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Sustainable Transportation

Škoda Auto University

Pre-assignment
Sustainable Transportation – Sustainable Aftersales
Spring 2022

Funded by the European Union

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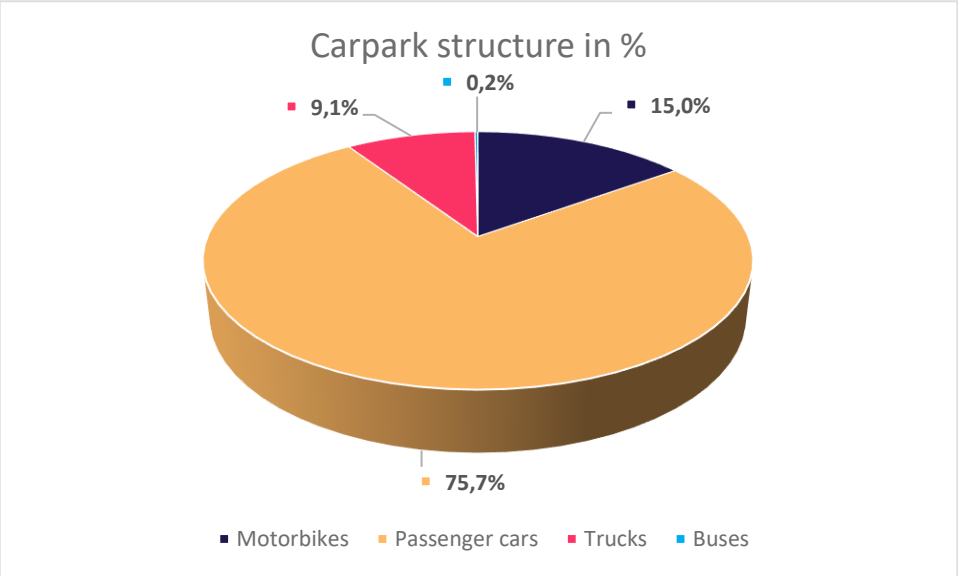
1 STRUCTURE OF VEHICLE POPULATION

1.1 Total number of vehicles

In Czechia is increasing trend of number of vehicles in total since 1933. In 2020 there are 9,772 thousand vehicles in total. However, in 2020 there is a slight dip in new registrations approximately by 49,8 thousand. Specifically, the following: passenger cars decreased by 18,8 %, light commercial vehicles by 16,1 % and vans by 25,3 %. Hence in category of buses we can see an increase by 12 % and motorbikes by 14,8 %.

According to latest statistics, the largest group of vehicles are passenger cars with 6 049 000. The number of motorbikes is 1 196 000 thousand, trucks 728 000 and buses 19 000.

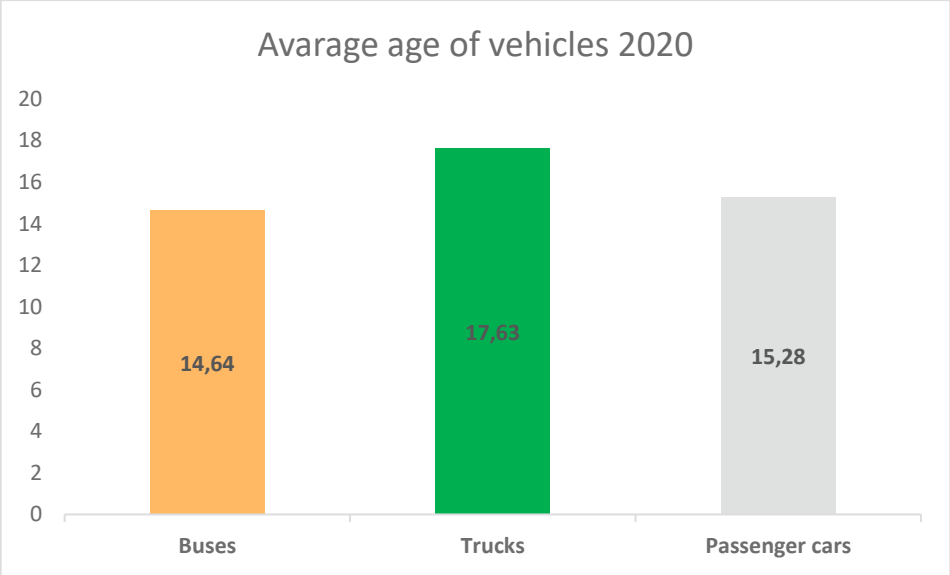


Picture 1 Carpark structure in %

Source: Jandová, 2021

1.2 Average age

1.2.1 Average age of vehicle types in 2020

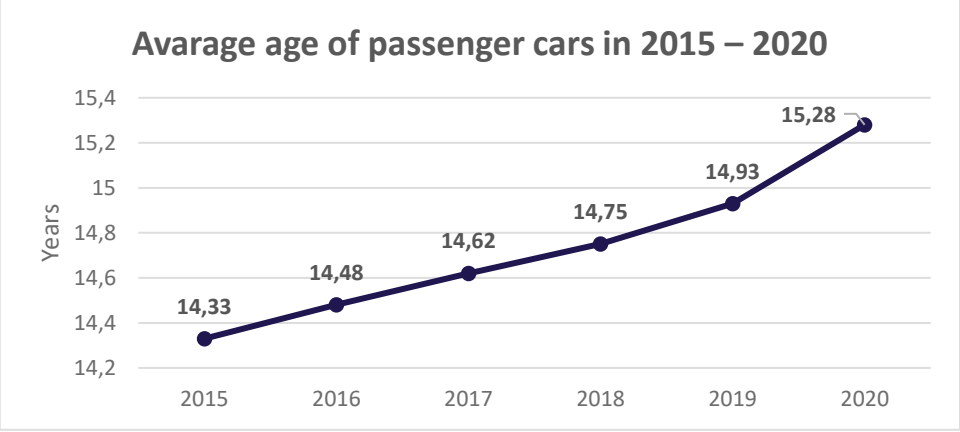


Picture 2 Avarage age of vehicle in 2020

Source: autosap.cz

1.2.2 Average age of passenger cars in 2015 – 2020

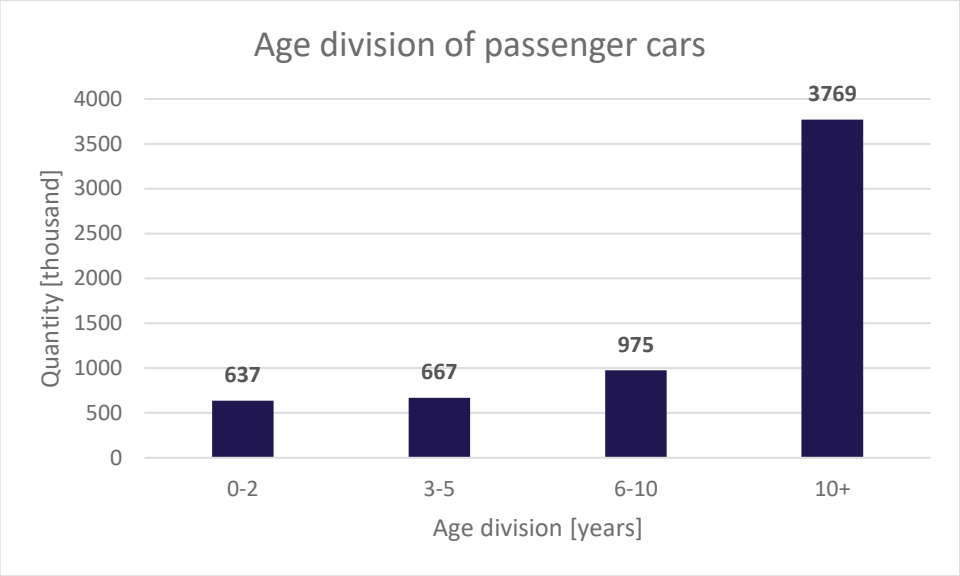
Latest data shows, that average age of passenger cars is slightly climbing. It means that the passenger cars population is getting older and older. This fact is evident from the Picture 3.



Picture 3 Avarage age of passenger cars in 2015-2020

Source: Jandová, 2021

1.2.3 Age division of passenger cars

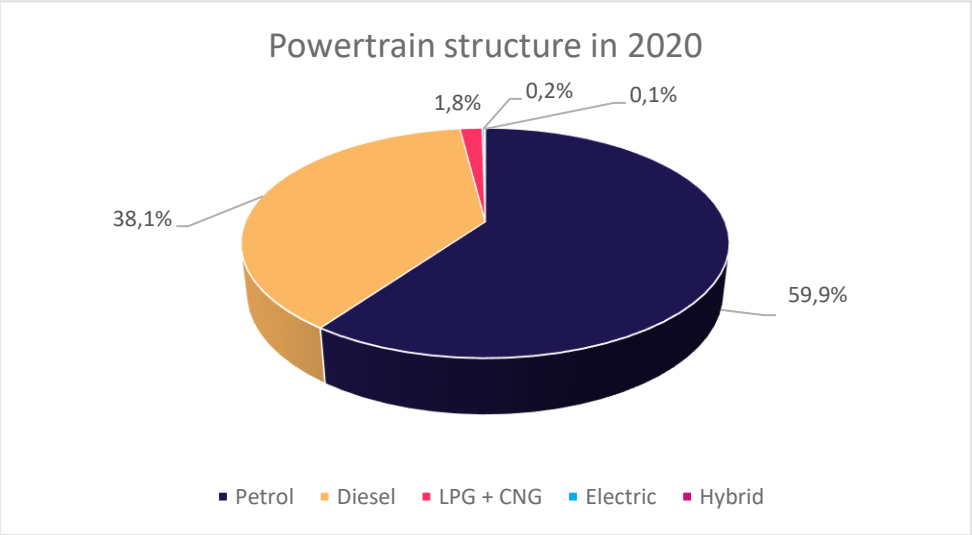


Picture 4 Age division of passenger cars

Source: Jandová, 2021

1.3 Structure of powetrains in 2020

The most common powertrains in 2020 were combustion engines. For clarity are numbers of vehicles written in thousands. Specifically, petrol 4 862 pcs., diesel 3 093 pcs., LPG 113 pcs. and CNG 20,8 pcs., electric 7,3 pcs. and hybrid 7,3 pcs.

