel consumption. In the subsequent chapter (Chapter 4) Data and Models will be described and discussed. The Analysis and Results will be discussed in the Chapter 5. Finally, the Conclusions and

Recommendations in the Chapter 6 will sum up the findings and suggestions for the company strategy in improving fuel efficiency.

2 Share of Fuel in Operating Costs

Before looking at the factors that influence fuel consumption of trucks, it is necessary to take a look at the role of fuel consumption in the expenses of road haulage companies. Fuel consumption is among the operating costs of transport companies. Transport companies are service providers who operate machinery and equipment in order to provide their services. The functioning and running of these assets typically incurs high costs, costs of operation. The road haulage sector in particular is one of the least profitable ones among the transport industries. According to Freight Transport Association (2012), the profit margin in road transport in UK varies between 1-4%. There are several reasons for that. On the one hand, European trucking market saturation, fierce competition, internationalization in competition and cabotage create a pressure on revenues of the trucking companies. On the other hand, the high and increasing price of fuel, motor and fuel taxes and overall inflation increase the total costs of operation of heavy trucks. These are the main causes for low profitability in the sector and the typical issues of each road haulage company. Hence, there is no doubt about the importance of understanding the operating costs and their minimization. The cost of fuel is a significant part of these costs and therefore this chapter will introduce the essential information about the role of fuel in the operating costs.

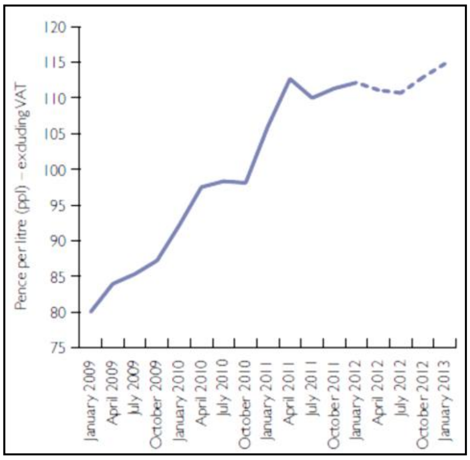


Figure 1: Bulk Diesel Prices and Price Expectations for 2012 (FTA 2012)

2.1 Operating Cost Components

The level of operating costs is a crucial factor in profitability of transport companies. Therefore, the operating efficiency is a factor of profitability. As the operating costs vary, consequently the profitability may vary. The size of operating costs depends on several factors, such as the type of transport service provided, as well as on the load type, weight and other characteristics. On top of that, government regulations or restrictions and many other factors partially influence these costs. On the other hand, the size of a firm (number of truckloads and kilometres per truckload), firm strategy (penalty or compensations for late deliveries) and type of firm (owner or operator) play a role in operating costs as well. Levinson et al. (2005) used these factors to estimate the operating costs of commercial vehicles. The study uncovered that the average and marginal costs also vary according to the type of goods transported. For instance, transport of aggregate goods incurs much lower operating costs that the one of agricultural products (Levinson, Corbett, & Hashami, 2005). Other elements affecting the costs are different pavement quality (pavement roughness and gravel roads increase fuel and maintenance costs), start-stop driving conditions or congestion. The stop-start driving in the city amounts to around 31% higher cost of fuel and 15% higher costs of maintenance, repair, and depreciation (Barnes & Langworthy, 2003). The Figure 2 shows the different amounts of costs under different driving conditions. In addition to that, the costs vary among different countries due to different pricing levels, labour conditions and regulations as well as they change over time.

Figure 2: Operating Costs, Different Driving Conditions (Barnes and Langworthy 2003)

	Baseline Costs		City Driving Conditions		Poor Pavement Quality	
Total Marginal Costs[1]	43,4		52,9		48,9	
Fuel	21,4	**49,3%**	28,0	**52,9%**	21,4	**43,8%**
Repair, maintenance	10,5	24,2%	12,1	22,9%	13,1	26,8%
Tires	3,5	8,1%	3,5	6,6%	4,4	9,0%
Depreciation	8,0	18,4%	9,2	17,4%	10	20,4%
		100%		100%		100,0%

Operating costs of trucks consist of all expenses incurred by the operator in order to run and maintain the vehicles and to provide the transportation service. Daniels (1974) divided the costs into running costs and standing costs. Running costs represented fuel, engine oil, tires and maintenance costs while standing costs consisted of license, insurance, and interest payments. In other sources, the division of fixed and variable costs was used. The definitions of structure of operating costs slightly vary among the literature, however, the most important and clear cost components are as follows:

- cost of fuel
- repairs
- maintenance
- oils
- spare parts
- tires
- depreciation
- interest
- driver and other labour costs
- overhead and other costs

Nevertheless, what is more important than definition of the structure of operating costs are the proportions of each cost among the operating costs. This master thesis analyses the cost of fuel and therefore, the proportion of fuel in the operating costs is the crucial item. For that reason, the next section will deal with the proportion of fuel cost and its role among operating costs.

[1] Total Marginal Costs – marginal costs of operation commercial trucks per mile

2.2 Fuel proportion

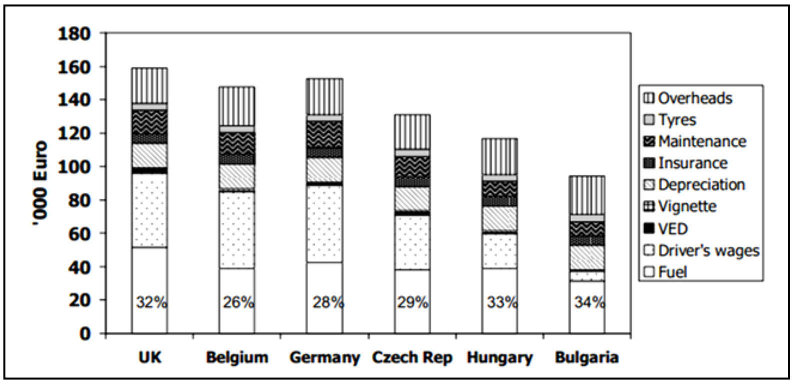
The main assets of a transport company are its vehicles. The vehicles create value for customers by transporting goods from point A to point B. For such a movement of goods, certain energy is needed to move the vehicles. In case of road haulage, the source of energy is a diesel powered engine. Diesel – an oil product is therefore the fundamental input that trucking companies facilitate to create value for their customers. As already mentioned before, there are also other inputs and costs of running a truck, however, according to scientific literature there is a consensus on the fact that, the fuel consumed by trucks represents a significant part of the operating costs of a company (Levinson, Corbett and Hashami 2005; Barnes and Langworthy 2003; World Bank 2000; FTA 2013). The percentage of fuel costs among the operating costs slightly varies throughout the literature. In spite of the variance caused by different time and location of studies, the fuel is always a crucial part of the operating costs. Therefore, if the fuel consumption is exceptionally high it may have severe effects on profitability of the company. Table 1 compares the fuel proportions estimated by several analyses.

Table 1: Fuel proportions (Source: Author)

Source	**Year**	**Fuel cost proportion**	**Proportion out of**
World Bank	2000	20-30%	total costs
Barnes and Langworthy	2003	14 – 19.8%	total costs
		43,8 - 52,9%	variable costs
McKinnon	2005	26 - 34%	total costs
FTA	2009	33%	total costs
FTA	2012	40%	total costs
KordaMentha	2012	40%	total costs

The differences in the fuel proportion estimations are partly caused by the different time of execution of the studies as well as the difference in studied locations. Nevertheless, there is a clear trend in increase of fuel proportion over time and the high proportion of fuel among the costs seems to be a global trend in the road transport. Even though costs of fuel or labour and other costs may vary throughout Europe and throughout the world, it is reasonable to state that the fuel consumed is one extremely crucial part of the operating costs. Moreover, in Europe as shown in Figure 3 on the following page, the fuel proportions among European countries do not vary in large amounts (McKinnon, 2007). Nowadays, the proportion of fuel costs tends to be at about 30 – 40% (FTA 2012, KordaMentha 2012, McKinnon 2007).

Figure 3: Structure of Truck Operating Costs in 6 European Countries in 2005 (McKinnon 2007)



Despite the different locations of the researched markets, there is no debate on the fact that there has been a high cost proportion of fuel among all countries. Since the fuel proportion recorded a clear increase as an expense, there is an increased importance of understanding fuel consumption and its factors. The above arguments confirm the importance of fuel economy and the considerable opportunity in improvement of expenses of trucking companies through lowering fuel expense.

2.3 Synthesis

An improvement in fuel consumption will lead to increased profitability. In line with the presented literature, it can be concluded that nowadays the fuel represents between 30% and 40% of total operating costs. In theory this means that with a 10% decrease of fuel consumption there exists a potential of 3% to 4% decrease in total operating costs what leads to significant improvement of profit margins in the industry. The exact amount of total costs improvement is yet depending on the differences in particular costs among the EU countries. Moreover, the company particular efficiency in operating the trucks is crucial as well. Therefore, the subsequent chapter provides detailed analyses of the factors of fuel consumption, with an emphasis on the human factor.

3 Factors Influencing Fuel Consumption

Having demonstrated the high importance of fuel consumption in operating costs, it is now necessary to look at the factors that can affect the fuel consumption. In order to see what the potential effects on fuel consumption are and what role the human factor plays in these effects, this chapter will pay close attention to these elements and their relationships. The fuel economy, and therefore the profitability heavily depend on several factors, which will be elaborated further. Scientific literature suggests several potential variables influencing fuel consumption. Nonetheless, all can be placed into 3 distinguishable groups: Uncontrollable factors, factors affected by a company's operational decisions and last but not least, factors directly or indirectly influenced by the driver depending on his skills, concentration and patience, etc.

3.1 Uncontrollable factors

Among the unmanageable factors that influence the fuel consumption we can find the traffic situation on the roads, which may lead to stop-start driving, policies affecting route limitations and traffic flow (maximum weights, lengths, speeds, constructions) and road characteristics (pavement quality and width) (Levinson, Corbett, & Hashami, 2005). These factors are similar to those of Sivak and Schoettle (2012) who claim that the quality and slope of the road and congestion on the roads are some among the factors of deviations in fuel consumption. Furthermore, rolling and air resistance, which significantly impact the consumption, depend on factors such as air temperature, weather conditions and other environmental factors. For instance, driving in a blowing headwind increases the resistance (Goodyear, 2012) and on the other hand, while driving on wet roads the rolling resistance of the tires increases as well. Another example of an external effect is the air temperature. If the air is warm the engine needs to be cooled down more frequently and the driver tends to use air conditioning more, for what additional energy is consumed. Last but not least, the quality of fuel should not be forgotten. In developed countries, most of the time fuel additives are used in order to decrease the fuel consumption, emissions and to extend the working life of engine and other components. These substances are not used by every producer of diesel and therefore the quality of fuel may vary (Mercedes Benz, 2009).

3.2 Factors of company decisions

Decisions of truck operators are a crucial part of the consumption factors since they decide about the types and characteristics of their vehicles. On the one hand, the newer the vehicle the more efficient it is as the average fuel consumption is constantly being improved over time by technological development of truck producing companies. According to Volvo Group Sustainability Report 2012, the fuel consumption of Volvo trucks has decreased since year 2000 on average from around 31 l/100km to around 27 l/100km in 2012. Not only the age, but also the technical and physical properties of the truck are more than important. When a buyer makes a decision in selecting the most suitable truck for his business, the following properties that relate to fuel consumption must be considered: type and model of the vehicle, power and type of the engine, weight, size and aerodynamics (i.e. size of cabin, trailer). The choices depend not only on the type of transport but on the owners preferences as well. Moreover, Mercedes Benz (2009) and Sandberg (2011) stress also the importance of correct powertrain configuration. Sivak and Schoettle (2012) also note that timely and regular maintenance has an impact on both, fuel consumption and working life of trucks. They extend the life of trucks and improve their functioning and fuel economy as a consequence. According to Levinson et al. (2005), the amount of consumption, and therefore operating costs of a vehicle are also based on these owner influenceable specifications: characteristics of a commodity, length of haul, types of equipment used for transport. Additionally, type, state, inflation and quality of tires affect the rolling resistance, together with the axles configuration and wheel alignment affect the consumption as well. That means that an incorrect number of axles or axle alignment increase the fuel consumption and wearing out of the tires due to higher rolling resistance. This leads to increase in cost of fuel as well (Goodyear, 2012).

3.3 Drivers' factors

Some sources indicate the average speed and average acceleration as the most significant variables influencing the fuel consumption (Delgado, Clark, & Thompson, 2012). Daniels (1974) argued that speed is a main factor that affects the fuel consumption and the maintenance costs as well. However, the effect of speed depends on the actual speed level. The trucks in Europe are usually limited in their maximum speed to 90 km/h. According to Volvo Trucks (2011) a decrease in the speed from 90 km/h to 80 km/h improves the fuel consumption by 6%. However, driving in unfavourable driving conditions with many stops in a city or on a bad quality pavement decreases the speed significantly, while the fuel consumption increases. Even though speed is a factor directly influenced by the driver, it is important to keep in mind that it depends on the road profile, weather and speed regulations as well.

Driver may affect the speed and engine rotations per minute (RPM) which are the primary factors of varying consumption. However, the important factor certainly affecting the consumption, which is related to engine rotations and speed, is the aggression in acceleration while driving and that is difficult to measure. Driver is responsible for acceleration and deceleration rate. Extremely fast or extremely slow changes of speed are inefficient and lead to unnecessary high fuel consumption. For instance, it is pointless to increase the speed to 50 km/h in the city if the driver sees red light 150 metres ahead and then hit the brakes vigorously. There would be more energy (fuel consumed) wasted than necessary. It is impossible to generalize an appropriate acceleration rate but cruise control may be of a great help here.

Another impacting factor of consumption variations is the idling time, the time when the engine runs, but the truck stands still. For instance, the time while the driver rests at a parking lot inactively and the engine is running. The running engine is consuming fuel, but truck does not generate any kilometres driven and therefore, the average consumption per kilometre increases. Driver can also control the use of air conditioning and other appliances in the cabin which consume energy as well. (Sivak & Schoettle, 2012)

Moreover, driving requires certain skills, concentration and patience. These factors, however, differ among drivers. The driver's styles and habits vary considerably. In a study by Balogun et al. (2011), the psychological factors, such as age, years of experience, educational and marital status etc., had different effects on the driving behaviour. This suggests that the different drivers would reach different consumption of diesel. According to Deierlein (2001) the drivers significantly influence the fuel economy by controlling the idle time, speed, brake usage, acceleration, coasting style, accessory use, shifting style and other determinants. Similarly, McElroy (2006) in his *"Driver's Ed for MPEG"* argues that by anticipating the ahead situation and avoiding brake use a driver can improve fuel economy by up to 10%. Training courses related to truck driving may be a way to teach drivers move more efficiently and stimulate the fuel consumption (Mercedes Benz, 2009) as well as motivational wage schemes or bonuses.

According to Ing. Peter Vavrík, the CEO and owner of PEVAS SK, a.s., the driver has the most power to influence the consumption. The drivers can do so by taking advantage of the inertia of the heavy vehicles and use of the maximum torque of the engine.

> ***"As the truck and semi-trailer set weights around 40 tonnes, its inertia energy is much higher than inertia of a passenger car. And this is, in my opinion; what only drivers who reach consumption at about 30 l/100km realize and take advantage of."***

Ing. Vavrík believes the driver through the use of the pedals is the main element in affecting the fuel consumption, no matter what the kind of a road profile he is driving on. From the experience of drivers it is also known that some of the semi-trailers might have different effect on driving as well. This depends on their quality and type of the trailers.

3.4 Synthesis

There are three groups of factors that influence the amount of fuel consumed: Uncontrollable factors, Company decisions and Drivers. The three groups of factors contain variables of many kinds. Some of them are easy to measure, other are not observable at all. Nevertheless, all the factors are put it the 3 groups and these are as follows:

Table 2: Factors of fuel consumption (Source: Author)

Uncontrollable	Company decisions	Drivers
traffic situation	aerodynamics	acceleration
fuel quality	age of vehicle	anticipating ahead situation
policies and regulations	engine power and type	brake usage
road limitations	goods transported	coasting style
road quality	maintenance	concentration
slope of the road	model of vehicle	cruise control
speed and other limits	power train configuration	drivers skills
weather conditions	size	engine rotations per minute
	tires quality and state	changes of speed
	type of vehicle	idle time
	weight	patience
	wheel alignment	shifting style
		speed
		taking advantage of the inertia
		use of A/C and other accessory

Despite the fact that not all factors are observed, there are measurable variables available in the database used for this analysis. These will be used and assigned to relevant factors to construct the model for analysis of human factor in fuel consumption. Now that the factors and their relationships are clear, the database can be introduced in the next chapter and the model can be constructed.

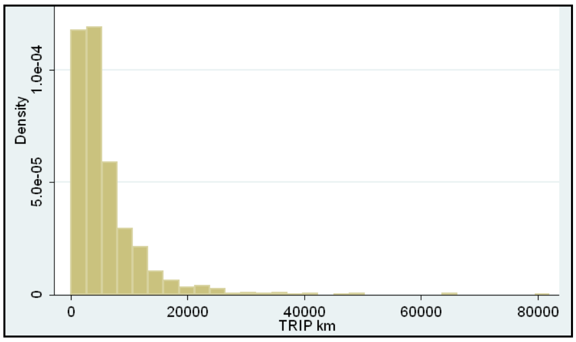
4 Data and models

This chapter examines the effects of drivers' behaviour on the fuel consumption of trucks through several factors by using the database provided by Slovak trucking and logistics company PEVAS SK, a.s. In the following sections the sample dataset will be introduced and variables terminology explained as well as the model that will be used for analysis. The information provided in Chapter 3 will be the base for building the model for the analysis of the human factor in fuel consumption. The scientific literature information will be combined and applied in order to construct the most fitting model.