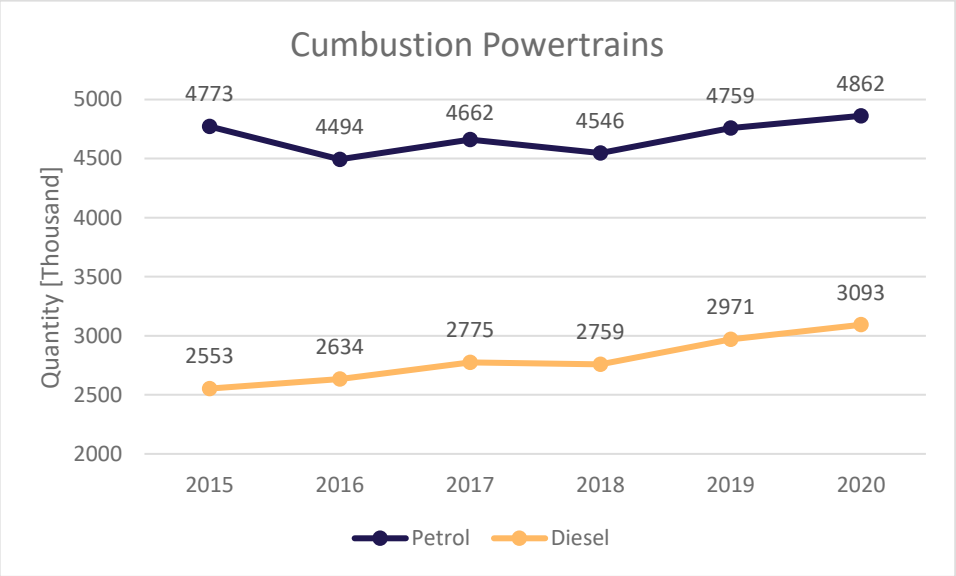


Picture 5 Powertrain structure in 2020

Source: Jandová, 2021

1.3.1 Combustion powertrain

At following diagram, you can see evolution of numbers of cars with combustion engines. As you can see the petrol powertrains fluctuated since 2015 while the diesels steadily increased.

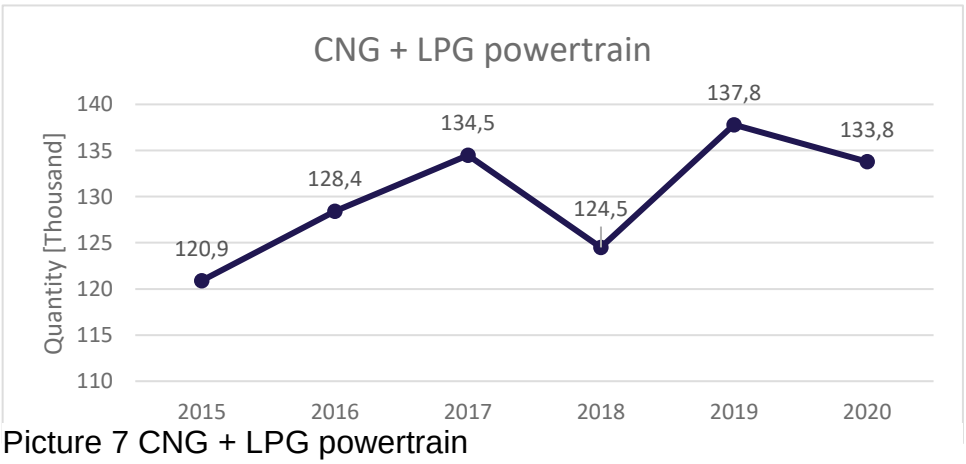


Picture 6 Combustion powetrains

Source: Jandová, 2021

1.3.2 CNG + LPG powertrain

The graph show figures of LPG + CNG from the period between 2015 and 2020. From 2015 quantity of these powertrains went up to 2017. Between the years 2017 and 2018 there was a plummet followed by rocket to the peak in 2019. After 2019 we can see gradual decrease.

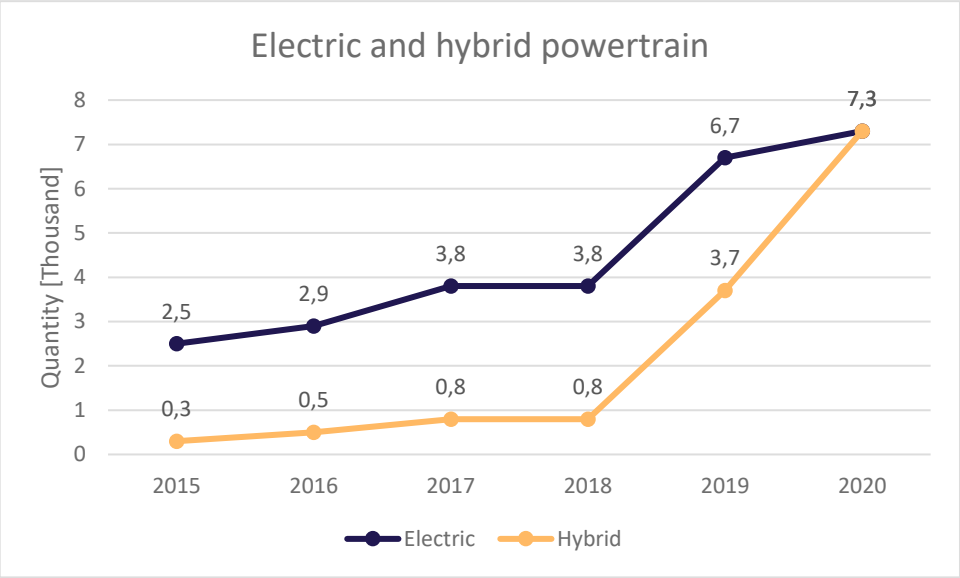


Picture 7 CNG + LPG powertrain

Source: Jandová, 2021

1.3.3 Electric and hybrid powertrain

Following diagram show figures of electrical and hybrid powertrains. When you look at the electric line you can see steady growth. However, when you look at hybrid line it remained stable in the period from 2015 to 2018. In 2018 there is a rocket which reached the same peak as electric cars.



Picture 8 Electric and hybrid powertrain

Source: Jandová, 2021

1.4 Mileage

The data are only for ŠKODA AUTO. Mileage is not recorded in the Czech Republic.
The average mileage is only indicative, it is found only on samples of cars that go to ŠKODA AUTO authorized services. They differ in individual years depending on whether they are owned by a company or a person. In the last two years, Covid-19 and the change in long-term behavior of individual customer groups have also had a significant impact on the average mileage.

Year	Fleet – Km average	Privat – Km average
2017	24 561	16 897
2018	30 413	16 722
2019	25 564	17 903
2020	22 189	11 443
2021	12 563	18 640

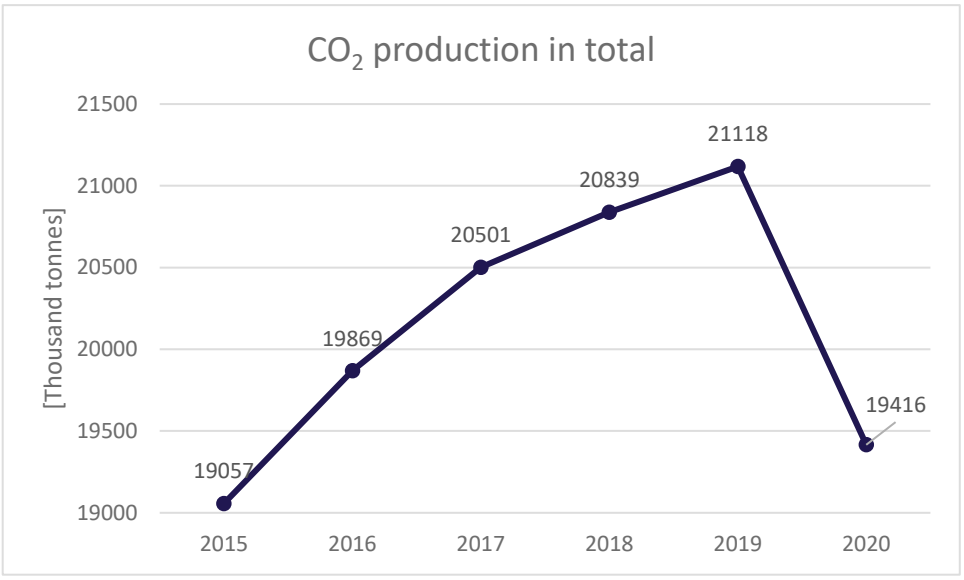
Table 1 – Mileage

Source: Internal documentation of Skoda Auto a.s.

1.5 CO_2 emissions

Carbon dioxide (CO_2) emissions are reported in grams per kilometre driven with combined consumption determined according to the new WLTP (Worldwide Harmonized Light-Duty Vehicles Test Procedure) measurement cycle. The US environmental Protection Agency's EPA calculation method can be used to calculate the amount of CO_2 produced by burning 1 litre of fossil fuel, and we need to add 1,6 kWh of electricity needed for refining to fossil fuels. To calculate emissions from electricity production, Czech source of energy mix, which is based on 411 grams of CO_2 per kWh produced and the European average is approximately 256 g CO_2 per kWh. However, if you charge an electric car only in the form of solar energy, the one kWh emits 65 g of CO_2. Electric cars are better for climate than conventional fossil fuels cars. Exhaust emissions, especially CO_2 emissions, are on the main topics of our time.

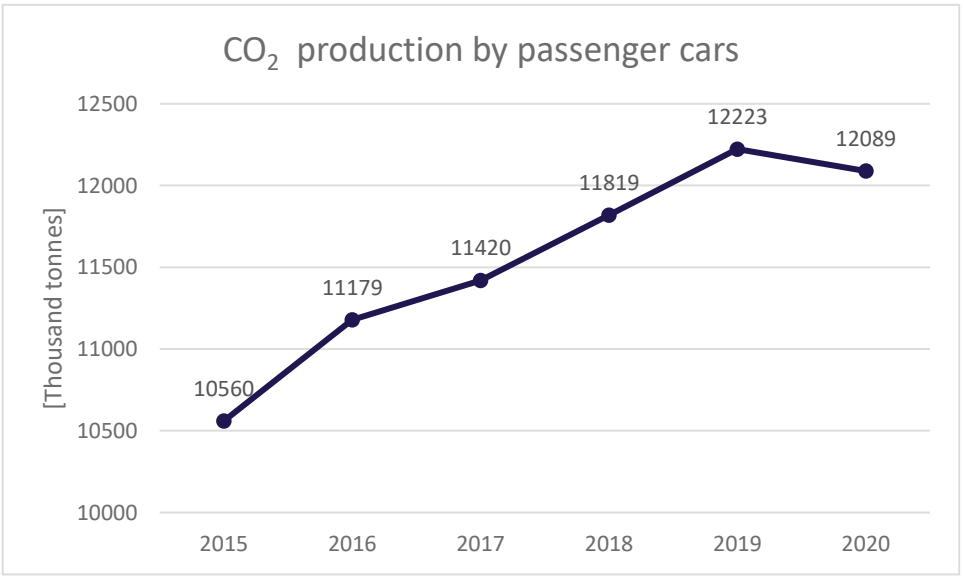
1.5.1 CO_2 emission by mode of transport (Total)



Picture 9 CO_2 production in total

Source: Jandová, 2021

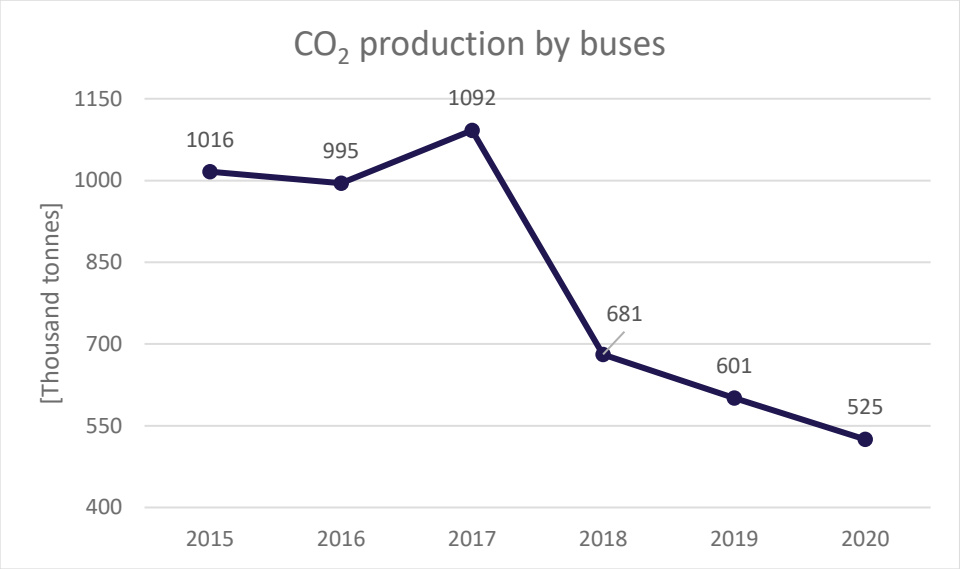
1.5.2 CO_2 emission produced by passenger cars



Picture 10 CO_2 production by passenger cars

Source: Jandová, 2021

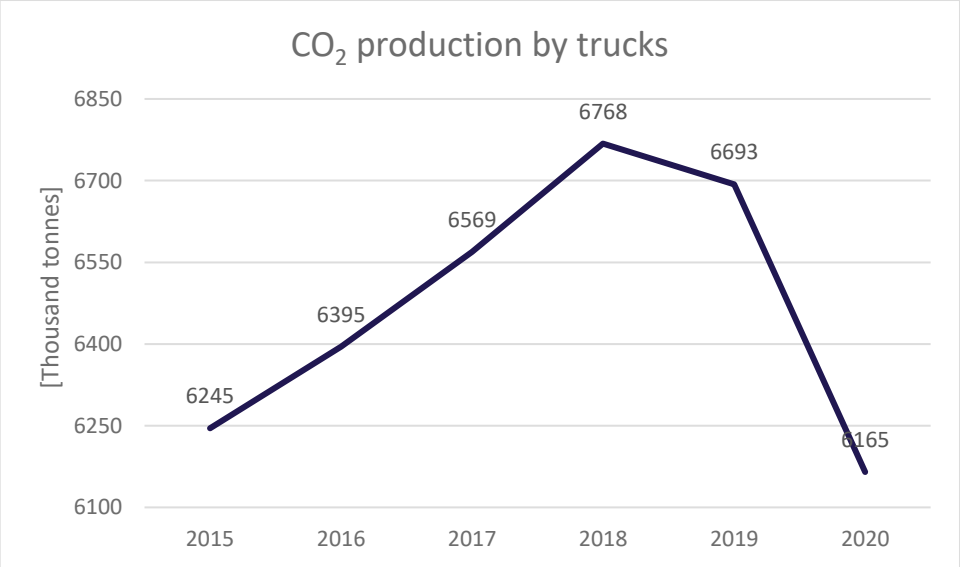
1.5.3 CO_2 emission produced by buses



Picture 11 CO_2 emission produced by buses

Source: Jandová, 2021

1.5.4 CO_2 emission produced by trucks

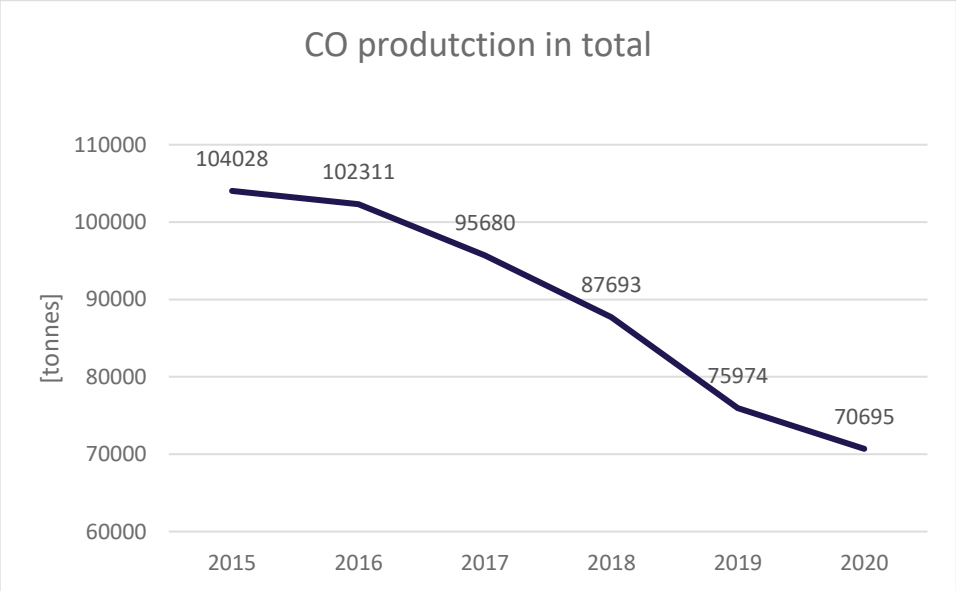


Picture 12 CO_2 production by trucks

Source: Jandová, 2021

1.6 CO emissions

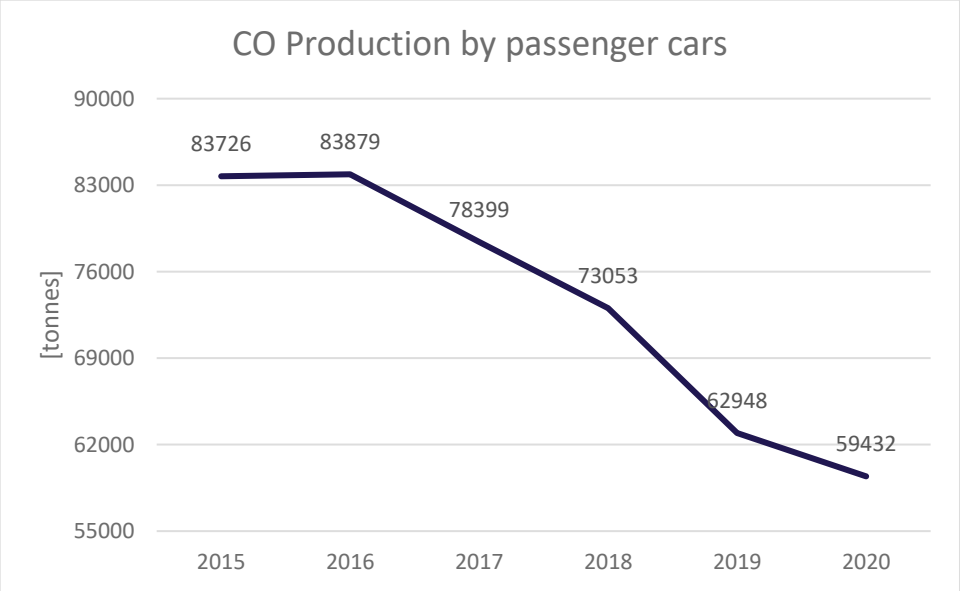
1.6.1 CO Emission by mode of transport (Total)



Picture 13 CO production in total

Source: Jandová, 2021

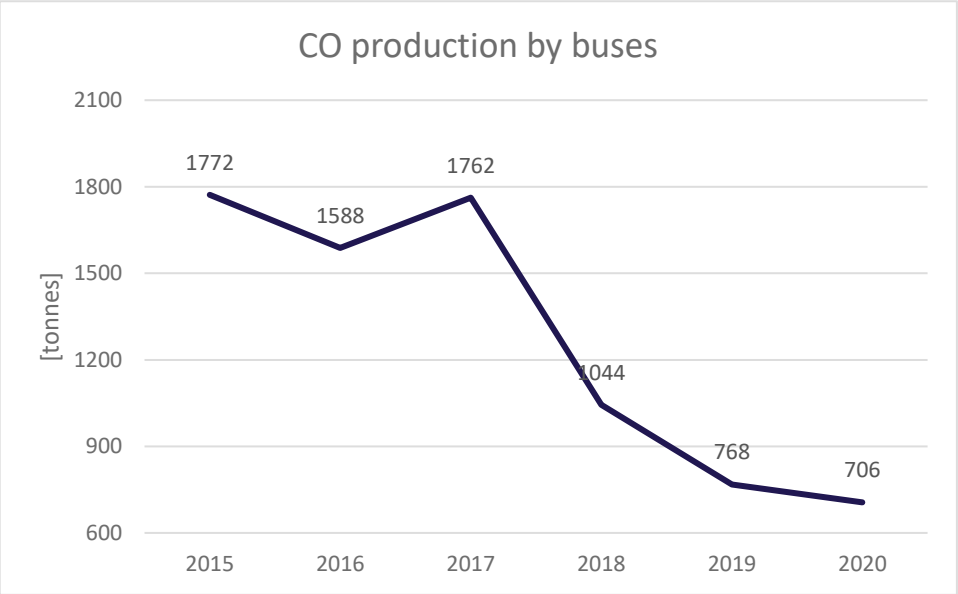
1.6.2 CO Emission produced by passenger cars