4.1 Data

In order to prove and apply the theory through the quantitative analysis and to analyse the magnitude of the effects, the database including crucial technical data will be used. The data contains information downloaded from Volvo trucks owned by PEVAS SK through specialized software Dynafleet during 7 years period. The sample includes information about per trip[2] performance of 10 Volvo FH trucks which differ in their age and in the engine power. Apart from their age and engine, they are assumed to be identical. There are 1,458 observations of trips with the average length of 5940.66 km.

Figure 4: Histogram - Trip kilometres (Source: Author)



The trips vary not only in their lengths and average consumption but in speed of driving, idling time, kilometres driven at high speed or RPM and use of cruise control. During each trip one or two drivers drove the vehicle either on the domestic or international routes. Therefore, each trip and truck have their assigned drivers as well as a label of being foreign, domestic or other transport route. The database therefore comprises of the following variables:

[2] Trip is a period between the points in time when the data were downloaded from the trucks. During this period the truck drove different amount of kilometres.

- Engine power
- Construction year
- Foreign transport
- Domestic transport
- Average speed
- High speed
- Idle time
- Cruise control use
- High engine rotations
- Average consumption

4.2 Terminology and variable relations

The theoretical framework introduced in Chapter 3 will be further used in building the model of relevant variables. First of all, it is necessary to clarify which are the relevant factors influencing the fuel consumption according to the scientific literature and which variables will represent these factors in the quantitative analysis. The factors and available variables were placed into three distinguishable categories:

4.2.1 Uncontrollable factors

The uncontrollable factors such as the type of the roads or weather conditions are not easy to measure. Therefore, these factors are assumed to be equal for each trip. However, in this analysis it is feasible to use the dummies variables of **foreign** and **domestic** transport as a proxy for road characteristics. The **speed** will be used as a proxy for the uncontrollable factors of characteristics of roads as well. Firstly, it is assumed that on the international routes, the trucks drive longer distances principally at higher speed on highways and on higher quality roads than those on short domestic routes. Therefore, the driving conditions vary. This has further effect not only directly on consumption, but on the **average speed** of driving and the ratio driven in **high speed** (speed over 85 km/h) as well (Sivak and Schoettle 2012; Levinson, Corbett and Hashami 2005). The **domestic** and **foreign** dummies partially influence the **idle ratio** as well due to the fact that on the international routes the drivers need to take more time to rest which can increase the idling time and fuel consumption consequently.

Table 3: Uncontrollable factors (Source: Author)

Uncontrollable	
Factors	**Variables**
traffic situation	**Average speed, High speed**
fuel quality	
policies and regulations	
road limitations	
road quality	**Foreign/Domestic, Average speed, High speed**
slope of the road	
speed and other limits	**Foreign/Domestic, Average speed, High speed**
weather conditions	

4.2.2 Factors influenced by the truck owners' decisions

Secondly, the factors influenced by the truck owners' decisions regarding the types and characteristics of their trucks, as well as maintenance influence the consumption directly (Sivak and Schoettle 2012; Levinson, Corbett and Hashami 2005). On the one hand, it is assumed that the maintenance quality and frequency as well as quality of spare are equal for each truck. The reason for this is that the company PEVAS SK does all its maintenance by its own employees and every truck has equal care. On the other hand, there are differences in the **age of trucks** what is an important factor (Volvo Group, 2012) and differences in their **engine power** of the trucks what in crucial as well (Sivak and Schoettle 2012; Levinson, Corbett and Hashami 2005). Therefore, these variables containing this information will be included in the model and represent the characteristics of the vehicles.

Table 4: Truck operators' factors (Source: Author)

Company decisions	
Factors	**Variables**
aerodynamics	
age of vehicle	**Construction year**
engine power and type	**Engine power**
goods transported	
maintenance	
model of vehicle	
powertrain configuration	
size	
tires quality and state	
type of vehicle	
weight	
wheel alignment	

4.2.3 Factors influenced by drivers

Finally, this section discusses the factors that can be influenced by the drivers. The drivers can influence the consumption directly and/or indirectly through their actions. The drivers' factors in this analysis are represented by **122 dummy variables**. Each driver dummy stands for one driver of the company. Firstly, the drivers manage the **average and high speed** which is also influenced by the type of road, as mentioned earlier. The variable of driving **over 85 km/h** represents the ratio of kilometres driven at **high speed**, what is not optimal with regards to fuel economy. Next, the drivers manage the use of **cruise control**, the **rotations of engine** and **idling time** through their decisions while operating the trucks. These factors have further direct effect on the consumption and therefore these relationships will be used in the model. However, there are many other factors such as brake usage, anticipation of the situation ahead, aggression in acceleration, etc. which are not directly observable. These unobserved factors are included in the **dummy variables of the 122 drivers** and their direct effects on consumption. Therefore, the effects of each dummy variable include all the other factors of drivers' behaviour that affect the fuel consumption. What need to be considered further are the correlations among the variables. As the **average speed** and ratio of **high speed** are significantly correlated[3], the correlation will be included in the SEM analysis in order to get more precise results.

Table 5: Drivers' factors (Source: Author)

Drivers	
Factors	**Variables**
acceleration	**Cruise control, High RPM**
anticipating ahead situation	**Driver dummies**
brake usage	**Driver dummies**
coasting style	**Driver dummies**
concentration	**Driver dummies**
cruise control	**Cruise control**
drivers skills	**Driver dummies**
engine rotations per minute	**High RPM**
changes of speed	**High RPM**
idle time	**Idle time**
patience	**Driver dummies**
shifting style	**Driver dummies**
speed	**Average speed, High speed**
taking advantage of the inertia	**Driver dummies**
use of A/C and other accessory	**Driver dummies**

4.2.4 Synthesis

The measured variables available in the database provided by PEVAS SK, a.s. were assigned to the factors of consumption. The variables are factors either influenced by company decision, proxies for uncontrollable factors, factors influenced by drivers or factors partly uncontrollable and partly controlled by drivers. The following table shows the fundamental information about the variables. These variables will be used in the construction of the model in order to answer the research questions.

[3] correlation =0.6143, p-value = 0.0000

Table 6: Variables (Source: Author)

Category	Variable name	Variable ID	Variable	Units	Values	Min	Max	Mean	Std. dev.
Company decisions	Engine power	**enginepower**	Power of the engine	HP	420, 460, 480, 500, 610	420	610	480,51	49,61
Company decisions	Construction year	**yearofconstruciton**	Year of construction of truck	Year	2001, 2002, …, 2006	2001	2006	2003,88	1,70
Uncontrollable	Foreign transport	**foreign**	Trips mostly in other countries than SR and CR	Dummy	1=foreign ; 0=other				
Uncontrollable	Domestic transport	**domestic**	Trips mostly in SR and CR	Dummy	1=domestic ; 0=other				
Partly Uncontrollable / Partly Driver	Average speed	**averagespeed**	Average speed of driving during each trip	Km/h	min 45.73 - max 75.43	47,57	75,43	61,94	5,15
Partly Uncontrollable / Partly Driver	High speed	**over85ratio**	Ratio of kilometres driven faster than 85km/h out of total km driven	Ratio	km speed > 85 / total km driven	0	0,702	0,274	0,143
Driver control	Idle time	**idleratio**	Ratio of time out of total time of trip spent Idling	Ratio	hrs idle / hrs total trip	0,048	0,791	0,205	0,089
Driver control	Cruise control use	**cruiseratio**	Ratio of kilometres driven with Cruise control out of total km driven	Ratio	km cruise idle / total km driven	0	0,603	0,122	0,119
Driver control	High engine rotations	**espdratio**	Ratio of kilometres driven with rpm > 1550 out of total km driven	Ratio	km rpm > 1550 / total km driven	0	0,199	0,015	0,014
Dependent variable	Average consumption	**tripconsl100km**	Average consumption of fuel during the trip	L/100km	min 27.03 - max 47.6	27,03	47,6	37,07	3,07
Drivers	Human factor	***122 drivers***	122 dummy variables	Dummies					

4.3 Model

The model that analyses the human and other factors in the fuel consumption represents a complex series of relationships. The relationships between the variables in the model are a system of functions which analyses the effects on the dependent variable. The dependent variable of fuel consumption depends on several variables directly or indirectly. To facilitate the construction of such a series of equations a statistical tool SEM is implemented. SEM is chiefly confirmatory statistical modelling technique for broad array of models with complex relations. It is necessary to build the model of variables and relationships based on strong literature, theoretical and logical background reasoning. Each relationship and therefore, each path in the model must be justified (StataCorp, 2011).