Picture 14 CO production by passanger cars

Source: Jandová, 2021

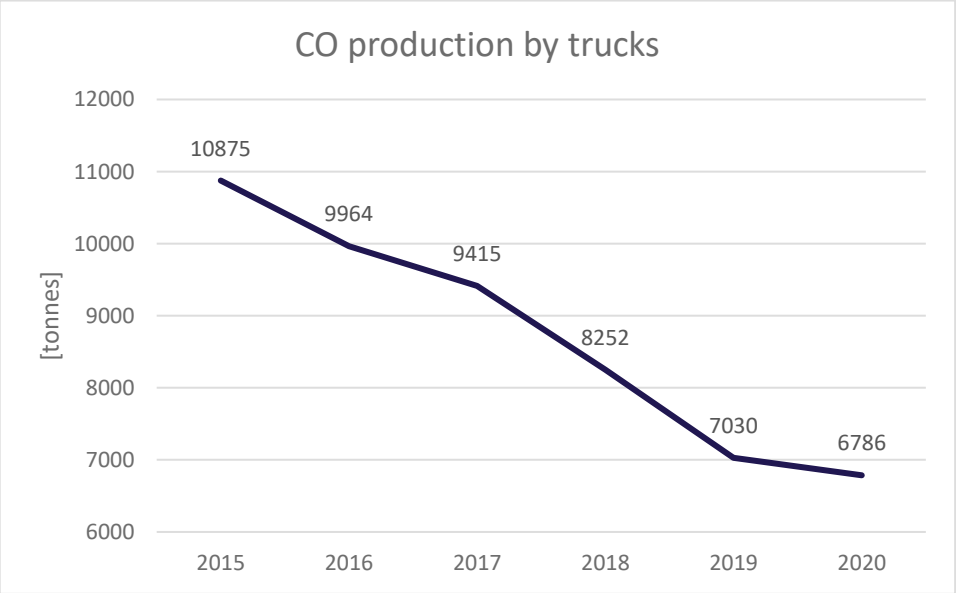
1.6.3 CO Emission produced by buses



Picture 15 CO production by buses

Source: Jandová, 2021

1.6.4 CO Emission produced by trucks

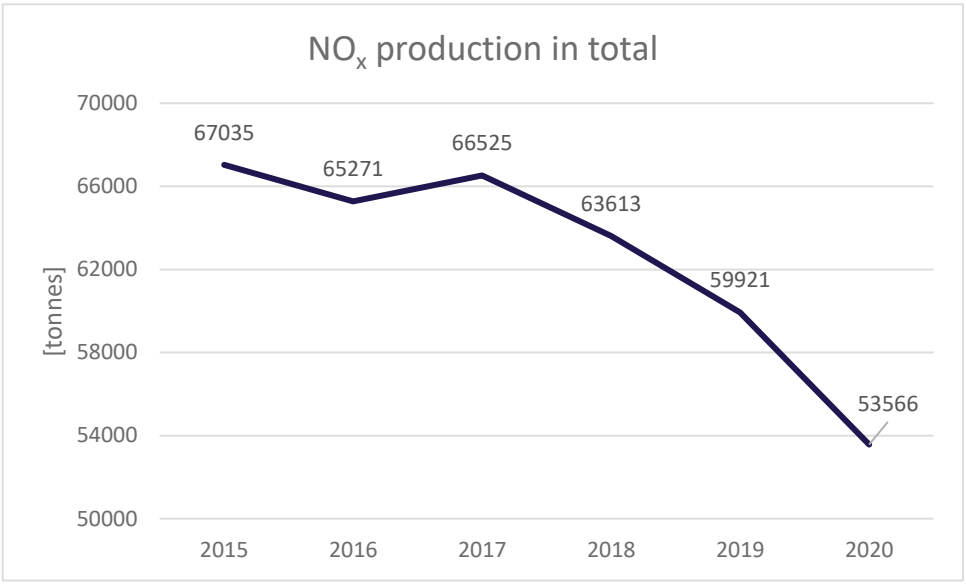


Picture 16 CO production by trucks

Source: Jandová, 2021

1.7 NOx emissions

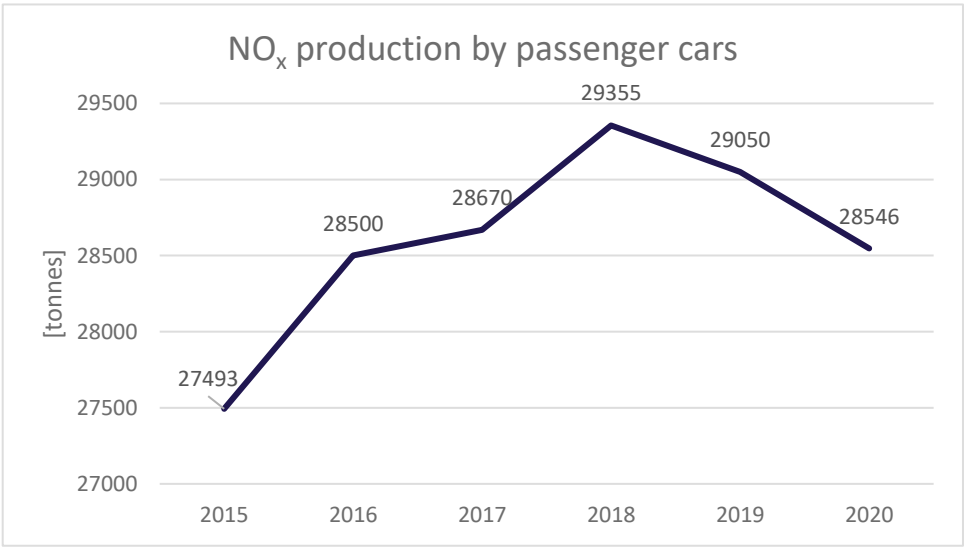
1.7.1 NO_x production by Mode of Transport (Total)