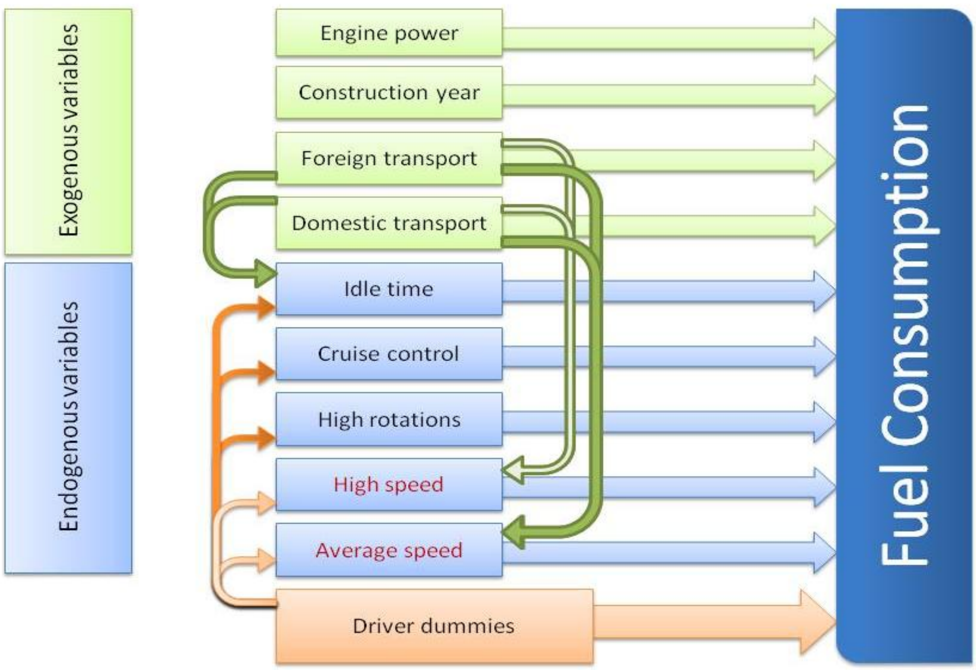
$$\begin{cases} \textbf{Fuel consumption}\left(\begin{array}{c}\textbf{Engine power, construction year, foreign transport,} \\ \textbf{domestic transport, idle time, cruise control, high engine rotations,} \\ \textbf{high speed, average speed, drivers dummies}\end{array}\right) \\ \textbf{Cruise control}\ (drivers\ dummies) \\ \textbf{High engine rotations}\ (drivers\ dummies) \\ \textbf{Idle time}\ (drivers\ dummies, foreign\ transport, domestic\ transport) \\ \textbf{High speed}(drivers\ dummies, foreign\ transport, domestic\ transport) \\ \textbf{Average speed}(drivers\ dummies, foreign\ transport, domestic\ transport) \end{cases}$$

First of all, the drivers as well as all other variables, affect the consumption directly through their behaviour. Therefore, the model includes a direct effect of drivers on consumption. Secondly, the drivers influence the consumption indirectly, through affecting other variables. These *endogenous* variables being affected by drivers and influencing the fuel consumption in the model are Cruise control, High engine rotations, Idle time, High speed and Average speed. Each of these factors influences the consumption, but also each is affected by the drivers. For that reason the drivers influence the consumption indirectly through these endogenous variables.

Moreover the variables Idle time, High speed and Average speed are affected not only by the driver dummies but by the foreign/domestic transport dummies as well. This is a result of the fact that different characteristics of local or foreign roads lead to different driving speed. Moreover, the longer international routes require longer breaks between driving what results in more idling. As the foreign/transport dummies represent the differences in road characteristics and regulations, they influence the consumption directly as well. The variables foreign and domestic transport control for the effects of uncontrollable factors.

Last but not least, the variables representing the characteristics of the trucks, Construction year and Engine power are directly affecting the consumption and therefore they are in the model as direct effects to control for differences among trucks. In addition to that, the variables are weighted to the length of a trip in order to grant more explanatory power to the longer trips. Therefore, the longer the trip the more explanatory power it has. And finally, the observed and logical *correlation between Average speed and High speed* is included in the model as well.

Figure 5: The model - Relationships among variables (Source: Author)

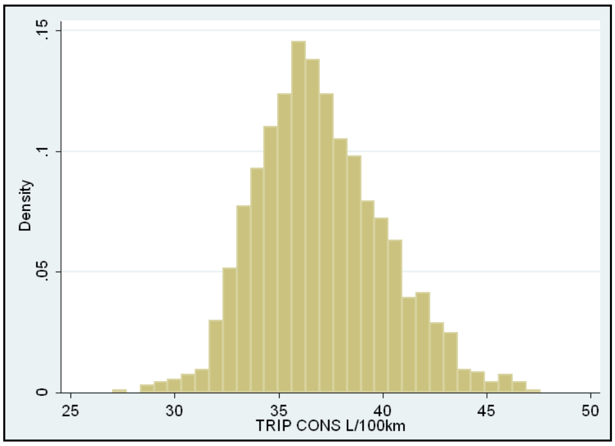


5 Analysis and Results

The model established trough the SEM analysis shows the relationships among the variables defined in the previous sections. These relationships among dependent and independent variables result in the direct and indirect effects on fuel consumption. The relationships between the variables are significant and in line with the scientific literature and theory, what confirms good specification and fit of the model. The fit indices confirm a good fit of the model as well. The size of residuals SRMR (Standard root mean squared residuals) was estimated at 0.007 what is below 0.05 and therefore the model has a good fit (Daire Hooper, 2008). Coefficient of determination (CD) is equal to 0.986, which is similar to R^2 and values close to 1 represent a good fit. Therefore, CD also proves a good fit of the model. And lastly, the overall R^2 is 0.986, as well as none of the variables in the model has R^2 lower than 0.43 what is a positive sign. Unfortunately, the Stata 12 software was unable to provide the rest of the fit indices and therefore we can rely on the above mentioned only.

The mean of the main dependent variable, the average consumption is 37 litres with standard deviation of 3. Therefore, 95% of the trips were driven with average fuel consumption between 31.1 and 42.9 litres per 100 km. That signifies more that 10 litres variations.

Figure 6: Histogram - Fuel consumption distribution (Source: Author)



These variations are a result of different driving behaviour as well as of the other factors in the model. The following table show the output of the SEM analysis. Not only the effects of the variables on the consumption but also the effects among the other factors can be seen in the SEM output on the following pages.