Picture 17 NO_x production in total

Source: Jandová, 2021

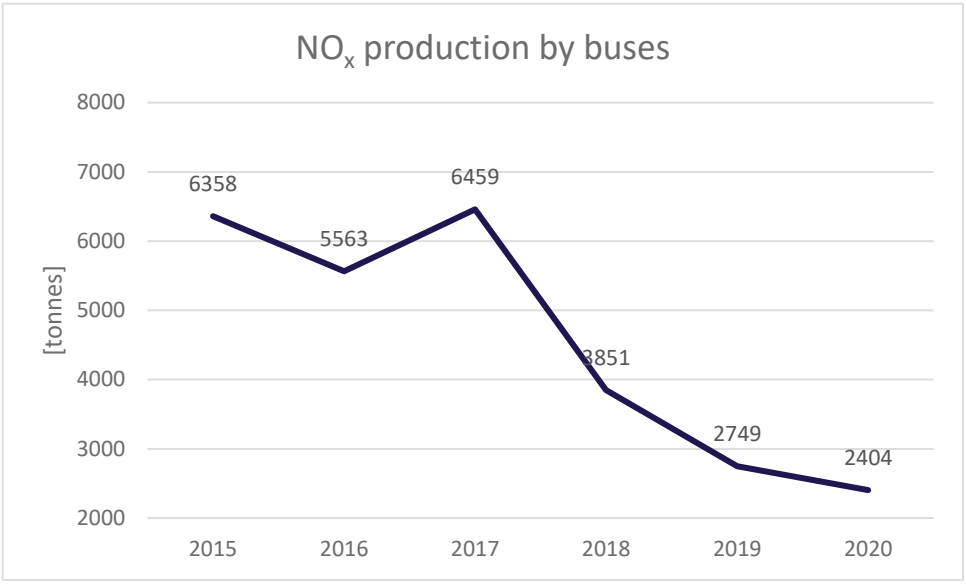
1.7.2 NO_x Production by Passenger Cars



Picture 18 NO_x production by passenger cars

Source: Jandová, 2021

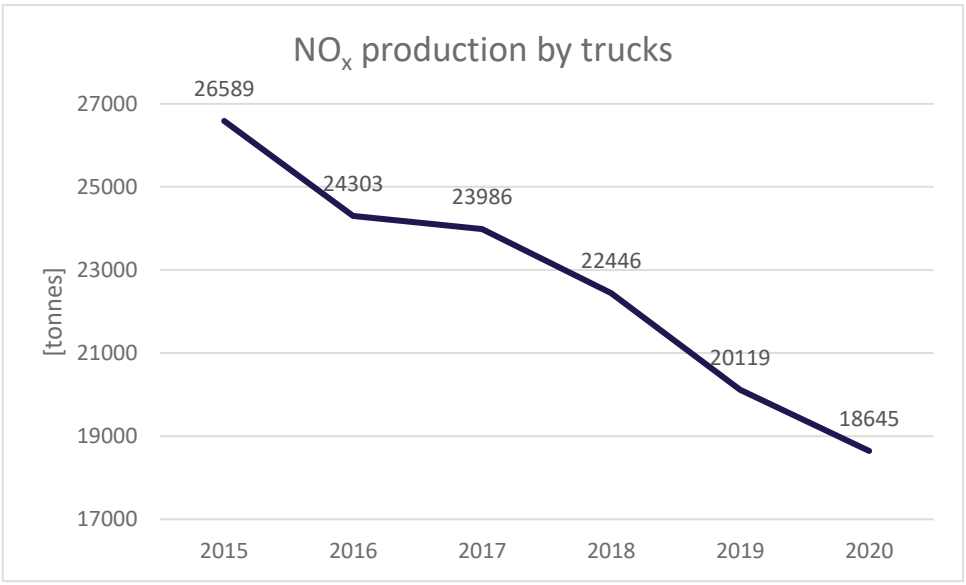
1.7.3 NO_x Production by Buses



Picture 19 NO_x production by buses

Source: Jandová, 2021

1.7.4 NO_x Production by trucks

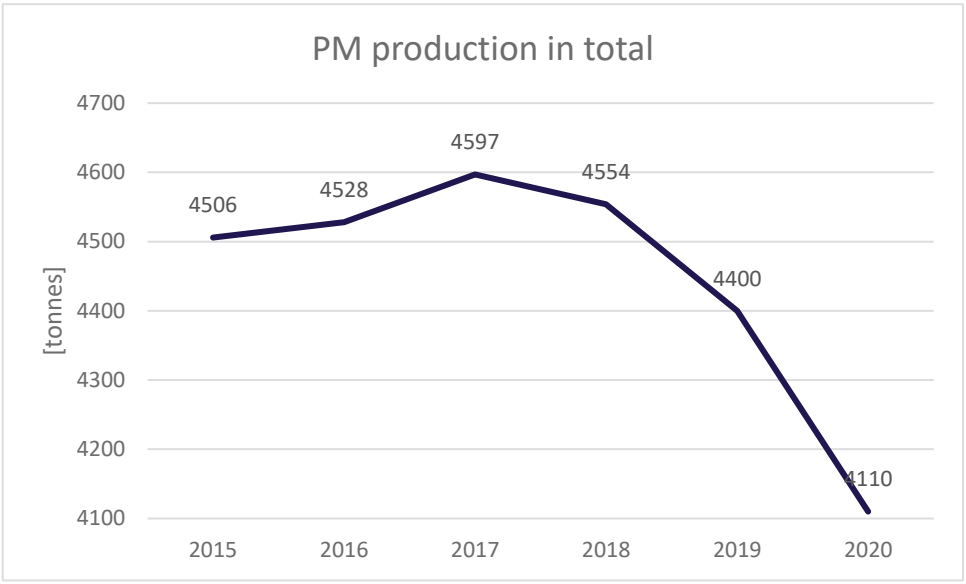


Picture 20 NO_x production by trucks

Source: Jandová, 2021

1.8 PM emissions

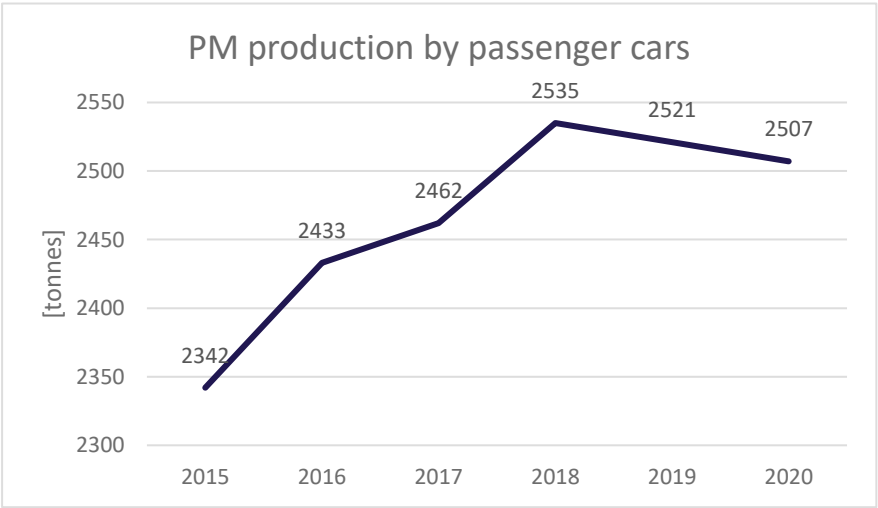
1.8.1 PM Production by Mode of Transport (Total)



Picture 21 PM production in total

Source: Jandová, 2021

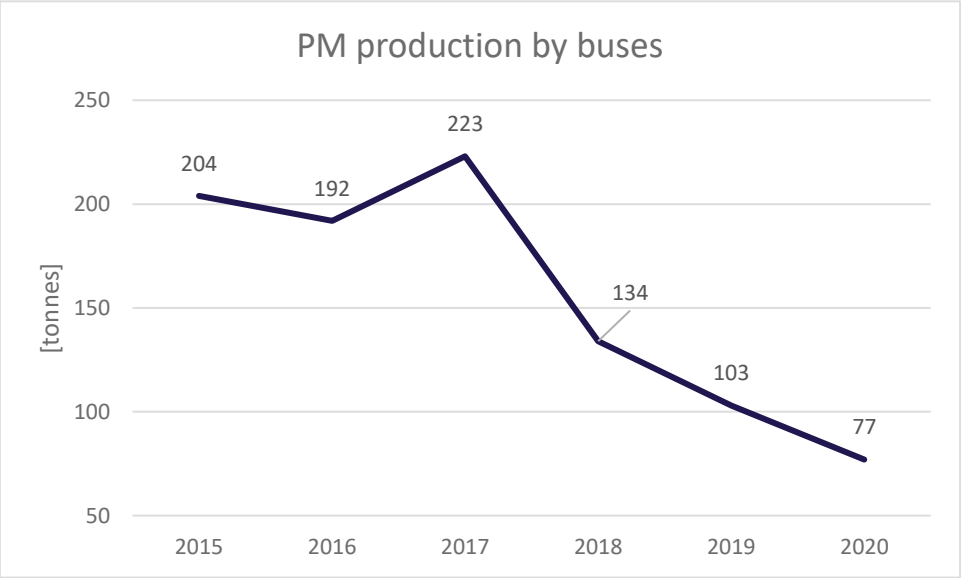
1.8.2 PM Production by passenger cars



Picture 22 PM production by passenger cars

Source: Jandová, 2021

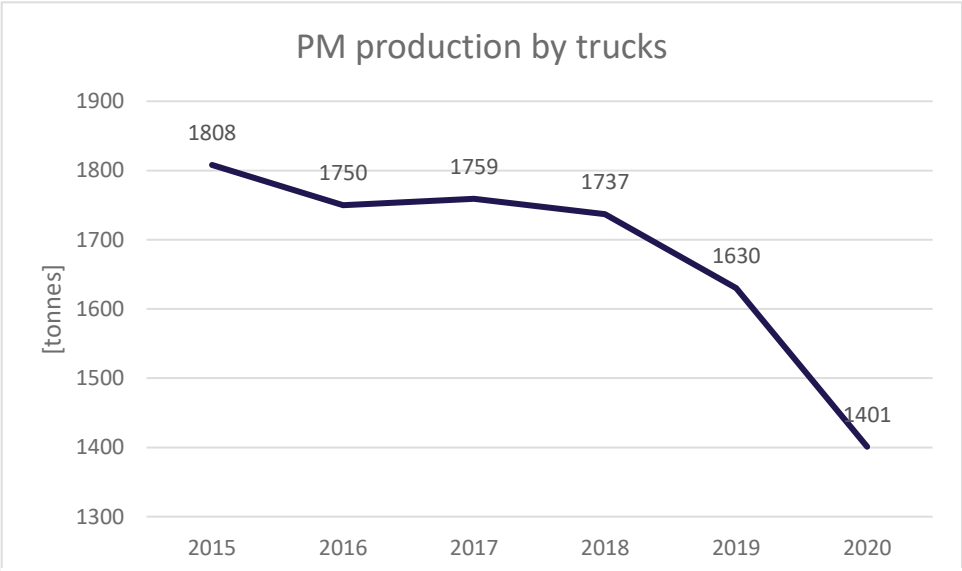
1.8.3 PM production by buses



Picture 23 PM production by buses

Source: Jandová, 2021

1.8.4 PM production by trucks



Picture 24 PM production by trucks

Source: Jandová, 2021

2 REGULATORY GUIDIANCE AND ENERGY DISTRUBUTION NETWORK

2.1 Traffic and vehicle taxation basis

This chapter is about taxation basis and its division. In Czech Republic there is two types of taxis. *Regular taxis*, and *taxis of the use of vehicles*. In regular taxis can be found road tax, road tolls and time fee for using highways (roads which name starts with D – for example D1). In taxis of the use of vehicles, can be found taxis depends on fuel type.

In some counties it can be usually found one time tax (for example in Denmark), where people must pay for new vehicle registration. In Czech Republic there are no one one-time taxis, but just administrative fee in amount of 33 € (Finance.cz, 2020).

2.1.1 Regular taxis

As was mentioned before, in regular taxis can be found road tax, road tolls, and time fees for using highways. It was decided that it will be started with road tax.

Road tax is a tax that must be pay if someone registered vehicle for business use. Amount of this tax for cars (per year) can be found in Table 2. Amount of this tax for trucks (per year) can be found in Table 3. Prices for trucks also depends on total weight for axles.

Road toll is a tax used only for trucks and buses with very complicated division mainly by road type, but it is divided also by time of the day, number of axles, total weight, category of vehicle and emission class of vehicle. Amount of this tax can be found in Table 4 and map of roads with road toll can be found in Picture 25.

Time fee for using highways is a fee for vehicles up to 3,5 tons. If someone with this vehicle wants to use highway is obliged to pay this fee. Division of this fee is shown in Table 5. Standard price is for regular vehicles with combustion engine (expect motorcycles, they are fee exemption). Eco price is for vehicles with engine powered by CNG or biomethane.

Engine size [cm^3]	Amount of tax [€]
Up to 800	50
From 800 to 1250	75
From 1250 to 1500	100
From 1500 to 2000	120
From 2000 to 3000	150
From 3000	170

Table 2 - Amount of road taxes for cars

Source: Kurzy.cz, 2021

Number of axles	Amount of tax [€]
1	70 - 290
2	70 - 1400
3	70 - 1530
4+	250- 1340

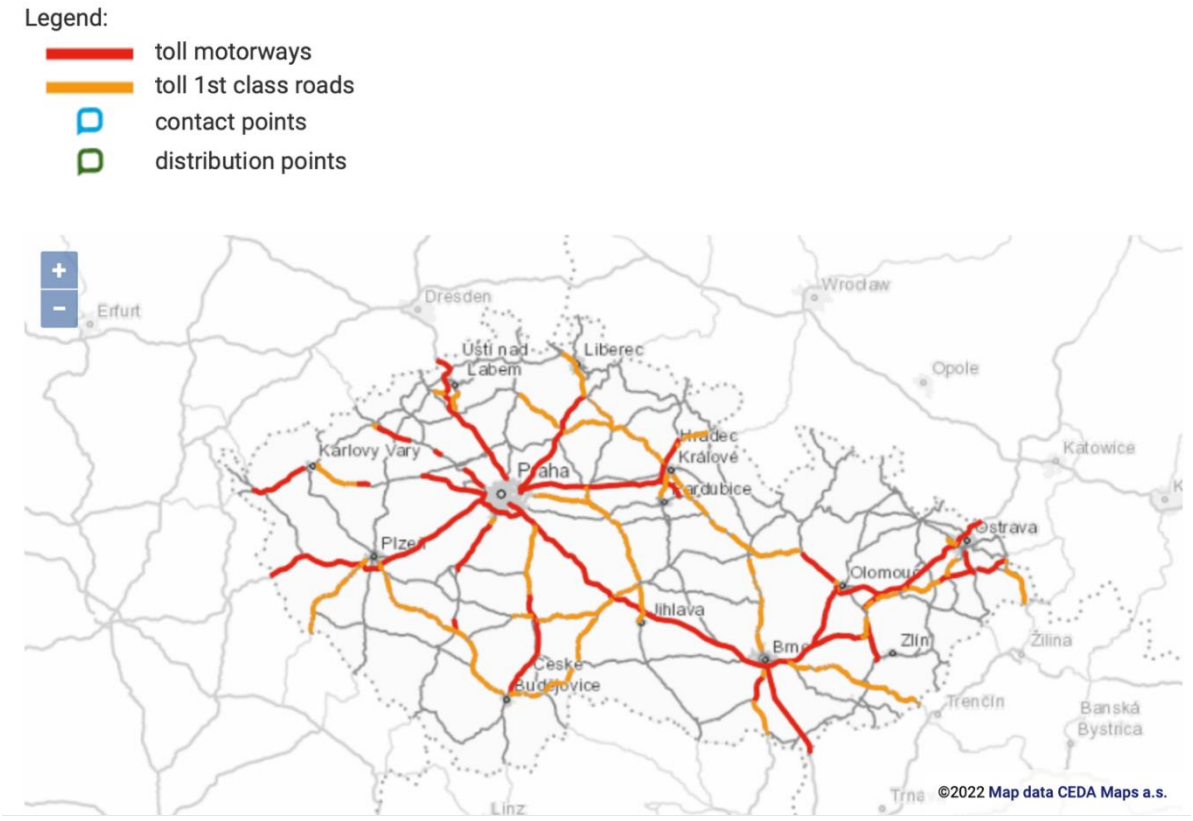
Table 3 - Amount of road tax for trucks

Source: Kurzy.cz, 2021

Emission class	***EURO 0 - II***			***EURO III - IV***			***EURO V***			***EURO VI + EEV***		
Number of axles	***2***	***3***	***4+***	***2***	***3***	***4+***	***2***	***3***	***4+***	***2***	***3***	***4+***
Highways and motorways	13,5	23,1	33,3	11,4	19,5	28,2	7,4	12,7	18,3	6,8	11,5	16,7
Friday 15-20	17,2	32,8	47,6	14,5	27,8	40,2	9,4	18,04	26,1	8,6	16,4	23,8
1st class roads	6,4	11,1	15,9	5,4	9,3	13,4	3,5	6,1	8,7	3,2	5,5	7,9
Friday 15-20	8,1	15,9	22,7	6,8	13,4	19,2	4,5	8,7	12,4	4,05	7,9	11,3
Buses	5,6			4,7			4,2			3,2		

Table 4 - Amount of road tolls (€/100 km)

Source: Kurzy.cz, 2021



Picture 25 - Map of roads with road toll

Source: Ředitelství silnic a dálnic, 2019

Period	**1 year**	**30 days**	**10** days
Standard price [€]	60	18	13
Eco price [€]	30	9	6,5

Table 5 – Amount of time fees

Source: edalnice.cz, 2022

2.1.2 Taxis of use vehicle

In this group of taxis can be found only taxis depends on fuel. In Czech Republic there are five kinds of fuels in general. It is BA (Natural), NM (Diesel), LPG, CNG, hydrogen and electricity. Amounts of these taxes can be found in Table 6.

	Amount of tax [€]	
BA	519,5	1000 litres
NM	420,6	1000 litres
LPG	159,1	ton
CNG	10,7	MWh
Electricity	1,1	MWh

Table 6 - Amount of taxis depends on fuel

Source: ČAPPO, 2021

Besides of taxis depends on fuel in Czech Republic there is also value added tax for fuels. For better imagination another table was prepared. In this table amount of value added tax for chosen countries can be found.

Country	Value added tax
Czech Republic	21 %
Germany	19 %
Finland	24 %
Belgium	21 %

Table 7 - Amount of value added tax for chosen countries

Source: STORMWARE, 2021

2.2 Vehicle inspection

In Czech Republic there is one mandatory inspection, which must be done periodically. Length of period depends on the vehicle type, it can be found in Table 8.

Course and conditions are regulated by Act number 56/2001 Collection, on the conditions of operation of vehicles on roads.

Inspection itself is divided into two parts. First part include measurement of emissions and second part is technical inspection itself. Second part includes visual and technical evaluation. Servicemen can find three types of faults – small, hard, and dangerous. If they find small fault(s), owner can still pass. If they find hard fault(s), owner has 30 days to fix this fault(s) and after that, he can repeat the inspection. If they find dangerous fault(s), owner cannot use this car on public roads and car must be towed away.

Vehicle type	First inspection [years]	Second (and next) inspections [years]
Car	4	2
Bus	1	1
Truck up to 3 500 kg	4	2
Truck over 3 500 kg	1	1
Motorcycle	6	4
Taxi	1	1
Rented vehicles	1	1

Table 8 - Lenghts of inspection periods

Source: Ministry of Transportation, 2021

Prices of inspections are divided into two groups – prices for technical inspection and prices for emissions measurement. Prices for inspections are not given by law, but it depends on station itself.

Average prices for technical inspection can be found in Table 9 , and average prices for emissions measurement can be found in Table 10.

Vehicle type	Car	Bus	Truck up to 3 500 kg	Truck over 3 500 kg	Motorcycle
Price [€]	40	65	40	65	25

Table 9 - Prices for technical inspections

Weight	Up to 3 500 kg		Over 3 500 kg	
Fuel	Gasoline	Diesel	Gasoline	Diesel
Price [€]	30	40	35	60

Table 10 - Prices for emissions measurement

Most common causes of inspection failure

In this section can be found most common causes of inspection failure by technical and measurement inspection. (DC.gov, 2022)

Emission measurement

- Air to fuel mixture can be incorrect
- Vacuum leak present
- Ignition time can be incorrect
- Catalytic converter may be clogged, missing or ineffective

- Dirty of contaminated engine oil
- Clogged air filter

Technical inspection

- On Board Diagnostic failure
- Rusty brake disc(s)
- Cracks in the windshields
- Axle leakage
- Parking brake malfunction
- Poorly bright lights
- Objects in the drivers view
- Missing mandatory equipment
- Missing or bad documents for the vehicle (for example wrong VIN)
- Bad steering geometry
- Noise
- Leaking of liquids

Requirements for vehicle inspector

Person who wants to work at station of technical inspection must have “professional certificate of inspection technician”. To obtain this certificate, person must accomplish some conditions:

- High school with diploma, or apprenticeship in a field related to automotive
- At least 3 years of experiences in automotive
- Is a holder of driving license in at least B category (cars)
- Must have passed technical inspector’s course
- Must have clean criminal record
- Must not be a conflict of interest

2.3 Energy distribution

In this chapter all things about energy and its distribution can be found. In Czech Republic there are basically 5 types of fuels – gasoline (E), diesel (B), CNG, LPG and electricity.

2.3.1 Fuel types

GASOLINE

Gasoline is divided into sub-groups. One distribution can be by octane number, where higher is better. For example, Natural 95 is gasoline with octane number 95. Most common octane numbers are 91, 95, 98 and 100.

Another distribution can be by volume of biocomponent content, where lower is better. Most common volumes are E5 (5 % biocomponent content), E10 (10 % biocomponent content), and E85 (85 % biocomponent content).

You can also have gasoline with additives, which may improve consumption, engine life, power, and so on.

DIESEL

Diesel is also divided into sub-groups, but only by volume of biocomponent. Most common volumes are B5 (5 % biocomponent content) and B7 (7 % biocomponent content). You can also find diesel marked as XTL, which means synthetic fuel.

Diesel can be found with additives too.

CNG

CNG is a shortcut for Compressed Natural Gas. It has no division. CNG is considered as more eco variant of fossil fuels. In Czech Republic are vehicles with this fuel benefited over others. They are exempt from road-tax, price for time fee (see chapter 2.1) is half, and CNG has also the lowest tax for fuel itself.

LPG

LPG is a shortcut for Liquified Petroleum Gas. Same as CNG is LPG considered as more eco variant of fossil fuels. This isn’t only similarity with CNG. LPG is also benefited – exemption from road-tax, lower price for time fee and lower tax for fuel itself.

There is one disadvantage, LPG reduces engine power by 5 - 10 %.

ELECTRICITY

Electrical vehicles are most favored by government. They are exempt from road tax, time fee and parking fees (in most cases).

Electrical vehicles have many disadvantages. Main disadvantage is thinner density of charging stations (800 vs 7 633). You can charge your vehicle at home, but it’s much slower.

AVERAGE PRICES FOR FUELS

Because there is very unstable situation at the market, all prices are to date 6. 3. 2022. Average price for 1 l gasoline was 1,672 €, for diesel it was 1,726 € for 1 l. Price for 1 kg CNG was 1,079 €, and for LPG it was 0,626 € for 1 l.

Prices for electricity are little bit complicated, there is low rate (for current consumed at night), high rate (for current consumed at day), and many companies providing this energy. Because of these circumstances only average price was mentioned here. Average price was 0,23 € for 1 kWh of electricity.

Summarization of all prices can be found in Table 11.

Fuel type and its volume	Average price [€]
Gasoline – 1 liter	1,672
Diesel – 1 liter	1,726
CNG – 1 kg	1,079
LPG – 1 liter	0,626
Electricity – 1 kWh	0,23

Table 11 - Average prices for fuels

Source: kurzy.cz, 2022

TAXIS FOR FUELS

Taxis for fuels depends on fuel type. Summary of taxis can be found in Table 12 and Table 13. Electricity has no excise duty, but it has electricity tax, that is the reason why there are two tables.