Dependent variables	Fuel consumption		Average speed		High speed		High rotations		Cruise control		Idle time	
	coefficient	p-values	coefficient	p-values	coefficient	p-values	coefficient	p-values	coefficient	p-values	coefficient	p-values
Engine power	0,003	0,000										
Construction year	-0,702	0,001										
Foreign transport	-0,080	0,002	0,633	0,004	0,037	0,000					0,005	0,000
Domestic transport	0,127	0,002	1,240	0,003	0,012	0,000					-0,011	0,000
Average speed	-0,258	0,000										
High speed	2,307	0,006										
High rotations	26,628	0,062										
Cruise control	-3,207	0,008										
Idle time	5,741	0,010										
Drivers												
1	0,535	0,009	1,888	0,021	0,176	0,001	-0,009	0,000	0,131	0,000	-0,019	0,000
2	-1,131	0,014	-2,842	0,033	-0,121	0,001	-0,006	0,000	-0,086	0,001	-0,033	0,001
3	0,532	0,005	2,212	0,010	0,085	0,000	0,027	0,000	-0,030	0,000	-0,007	0,000
4	-0,063	0,005	-3,000	0,011	0,046	0,000	-0,003	0,000	-0,067	0,000	0,004	0,000
5	-3,158	0,010	-8,024	0,024	-0,129	0,001	-0,011	0,000	-0,053	0,001	0,069	0,000
6	0,237	0,009	-7,328	0,019	-0,084	0,001	-0,008	0,000	-0,139	0,000	0,093	0,000
7	-1,728	0,029	-3,339	0,066	0,002	0,002	-0,011	0,000	0,107	0,001	0,001	0,001
8	-0,921	0,055	-10,359	0,126	-0,091	0,004	-0,011	0,000	0,003	0,003	-0,023	0,002
9	-1,009	0,006	-1,598	0,014	-0,060	0,000	-0,003	0,000	0,108	0,000	0,097	0,000
10	-1,532	0,003	2,559	0,007	0,003	0,000	0,002	0,000	-0,023	0,000	0,030	0,000
11	-2,288	0,021	-3,939	0,049	-0,178	0,002	-0,007	0,000	0,023	0,001	0,015	0,001
12	0,344	0,011	3,914	0,025	0,054	0,001	0,019	0,000	0,334	0,001	0,002	0,000
13	-1,288	0,005	-3,647	0,011	-0,160	0,000	-0,015	0,000	-0,036	0,000	-0,003	0,000
14	1,679	0,005	-4,358	0,011	-0,175	0,000	-0,007	0,000	0,112	0,000	0,152	0,000
15	2,815	0,033	-4,619	0,075	0,061	0,002	0,007	0,000	0,082	0,002	0,017	0,001
16	-0,268	0,012	-3,034	0,026	0,027	0,001	0,026	0,000	-0,133	0,001	0,219	0,000
17	-2,207	0,005	2,007	0,010	0,144	0,000	0,014	0,000	0,068	0,000	-0,072	0,000
18	1,304	0,012	1,740	0,027	0,045	0,001	0,005	0,000	0,003	0,001	0,027	0,000
19	-0,793	0,007	3,000	0,016	0,053	0,001	-0,005	0,000	-0,051	0,000	-0,030	0,000
20	0,887	0,018	-4,151	0,040	-0,120	0,001	0,002	0,000	-0,123	0,001	-0,042	0,001
21	-0,513	0,014	0,061	0,032	0,015	0,001	-0,003	0,000	0,011	0,001	-0,060	0,001
22	-2,211	0,021	1,349	0,048	0,119	0,002	0,011	0,000	0,286	0,001	-0,017	0,001
23	0,007	0,013	0,719	0,031	0,039	0,001	0,005	0,000	0,044	0,001	-0,022	0,000
24	0,778	0,014	-4,268	0,031	-0,061	0,001	-0,011	0,000	-0,062	0,001	0,023	0,001
25	0,529	0,010	-1,429	0,022	-0,053	0,001	0,006	0,000	-0,008	0,000	-0,044	0,000
26	-0,658	0,014	-4,488	0,031	-0,068	0,001	0,002	0,000	-0,120	0,001	0,077	0,000
27	-2,257	0,006	-3,583	0,013	-0,092	0,000	0,004	0,000	0,041	0,000	0,058	0,000
28	-10,680	0,083	-17,489	0,190	-0,306	0,006	0,005	0,000	-0,146	0,004	0,960	0,003
29	0,711	0,017	5,681	0,039	0,136	0,001	-0,007	0,000	0,003	0,001	-0,008	0,001
30	0,787	0,020	-3,527	0,046	-0,108	0,002	0,007	0,000	-0,107	0,001	0,107	0,001
31	0,898	0,019	2,807	0,042	-0,243	0,001	-0,010	0,000	-0,148	0,001	0,028	0,001
32	-0,306	0,004	-1,340	0,010	-0,027	0,000	-0,007	0,000	-0,004	0,000	0,015	0,000
33	0,924	0,004	1,218	0,009	0,072	0,000	0,012	0,000	-0,032	0,000	-0,011	0,000
34	-0,279	0,009	-0,689	0,020	-0,011	0,001	-0,002	0,000	0,063	0,000	0,003	0,000
35	-1,684	0,030	0,590	0,069	0,078	0,002	0,084	0,000	-0,064	0,002	0,026	0,001
36	0,433	0,007	2,061	0,015	-0,019	0,001	0,004	0,000	0,108	0,000	-0,060	0,000
37	0,859	0,016	-11,092	0,036	-0,166	0,001	0,074	0,000	0,010	0,001	0,009	0,001
38	-0,861	0,003	-2,385	0,007	-0,013	0,000	0,003	0,000	0,036	0,000	-0,002	0,000
39	-1,137	0,014	-7,110	0,031	-0,087	0,001	-0,009	0,000	-0,021	0,001	0,226	0,000
40	-0,641	0,004	0,195	0,008	0,055	0,000	0,000	0,000	-0,007	0,000	-0,016	0,000
41	-0,879	0,009	-2,045	0,020	-0,069	0,001	0,006	0,000	-0,024	0,000	0,002	0,000
42	-0,378	0,010	-1,440	0,024	0,012	0,001	-0,008	0,000	-0,026	0,001	-0,026	0,000
43	2,906	0,006	-1,308	0,014	0,094	0,000	-0,011	0,000	-0,150	0,000	0,002	0,000
44	1,121	0,004	1,247	0,009	-0,225	0,000	-0,003	0,000	0,093	0,000	-0,055	0,000
45	0,248	0,006	3,223	0,014	0,154	0,000	0,004	0,000	-0,024	0,000	-0,018	0,000
46	-0,264	0,019	-1,438	0,044	0,033	0,001	-0,008	0,000	-0,019	0,001	-0,029	0,001
47	4,635	0,017	6,091	0,040	0,025	0,001	0,036	0,000	0,037	0,001	-0,068	0,001
48	-1,693	0,006	1,139	0,014	-0,106	0,000	-0,001	0,000	-0,100	0,000	-0,061	0,000
49	-0,412	0,006	3,545	0,013	0,064	0,000	0,000	0,000	-0,074	0,000	-0,008	0,000
50	-0,559	0,007	2,160	0,016	-0,133	0,001	-0,001	0,000	-0,003	0,000	0,032	0,000
51	-2,033	0,007	-0,595	0,017	-0,010	0,001	-0,017	0,000	0,070	0,000	0,021	0,000
52	1,012	0,008	-6,100	0,017	-0,119	0,001	0,006	0,000	-0,097	0,000	0,037	0,000
53	0,100	0,014	-2,084	0,031	0,005	0,001	0,002	0,000	-0,093	0,001	0,039	0,001
54	0,858	0,005	0,636	0,010	0,039	0,000	-0,004	0,000	-0,132	0,000	-0,019	0,000
55	1,680	0,010	1,643	0,022	-0,001	0,001	-0,006	0,000	0,113	0,000	0,040	0,000

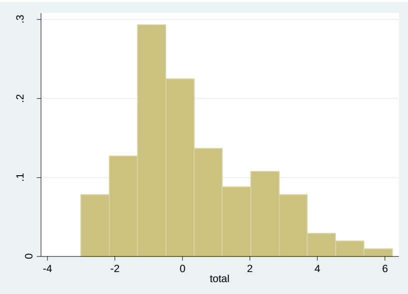
Dep. Variables	Fuel consumption		Average speed		High speed		High rotations		Cruise control		Idle time	
56	0,135	0,014	-4,834	0,032	0,075	0,001	0,023	0,000	0,020	0,001	0,056	0,001
57	-0,595	0,004	3,216	0,009	0,112	0,000	0,004	0,000	-0,133	0,000	0,005	0,000
58	0,564	0,006	3,241	0,015	0,159	0,000	0,005	0,000	0,034	0,000	-0,072	0,000
59	0,094	0,007	1,197	0,015	0,015	0,000	0,000	0,000	-0,042	0,000	-0,026	0,000
60	-0,078	0,008	0,799	0,018	-0,204	0,001	0,006	0,000	-0,077	0,000	-0,004	0,000
61	-1,921	0,007	5,114	0,016	0,133	0,001	0,028	0,000	0,007	0,000	-0,041	0,000
62	0,610	0,006	1,549	0,014	0,049	0,000	0,016	0,000	0,036	0,000	-0,122	0,000
63	-0,092	0,004	0,344	0,008	0,071	0,000	-0,006	0,000	0,007	0,000	-0,032	0,000
64	-3,424	0,037	-6,082	0,084	-0,173	0,003	-0,012	0,000	-0,162	0,002	0,032	0,001
65	2,219	0,025	-1,959	0,057	-0,208	0,002	0,000	0,000	-0,105	0,001	0,103	0,001
66	-3,667	0,017	-6,016	0,039	-0,152	0,001	0,002	0,000	-0,065	0,001	-0,035	0,001
67	-1,544	0,017	2,768	0,038	-0,043	0,001	0,010	0,000	0,034	0,001	-0,040	0,001
68	-0,517	0,005	0,284	0,011	0,003	0,000	0,006	0,000	-0,019	0,000	-0,035	0,000
69	2,732	0,034	-0,089	0,079	0,017	0,003	-0,006	0,000	0,208	0,002	0,160	0,001
70	-0,011	0,035	-7,439	0,080	-0,051	0,003	-0,015	0,000	-0,149	0,002	0,181	0,001
71	-0,527	0,023	-0,874	0,053	-0,028	0,002	0,058	0,000	-0,125	0,001	0,106	0,001
72	-0,091	0,004	0,146	0,009	-0,057	0,000	-0,006	0,000	0,002	0,000	0,002	0,000
73	1,690	0,012	3,047	0,027	0,068	0,001	-0,010	0,000	0,196	0,001	0,026	0,000
74	-0,033	0,010	-1,419	0,023	-0,062	0,001	0,006	0,000	0,026	0,001	-0,002	0,000
75	-1,237	0,005	-2,297	0,010	-0,216	0,000	-0,011	0,000	-0,057	0,000	-0,105	0,000
76	-1,425	0,015	1,300	0,033	-0,216	0,001	0,006	0,000	-0,034	0,001	-0,004	0,001
77	-0,466	0,021	1,133	0,049	0,039	0,002	-0,004	0,000	-0,067	0,001	-0,051	0,001
78	0,988	0,005	1,894	0,011	-0,122	0,000	0,007	0,000	0,151	0,000	-0,080	0,000
79	-1,353	0,012	-2,433	0,027	0,002	0,001	0,001	0,000	-0,063	0,001	-0,035	0,000
80	-1,116	0,005	2,056	0,010	0,098	0,000	0,009	0,000	0,270	0,000	0,028	0,000
81	-0,291	0,009	-0,170	0,020	0,065	0,001	0,002	0,000	0,102	0,000	-0,043	0,000
82	-0,843	0,008	-2,260	0,019	-0,060	0,001	-0,002	0,000	0,064	0,000	0,019	0,000
83	0,340	0,006	0,093	0,013	0,127	0,000	0,017	0,000	0,073	0,000	-0,036	0,000
84	1,580	0,011	3,157	0,026	0,120	0,001	0,002	0,000	-0,006	0,001	0,015	0,000
85	-0,504	0,032	2,851	0,074	0,057	0,002	-0,013	0,000	-0,130	0,002	0,014	0,001
86	2,864	0,022	0,889	0,050	0,030	0,002	-0,006	0,000	0,038	0,001	0,002	0,001
87	-7,830	0,028	-8,979	0,062	-0,065	0,002	0,108	0,000	-0,162	0,001	0,154	0,001
88	-1,344	0,032	-5,329	0,073	0,028	0,002	-0,012	0,000	-0,075	0,002	0,145	0,001
89	0,179	0,004	3,458	0,007	-0,102	0,000	-0,003	0,000	0,087	0,000	-0,043	0,000
90	0,604	0,029	3,171	0,067	0,036	0,002	-0,005	0,000	0,106	0,001	-0,054	0,001
91	-0,548	0,003	3,801	0,007	0,045	0,000	0,007	0,000	-0,125	0,000	0,005	0,000
92	0,078	0,006	4,092	0,007	0,035	0,000	-0,010	0,000	-0,134	0,000	-0,020	0,000
93	1,992	0,016	-0,050	0,036	-0,013	0,001	-0,011	0,000	-0,109	0,001	0,116	0,001
94	-1,790	0,014	3,659	0,033	0,045	0,001	-0,005	0,000	-0,162	0,001	0,033	0,001
95	-2,934	0,005	-5,898	0,010	-0,202	0,000	0,003	0,000	-0,106	0,000	0,013	0,000
96	1,830	0,005	-0,999	0,011	-0,020	0,000	-0,013	0,000	-0,085	0,000	0,109	0,000
97	-1,977	0,015	-0,121	0,034	-0,153	0,001	-0,008	0,000	-0,034	0,001	-0,054	0,001
98	-0,836	0,010	0,279	0,024	0,034	0,001	-0,003	0,000	-0,072	0,001	-0,011	0,000
99	-3,969	0,036	-8,066	0,081	-0,046	0,003	0,019	0,000	-0,096	0,002	0,044	0,001
100	0,522	0,013	-3,495	0,029	-0,094	0,001	0,011	0,000	-0,117	0,001	0,080	0,000
101	-4,328	0,024	-10,284	0,054	-0,208	0,002	0,000	0,000	-0,159	0,001	0,198	0,001
102	-0,448	0,016	-8,425	0,037	-0,170	0,001	-0,006	0,000	-0,065	0,001	0,060	0,001
103	-0,281	0,010	-0,012	0,023	0,109	0,001	0,001	0,000	0,031	0,001	0,049	0,000
104	-0,167	0,007	-9,414	0,016	-0,281	0,001	-0,005	0,000	-0,022	0,000	0,194	0,000
105	2,310	0,009	-7,963	0,020	-0,108	0,001	-0,003	0,000	-0,161	0,000	-0,012	0,000
106	-0,042	0,060	-13,529	0,138	-0,229	0,005	0,004	0,000	-0,090	0,003	-0,033	0,002
107	-1,036	0,019	-5,579	0,044	-0,040	0,001	0,004	0,000	-0,070	0,001	-0,065	0,001
108	3,142	0,008	-8,806	0,018	-0,105	0,001	0,017	0,000	-0,133	0,000	0,028	0,000
109	1,817	0,022	-9,439	0,051	-0,142	0,002	0,009	0,000	-0,005	0,001	0,077	0,001
110	2,014	0,011	-1,100	0,024	-0,130	0,001	0,016	0,000	-0,084	0,001	0,211	0,000
111	-0,344	0,024	-1,249	0,054	-0,313	0,002	-0,012	0,000	0,087	0,001	0,004	0,001
112	-0,269	0,014	2,123	0,031	-0,054	0,001	0,013	0,000	-0,018	0,001	-0,054	0,001
113	0,401	0,031	-2,629	0,071	-0,069	0,002	0,010	0,000	-0,091	0,002	0,068	0,001
114	0,368	0,031	0,131	0,071	-0,012	0,002	-0,006	0,000	-0,085	0,002	0,098	0,001
115	-0,902	0,007	-1,831	0,016	-0,136	0,001	-0,010	0,000	-0,028	0,000	-0,056	0,000
116	1,487	0,020	3,441	0,043	0,024	0,001	-0,013	0,000	-0,049	0,001	-0,079	0,001
117	-0,071	0,022	-0,882	0,051	0,130	0,002	0,004	0,000	0,011	0,001	-0,007	0,001
118	-0,139	0,014	-3,789	0,032	0,008	0,001	0,014	0,000	-0,038	0,001	-0,055	0,001
119	1,003	0,028	4,841	0,064	0,195	0,002	-0,003	0,000	0,245	0,001	-0,077	0,001
120	0,234	0,008	-6,217	0,018	-0,030	0,001	0,007	0,000	-0,093	0,000	0,067	0,000
121	-0,079	0,009	-1,698	0,020	0,019	0,001	0,015	0,000	-0,041	0,000	-0,021	0,000
122	0,552	0,003	1,958	0,008	0,019	0,000	0,004	0,000	-0,052	0,000	-0,012	0,000
Goodness of fit	SRMS = 0.007 , CD = 0.986, R^2 = 0.986											

5.1 Total Drivers' Effects

The total effect of the drivers on fuel consumption comprises of the combination of the average direct and indirect effects. The total effects include all the average effects of drivers on fuel economy and therefore, the sum of direct and indirect effects is equal to total effects. The magnitude of the total effects varies among the drivers. However, the average magnitude of the effects is not analysed in this paper since we are not interested in the average effects but in the range of the effects distributions instead. The variations in the magnitude of the effects and the ranges in which the drivers drive are compared as the potential improvements in consumption. It is important to understand that the ranges of direct and indirect effects cannot be added up together as they do not represent the coefficients of the effects, but their variations.

The more differences among the drivers, the more potential to improve there is. The most efficient drivers are an example and prove that the consumption can be improved. The least efficient ones shall change something in their driving behaviour and learn from the better drivers. To analyse the potential, it is essential to construct a 95% confidence interval of the effects. The confidence interval provides us with a range of 95% of the effects. This interval is given by the lower boundary and the upper boundary. The lower boundary is calculated by subtracting 1.96 times the standard deviation from the mean and the upper boundary is calculated by adding the same number to the mean. The 95% of the total drivers' effects are in a range between -3.69 and 3.69, what ranges to 7.39 litres difference. This confirms that the variations among drivers' fuel economies are immense and may represent up to 7.4 litres difference between the most and the least efficient drivers. Therefore, the drivers through their behaviour and controlling driving factors are able to improve or worsen the fuel consumption by more than 3 litres per 100 km. The rest of the variance in consumption, which varies between 31.1 and 42.9 litres (i.e. 95% of the trips), is caused by the other variables in the model, such as the age of truck, engine power and other unknown factors.

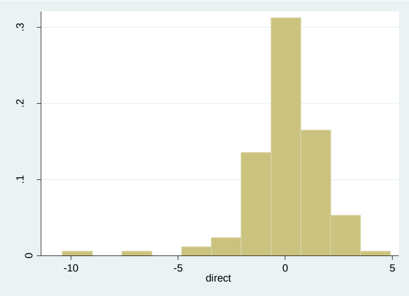
Figure 7: Histogram - Total drivers' effects (Source: Author)



5.2 Direct Drivers' Effects

The direct effects of the drivers on consumption include all factors that are not included in the variables in the model. The direct effects of drivers are not directly observable. They may comprise brake usage, anticipation of the situation ahead, aggression in acceleration, etc.