Fuel type	Excise duty [€/l]	Value added tax [%]
Gasoline	0,395	21 %
Diesel	0,51	21 %
CNG	0,111	21 %
LPG	0,085	21 %

Table 12 - Taxis for fuel types

Source: finance.cz, 2022

Fuel type	Electricity tax [€/MWh]	Value added tax [%]
Gasoline	1,125	21 %

Table 13 - Taxis for electricity

Source: INNOGY, 2022

2.3.2 Distribution network for fuels and energy

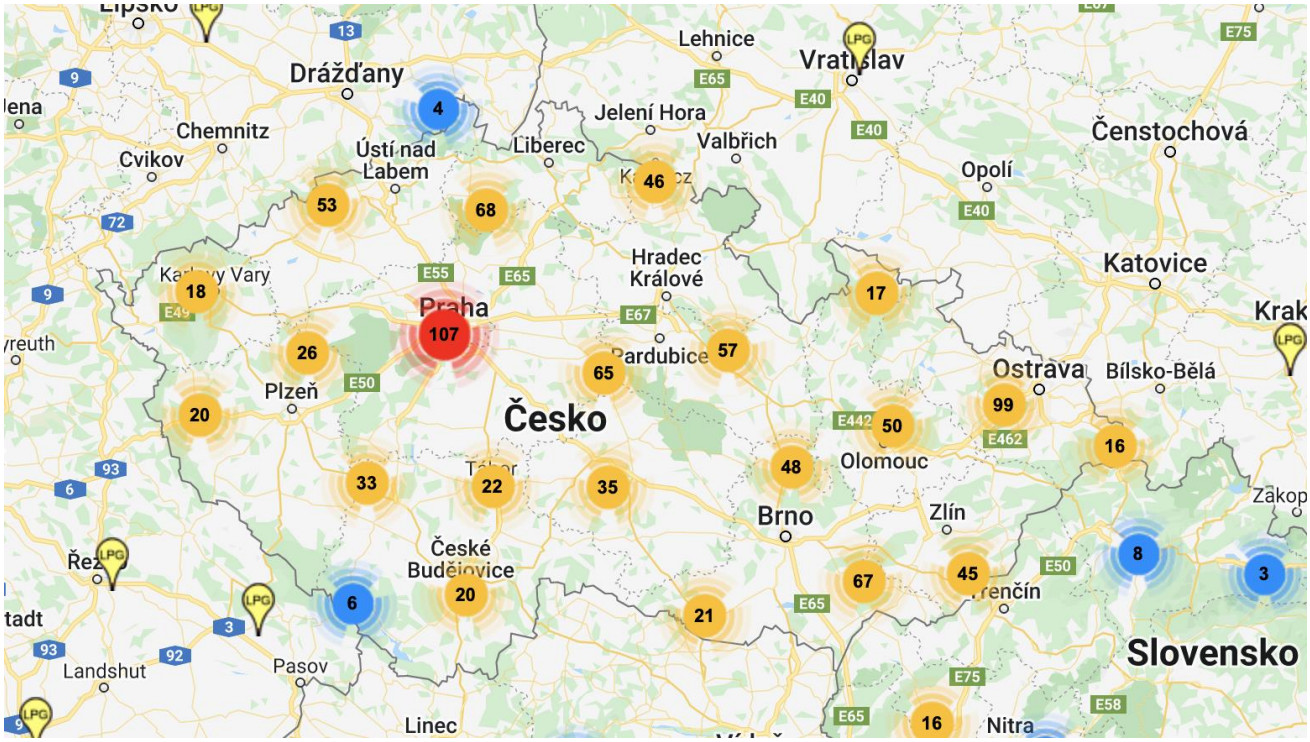
In Czech Republic there are 7 633 fuel stations offering gasoline and diesel (and its subgroups).

On the other hand, in Czech Republic there are 228 fuel stations offering CNG and 973 fuel stations offering LPG. Map of density can be found at Picture 26 (for CNG stations) and at Picture 27 (for LPG stations).

If person has an electrical vehicle, it can be charged at 800 public charge places. Map of density can be found at Picture 28.

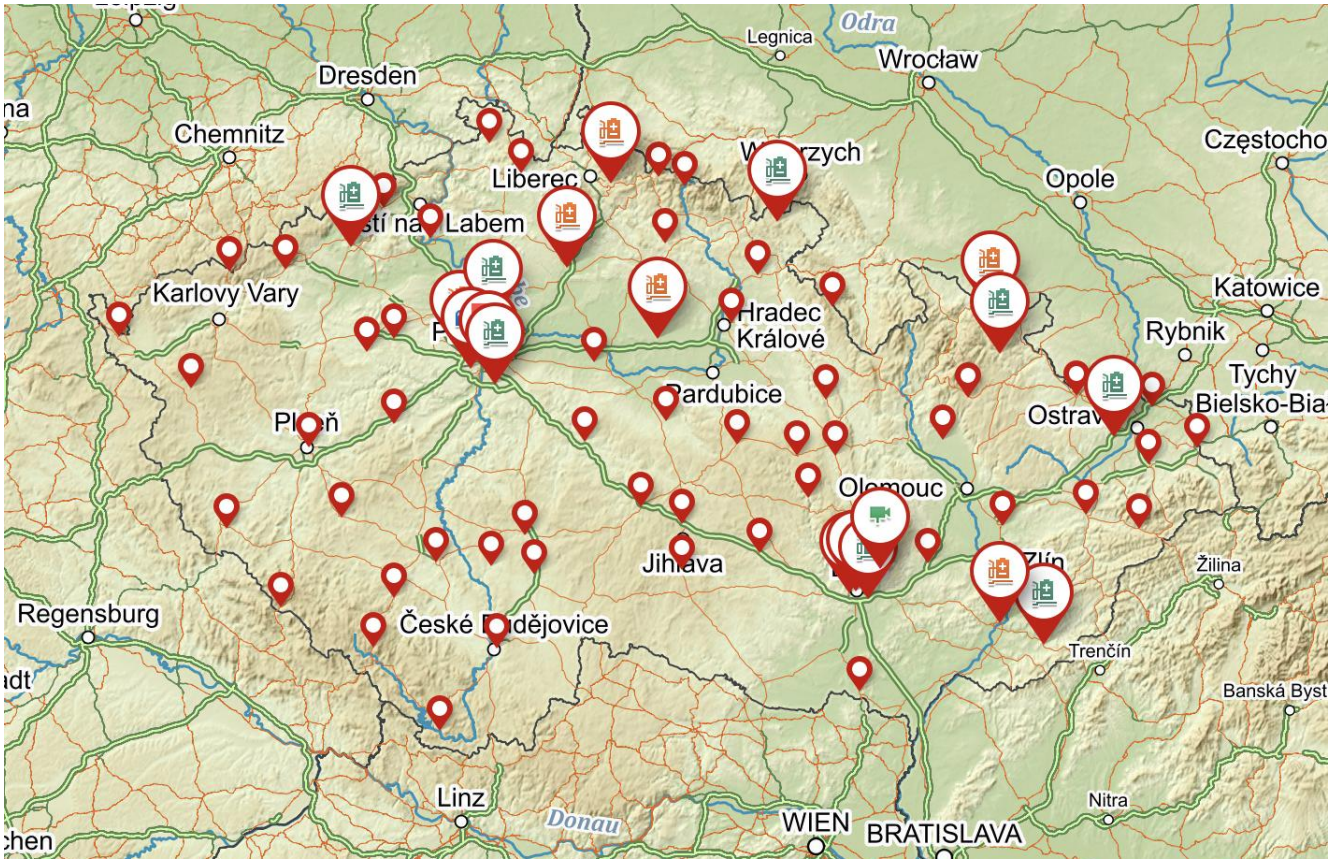
Picture 26 - Map of CNG fuel stations

Source: cng.cz, 2022



Picture 27 - Map of LPG fuel stations

Source: levnelpg.cz, 2022



Picture 28 - Map of electric chargers

Source: seznam.cz, 2022

In Czech Republic there are 55 799 km of roads (1 305 km of highways and 5 807 km of 1st class roads). Area of Czech Republic is 78 871 km^2. (Ředitelství silnic a dálnic ČR, 2021)

As was mentioned, there are 7 633 fuel stations in Czech Republic. Density of fuel stations can be calculated by dividing area of Czech Republic by number of the fuel stations.
In numbers: 78 871/7 633 = 10,33, which means one fuel station per 10,33 km^2.

Density can be also calculated by dividing number of road kilometers by number of the fuel stations. In numbers: 55 709/7 633 = 7,29, which means one fuel station per 7,29 road kilometers.

These data for CNG, LPG and electricity can be found in Table 14.

Fuel type	Density per km^2 of territory	Density per road km
CNG	345,93	244,33
LPG	81,05	57,25
Electricity	98,59	68,63

Table 14 - Density for fuel types

3 STRUCTURE OF THE AFTERSALES SECTOR

Car manufacturers place a huge emphasis on the aftersales sector. In fact, revenues from this sector are quite substantial for automotive companies. Most of them also have defined aftersales strategies for the future.

Manufacturers also look after their authorised dealerships and want to influence their operations. For example, ŠKODA AUTO a.s. trains around 10,000 employees of importers every year. It organises interesting competitions and workshops for them on various topics. As part of such training, ŠKODA AUTO a.s. has taken a step forward in the field of digitalisation. It organises online training sessions in virtual reality, for example, or trains sales staff in communicating with customers using artificial intelligence.

3.1 Structure of automotive aftersales sector

The aftersales sector in the Czech Republic is very extensive. The whole aftersales sector is divided into authorized and unauthorized service stations and also departments of companies directly dealing with aftersales. However, the total number of people employed in this sector cannot be accurately determined as such data is not available for the Czech Republic. According to our estimate, the number of employees in aftersales may range from 30,000 to 50,000. This estimate includes repair shops personnel as well as employees of aftersales departments of automotive companies in Czech Republic.

In independent repair shops the majority of employees are mechanics and repairers, in authorised repair shops the number of employees is increasing and the number of administrative and management staff is also increasing. In the specialised departments of car manufacturers, the ratio of administrative staff to mechanics is even more equal.

3.2 Aftersales sector total revenue

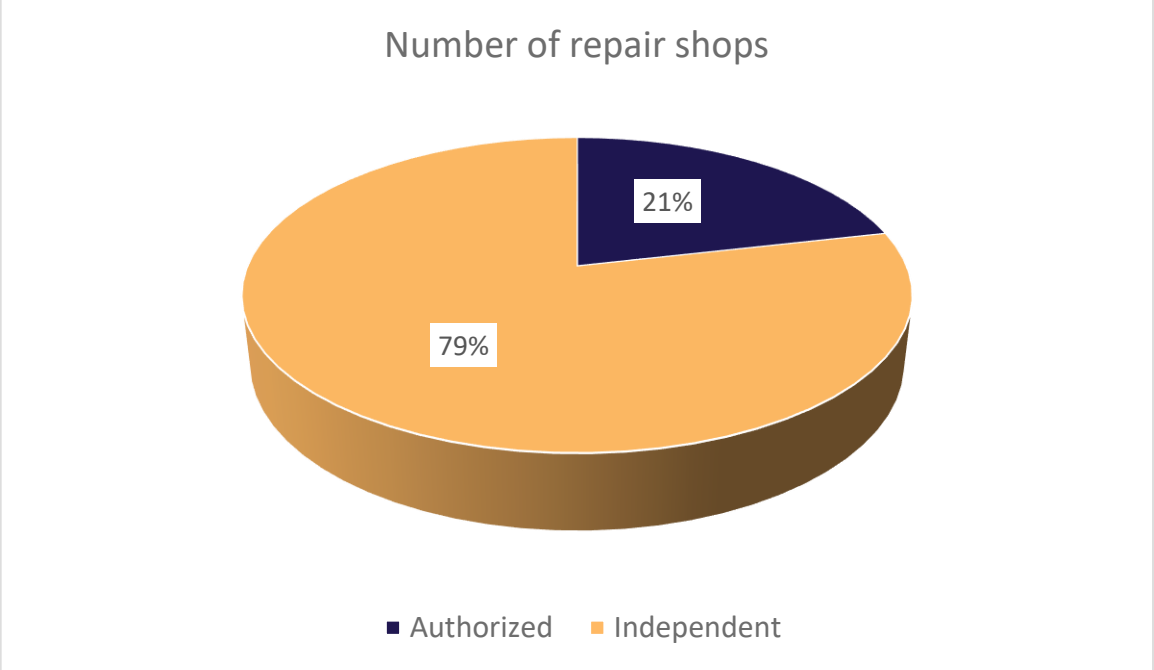
Aftersales sector is a huge opportunity for companies not only on a global scale but also in the Czech Republic. For all companies in the automotive sector, aftersales is one of the key

areas and therefore they make huge efforts to improve their products and services in this area.