Figure 8: Histogram - Drivers' direct effects (Source: Author)

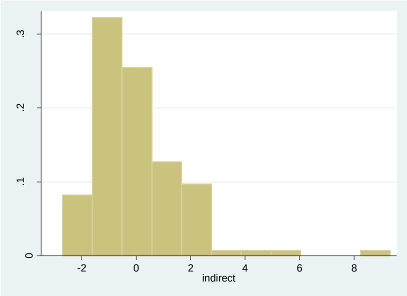


The variations among drivers' direct effects are large and therefore, 95% of the drivers drive within a range of up to 7.4 litres difference between the most and the least economic drivers. Therefore, in the best case scenario the worst drivers through their behaviour are able to improve the consumption directly by about 7.4 litres per 100 km.

5.3 Indirect Drivers' Effects

The indirect effects of the drivers on consumption include the effects through other endogenous variables. These endogenous variables affect the consumption in certain way, but they are also being affected by drivers. The drivers affect the variables of Cruise control, High RPM, Idle time, Cruise control, High speed, and Average speed. As a consequence the consumption is affected as well.

Figure 9: Drivers' indirect effects distribution (Source: Author)



The potential, the 95% confidence interval for the indirect drivers' effects is 6.57 litres. Therefore, in the best case scenario, the improvement of the fuel consumption of some drivers is more than 6.5 litres through the indirect variables. These indirect variables consist of Idle time, High speed, Average speed, High RPM and Cruise control use.

5.3.1 Drivers' indirect effects through idle time

An increase in **idle time** on average increases the fuel consumption. With a 10% increase in idle time the consumption increases on average by 0.57 litres. Therefore, the more the driver **idles** the less efficient he is. The indirect effects of drivers on consumption through control of idle time depend on the drivers. The effects therefore vary among drivers. 95% of the drivers' effects are in the range of 2.5 litre size. Therefore, the potential variation in consumption thanks to different **idle time** is almost 2.5 litres. This means that there is almost 2.5 litre difference in consumption of the most and least efficient drivers and potential improvement of the inefficient drivers.

Figure 10: Histogram - Indirect effect through Idle time (Source: Author)

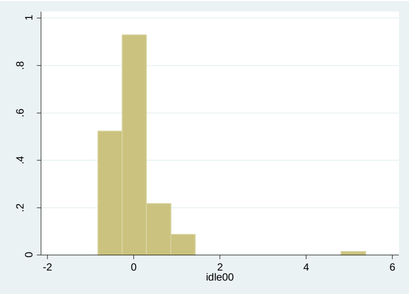
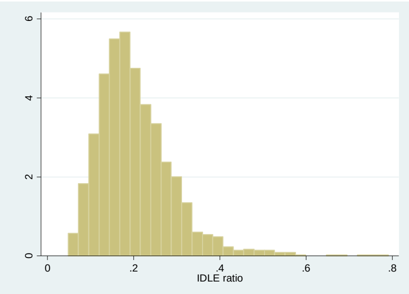


Figure 11: Histogram - Idle time ratio distribution (Source: Author)



5.3.2 Drivers' indirect effects through cruise control

On average the use of **cruise control** improves fuel consumption. With a 10% increase in use of **cruise control** the consumption decreases on average by 0.32 litres. Therefore, the more the driver uses the **cruise control** the more efficient he is. Unfortunately, some of the drivers do not use the **cruise control** or use it inefficiently. Nevertheless, 95% of the drivers are within 1.25 litres difference in fuel consumption. Therefore the potential variation in consumption thanks to different **cruise control** use is 1.25 litres. Moreover, there are fairly many drivers who do not use the **cruise control** at all or use it very little (Figure 12) and therefore, some of the drivers have exceptionally negative effects on the consumption through use of cruise control.

Figure 12: Indirect effect through Cruise control (Source: Author)

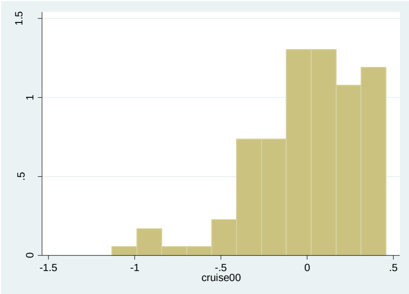
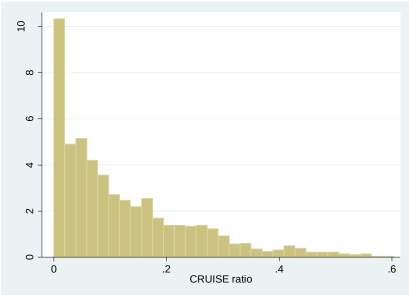


Figure 13: Histogram - Cruise control ratio distribution (Source: Author)



5.3.3 Drivers' indirect effects through high engine rotation

On average driving at **high RPM** worsens fuel consumption. With a 10% increase in driving at **RPM over 1550** the consumption increases on average by 2.66 litres. Therefore, the more a driver drives at **high RPM** the less efficient he is. The indirect effect of drivers on consumption through driving with **high RPM** varies, as the drivers have different driving styles. Yet, 95% of the drivers' effects are in the range of 1.86 litres. Therefore, the range and the potential variation in consumption among drivers as a result of variations in driving at **high RPM** is 1.86 litres.

Figure 14: Indirect effects through High rotations (Source: Author)

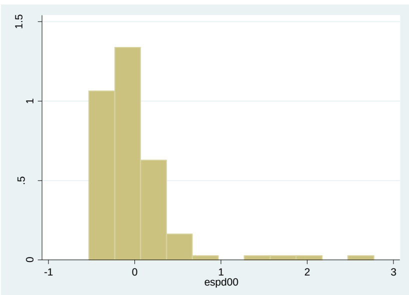
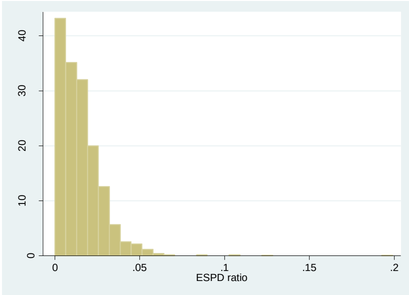


Figure 15: Histogram - High rotations ratio distribution (Source: Author)



5.3.4 Drivers' indirect effects through high speed

On average driving more at **high speed** worsens fuel consumption. The speed over 85 km/h is therefore inefficient. With a 10% increase of **driving over 85 km/h** the average consumption increases on average by 0.23 litres. However, the speed factor depends not only on the drivers, but on the road characteristics as well (uncontrollable factors). On some roads driving at such a speed might not be possible at all. Nevertheless, the more the driver drives at **high speed** the less efficient he is. The indirect effect of drivers on the consumption through driving fast varies among the drivers as well. The 95% of drivers' effects through driving at **high speed** are in the range of 1 litre. Therefore, the potential variation in consumption owing to variations in driving at **high speed** is around one litre.

Figure 16: Indirect effects through High speed (Source: Author)

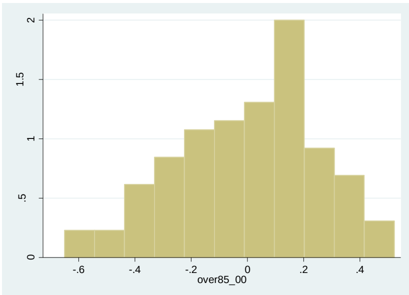
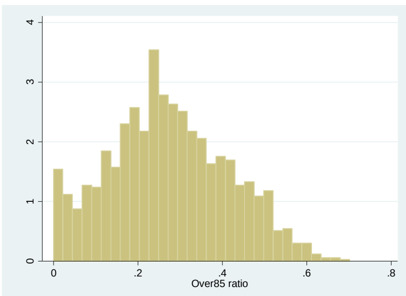


Figure 17: Histogram - High speed ratio distribution (Source: Author)



5.3.5 Drivers' indirect effects through average speed

The effect of average speed needs more explanation. According to the model, the higher the average speed the lower the consumption. The cause of this are the effects of road characteristics factors (uncontrollable factors). This is because average speed is strongly dependent on other factors, such as road quality, speed limits and others. Generally an increase of **average speed** by 1 km/h decreases the consumption on average by 0.26 litres. This is primarily caused by the better quality of roads and more stable driving conditions during driving at higher speeds. For instance, driving on a highway at a constant speed is more efficient than driving at city conditions. Even though, the drivers have some influence on consumption as well, it is not feasible to interpret the effect of drivers on consumption through average speed. Otherwise we would argue that the driver has to drive faster to gain more favourable fuel consumption. The model lacks sufficient control variables for the road characteristics and therefore the average speed effect is ambiguous.

Figure 18: Indirect effects through Average speed (Source: Author)

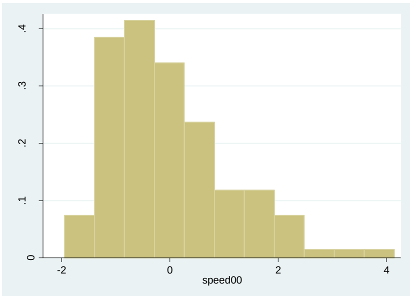
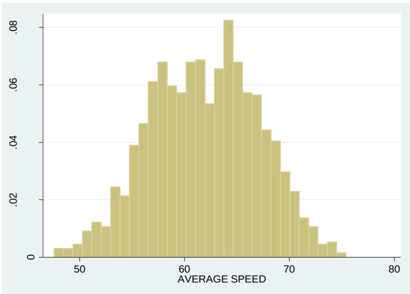


Figure 19: Histogram - Average speed distribution (Source: Author)



5.4 Synthesis

In short it can be concluded that drivers influence the fuel consumption significantly. Difference between the best and the worst drivers in terms of fuel consumption represents more than 7 litres per 100km. These variations are caused by direct or indirect effects. The direct effects cannot be specified more closely as they are not available in the database and are not observed. The indirect effects of drivers are effects through Idle time ratio, High RPM ratio, Cruise ratio, High speed ratio and Average speed. The largest range in variations among drivers, the 95% confidence interval and therefore the highest potential in improvement of the consumption is in the indirect effect through controlling idle time. The next highest potential is in controlling high RPM followed by cruise control and high speed (Table 8). The average speed effect is not feasible to interpret due to insufficient control for effects of road characteristics and other factors.

Table 7: Summary of potential effects (Source: Author)

VARIATIONS BETWEEN DRIVERS' EFFECTS	**Range 95% CI**		**Spread of range (potential)**
Idle ratio	-1,242	1,242	**2,485**
High RPM ratio	-0,926	0,926	**1,853**
Cruise ratio	-0,625	0,625	**1,250**
High speed ratio	-0,497	0,497	**0,994**
Average speed	-2,185	2,185	4,370
Drivers' indirect effects	-3,285	3,285	**6,570**
Drivers' direct effects	-3,711	3,711	**7,421**
Drivers' total effect	-3,693	3,693	**7,387**

6 Conclusions and Recommendations

The results of the analysis show significant potential improvement in terms of fuel consumption savings through several variables. The effects vary throughout the variables. First of all, the total effect of drivers' behaviour effects range is higher than 7 litres. The result of the research demonstrates that the drivers have an enormous impact on the fuel consumption and may influence it in a positive or negative way. The difference between the impact that the most and least efficient drivers have is more than 7 litres. This means that it is crucial for truck operating companies to focus on driver education and/or motivation with the aim of improving fuel economy. This may result in lower total costs of company. The average fuel consumption of trucks operated by PEVAS SK is 37.07 litres per 100 km. An improvement in consumption by 3.7 litres is equal to 9.98% decrease in fuel consumption. Therefore, it would result in 9.98% decrease in cost of fuel. This means that the best drivers currently consume almost 10% less fuel than average. On the other hand, the least efficient drivers consume almost 10% more fuel than average drivers. Assuming that the fuel cost represents 30 – 40% of total operating costs of trucking companies, there is a potential in lowering the total operating costs through improvement of fuel consumption of the inefficient drivers by 3 – 4%, if the average consumption is decreased by 10%. Hypothetically, in the best case scenario, if the least efficient drivers improve their driving skills and drive as efficiently as the best drivers, the operating costs of their trucks may decrease by 6 – 8%.

Nonetheless, it is not always easy to change human behaviour and habits. Therefore, to suggest the best factors to focus on with intention of improvement of the fuel economy, the variables with highest potential should be prioritized. As a result, these variables with the highest potential should be considered first in the education process when stressing out the importance of fuel consumption. These are as follows:

1. Idle ratio
2. High RPM ratio
3. Cruise ratio
4. High speed ratio

Therefore, the highest potential in improvement fuel economy is in the control of idle time. The range of effects of drivers controlling idle time is almost 2.5 litres what means that the efficient drivers keep the engine running while standing at a parking lot much less that the inefficient drivers. This can be also associated with using other appliances while standing at a parking lot, such as heating or air conditioning. Therefore, there is the highest potential in improvement of fuel consumption through motivating drivers to turn off the engine while standing still. Not only the truck does not make any value while standing still, but what is more the fuel is consumed and the operating costs grow. As the range of effects and therefore the potential of improvement of fuel consumption are the highest among all the variables, the truck operators should primarily communicate the problem of idle time to their drivers. The importance and control of idling should be emphasized. The education and knowledge provision of drivers about the potential negative effect of too much or positive impact of no idling on fuel consumption should be the first step towards more economic driving and lower fuel costs.

As soon as the high potential of idle time improvement is stressed, the operators should focus on training of optimal shifting and avoiding unnecessary high RPM. The high RPM effects represent the second largest range among the drivers' effects. Therefore, there exists a large gap and potential improvement of the consumption. High RPM are often used while accelerating rapidly and driving aggressively. On the other hand, the high RPM may be also associated with incorrect gear shifting by inexperienced or not well trained drivers. The difference between the most and least efficient user of high RPM is 1.85 litres. For that reason, motivating the drivers not to drive at RPM higher than 1550 can be the second most beneficial step in reaching the goal of improved fuel efficiency. Not only training and education but also financial motivation may be of help in these issues.

The next highest potential improvement in cost of fuel can be reached through cruise control use. Yet again, the range of effects is larger than 1 litre. The difference between the most and least economic drivers is 1.25 litres. The use of cruise control is a very simple and effective tool to minimize speed variations and aggressive acceleration. However, it seems that many drivers still do not identify themselves in applying it to their driving (Figure 20). Regarding the use of cruise control, the primary aim should be to motivate the drivers who do not use the cruise control at all (or use it very little) to start taking advantage of this tool. An option how to demonstrate the advantages of cruise control is to mix the drivers in one truck who do not use the cruise control with those who are keen on using it.

Last and the least potential in improvement among the factors is in the variable of driving at high speed. The range between effects on consumption between the best and worst drivers in terms of driving over 85 km/h is 0.99 litre.

And finally, the rest of the factors, which are not measured in the analysis, but have direct effect on fuel consumption are included in the drivers' dummy variables. The dummies include all the factors such as aggression in acceleration, coasting style, anticipation of situation ahead, shifting style or braking style, etc. Drivers directly influence the consumption through the above mentioned factors in certain way. The difference between the most and least efficient drivers is 7.4 litres. Even though there is a large potential of improving the diesel consumption through drivers' direct effect, it is not apparent how particularly the improvement can be reached. These direct effects are not observed and therefore cannot be analysed. It would be of great advantage if such variables were measured while driving and available for research.

6.1 Recommendations

For the above mentioned reasons it is advisable to focus primarily on the management of idle time in order to decrease amount of fuels consumed ineffectively. This can be done by explanation of the matter and education of the drivers about the significance of turning off the running engine and motivating them to do so by a variety of financial or non-financial incentives. The same way drivers can be stimulated to improve the consumption by driving less at high RPM and using cruise control more often. Moreover, there is a considerable difference between the drivers' use of cruise control. Some drivers do not take advantage of it at all. It is important to motivate the drivers who do not use it at all to realize the benefits of this tool and to start implementing it into their driving. One of the potential measures can be mixing different drivers of different style in one truck in order to encourage them to learn from each other. For instance, a driver who uses the cruise control a lot with one who never takes advantage of this tool could be driving in the same truck.

For governments and transport organizations it is also advisable to promote the fuel efficiency through education of the drivers about the effects and significant importance of idling time as well as cruise control use of driving in high rotations. For instance, the public awareness of the benefits of cruise control and turning off the engine with positive impact on costs as well as environment might be created through several marketing strategies.

6.2 Limitations

With regards to limitations in this research it is advised to elaborate these issues on the effects on consumption in more detail. An analysis of same basis with more variables which were not available in this research would be a valuable addition to this research. In order to differentiate between the uncontrollable factors, owners' decision and drivers' factors, the detail characteristics of routes are advised to be included. If the specific routes were differentiated it would be helpful for the control of additional routes' factors and the results of this analysis would be even more precise. In this way some of the missing variables can be added to the model. As well as it would be recommended to include other driver specific variables. However, the variables such as brake usage, level of acceleration or use of cabin appliances are currently not observed and impossible to measure. Furthermore, the variable of average speed does not have much explanatory power as there is a lack of control variables in respect to route specifications.

Last but not least, it is strongly advised to follow up on this study and elaborate more on the differences among drivers in terms of their age, experience, education, etc. This can be done in order to observe the effects of these differences among different drivers. The suggested variables might have various effects on driving behaviour and therefore, it would be of great advantage for the trucking companies to know what kind of drivers to employ to drive their trucks.

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8 List of Abbreviations

CEO – Chief executive officer

CI – Confidence Interval

CR – Czech Republic

Km/h – Kilometres per hour

MPEG – Mileage per gallon

RPM – Rotations per minute

SEM – Structural equation modelling

SR – Slovak Republic

UK – United Kingdom

9 List of Figures and Tables