However, the total revenue cannot be clearly quantified. Usually companies guard this information carefully from competitors and the public. Despite the fact that this information is really secret, it is possible to estimate that the total revenue from aftersales activities in the Czech Republic is in the order of several tens of millions of euros. For car manufacturers, we estimate that aftersales revenue can account for 30-40% of total revenue.

3.3 Statistics of companies

There are approximately 7,000 companies in the aftersales sector in the Czech Republic, 1,500 of which are authorised repair shops and the remaining 5,500 are independent repair shops. The number of independent repair shops cannot be determined in detail, as the area is difficult to control. (Autoservis Advisor, © 2014 – 2022)



Picture 29: Number of repair shops

Source: (Autoservis Advisor, © 2014 – 2022)

Unfortunately, there is no official data on the specific number of employees of each company. This information is internal to each company, but based on our research we estimate the number of After Sales employees to be between 30,000 and 50,000.

3.4 Vehicle recycling company types

For ordinary people in the Czech Republic, there are usually two ways to recycle a car. The first is through the car manufacturer. The European Union directive obliges them to recycle the vehicle. The second way is to have the vehicle recycled at a scrap yard or a specialist scrap metal yard.

However, all of them are now obliged not only to dispose of the car wreck, but above all to recover it - to recycle it, for which they also have a special permit from the EU. If a person wants to take a vehicle off the register, they will need a certificate of recycling from such an accredited scrapyard. (TŘÍDĚNÍODPADU.cz, © 2007 – 2022)

As part of the further recovery of car wrecks, scrapyards use different methods to obtain material for further use. These techniques include: shredding/compression, dismantling and also Q-REC. Q-REC is a new industrial concept of recycling that combines certain principles in car manufacturing, the creation of dismantling technologies and also a network of recycling stations. (ŠROTY.cz, 2015)

The topic of recycling car batteries is also linked to the emerging electromobility. Companies in the automotive industry are obliged to recycle used batteries. ŠKODA AUTO is interested in this topic and has ways of recycling these batteries so that as many materials as possible can be reused. (Internal materials of ŠKODA AUTO a.s., 2022)

3.5 Steps to recycle vehicle for common people

The correct recycling of end-of-life vehicles should help to minimise the environmental impact and help to protect environmental quality and save energy. Old vehicles are included in the category of dangerous waste because they contain a number of dangerous substances (such

as oil, acids and chemical compounds contained in liquids). By law, the handling and disposal of old vehicles is only allowed to authorised old vehicle processors.

To recycle an old vehicle, *individuals* need an ID card or other proof of identity and an original large technical licence. In the case of destruction from an estate, it is necessary to bring the decision of inheritance. If the person is not the owner of the vehicle, but only the operator, they must bring a power of attorney for disposal. *Legal persons* need a certificate of incorporation to liquidate an old vehicle.

The next step is to permanently remove the vehicle from the Central Vehicle Register. The operator of the wrecking yard will provide you with a certificate of ecological disposal. With the document, the registration certificate and the registration plate, you will present yourself to the transport office of the relevant local authority where the removal will take place. Here you will fill in an Application for Removal of Vehicle from the Road Vehicle Register and you will receive an entry in the registration certificate.

The last step is just a visit to the insurance company to cancel the insurance policy and get a refund of the unused insurance premium. Legal entities deregister their vehicle from the Tax Office and claim a refund of the unused part of the road tax. (Jandusová, 2021)

3.6 Vehicle maintenance and repair

Vehicle maintenance is a hotly debated topic in Aftersales today. Automotive manufacturers and dealers are striving to provide the best and innovative services in the field of predictive vehicle maintenance.

For example, ŠKODA AUTO is involved in predictive maintenance and has previously introduced the Sound Analyzer concept. The program records the sound of a car and compares it with already available acoustic patterns. If there are any discrepancies, the app uses an algorithm to find out what could be causing the deviations and how they can be eliminated.

ŠKODA AUTO also creates various advantageous service packages that can be purchased at the time of purchase. ŠKODA AUTO has developed several vehicle maintenance projects. The Key Drop-Off project is certainly worth mentioning. In this project, customers drop off their cars for service almost around the clock. A key drop-off box is placed outside the service station and in this way the customer can drop off the car even when the service station is not open. (Internal materials of ŠKODA AUTO a.s., 2022)

The main goal of car manufacturers is therefore to strengthen predictive maintenance services and to provide customers with all the comfort they need when using their products. The main business model in the field of car maintenance is to fully exploit the potential in predicting defects or needs on the customer's side and effectively eliminate or fulfill them.

4 PREDICTIVE MAINTENANCE - PdM

Or in nutshell PdM is in the automotive industry a great example of predictive analytics. It helps business determine when a vehicle part needs servicing, using techniques, such as data mining, data preprocessing and employing machine learning algorithms.

PdM can be leveraged to optimize engine performance, transmission function, exhaust systems and structural stability of vehicles.

4.1 ŠKODA AUTO Predictive Maintenance

Škoda Auto describes Predictive Maintenance as functionality which determines the condition of vehicle components in order to predict when the maintenance should be based on vehicle's collected data.

In this moment, Škoda Auto is using "Predictive Maintenance 1.0", which divides it into three levels:

1. Level 0 – Monitoring:
    - The customer gets support for warning signals in the car. Currently, there is approximately 350 warning signals. This is already implemented as Service Scheduling in Škoda vehicles
2. Level 1 – Reactive:
    - Parts are predicted based on mileage or age. Components can be extended based on service tables / maintenance tables. This is also already implemented as Service Scheduling in Škoda vehicles.
3. Level 2 – Preventive:
    - Parts the prediction is based on signals (thresholds), such as voltage or power. There are additional signals to be added.

Škoda Auto continues to prepare project ”Predictive Maintenance 2.0”, or level 3, where parts use prediction based on multiple signals from various sources. The prediction requires complex algorithms and long-term learning processes. This method is bases on data mining methods.

Predictive Maintenance entails *two benefits*. The first one is for costumers, when Škoda Auto is trying to prevent vehicle breakdowns on the road using early notification of outstanding service events and wear and tear. The second benefit is for Škoda Auto, where predictive maintenance increase revenue and customer loyalty after expiration of warranty period.

4.2 ŠKODA AUTO Service Scheduling

The vehicle reports required service needs such as a due service or oil change interval to the backend server. The data are provided to the preferred service partner selected by the costumer. The service partner can then contact costumer and schedule an appointment. The customer either accepts the appointment or rejects it.

Among customer benefits are that the vehicle announces a service need, then costumer can be proactively contacted by a preferred service partner through his preferred communication channel. Vehicle data are transmitted automatically. The service partner can announce appointment via Škoda Connect Portal or MyŠKODA App.

4.3 Purpose of the Predictive Maintenance

4.3.1 Initial Situation

Negative	Positive
Events occur unexpected for the customer	**None**
Customer “left alone“ with his problem	
Repair activities must be always initiated by the customer	

Table 15 - Initial Situation

Source: Internal documentation of Skoda Auto a.s.

4.3.2 Service Scheduling (Since 2016)

Negative	Positive
Maintenance events still occur unexpected	The Customer is proactively contacted with the appointment scheduling
	It contributes to the improved customer experience
	Better service capacity planning

Table 16 - Service Scheduling (Since 2016)

Source: Internal documentation of Skoda Auto a.s.

4.3.3 Predictive Maintenace

Negative	Positive
None	The maintenance events can be predicted before they occur
	The service appointment is scheduler just in time
	Vehicle repair will be proactively initiated by dealer
	Optimal customer experience and efficient maintenance process
	Better service capacity planning

Table 17 - Predictive Maintenace

Source: Internal documentation of Skoda Auto a.s.

4.4 Porsche Predictive Maintenance

Porsche is using ”Over-the-Air predictive maintenance”. With levels of wear continually and automatically monitored, comunicated to the costumer, where costumer will be aware of the future service or repair requirements before they become critical – enabling the costumer to play in Porsche’s workshop appointment for a time that suits the costumer best. (Porsche, 2022)

4.5 Ford Predictive Maintenace

In 2020, Ford announced that it was developing a range of integrated, connectivity-enabled solutions that will enable operators manage their fleets with greater ease and convenience and maximise their vehicle's productivity. Based on the latest generation of connected products featuring the FordPass Connect on-board modem technology, Ford is introducing an innovate and predictive usage-based maintenance sulition as it strive to deliver 100% uptime for fleet customers. (Field Service Connect, 2020)

The solution utilises IoT sensors that are connected to key systems within vehicles. There sensors provide real-time data directly to a convenient app, allowing business owners to check the status of every individual vehicle in their fleet and drivers to view live and predicted vehicle health data. (Field Service Connect, 2020)

The benefits are more or less the same as already mentioned. (Field Service Connect, 2020)

4.6 MAN Predictive Maintenance

MAN is using a modern fleet and trip management based on the direct availability of data. Forward-looking planning and management can be exclusively based on all relevant information. With TeleMatics®, all essential information about vehicles and drivers avaible in real time, which allows dispatchers to process transport orders effectively and efficiently. It is possible to check and control the deployment of the vehicle using MAN TeleMatics® access software. (MAN Truck & Bus, 2014)

TeleMatics® is using a lot of data, for example about the order status, location of the truck, trip history and detailed information about driving times and downtimes. For fleet management this means optimal planning ability, maximum flexibility in vehicle deployment, optimized vehicle availability due to predictive maintenance planning. This is also part of MAN Service Care. (MAN Truck & Bus, 2014)

4.7 SCANIA Predictive Maintenance

Scania is developing a cutting edge data integration tool for real-time vehicle performance assesment. The concept is called ”Digital Twin” and it is based on linked data, where it will take predictive maintenance to the next level. (SCANIA AB, 2019)

The technology is unlike which customers use every day when they are entering term into internet search engines. Countless information is identifixed, correlated and linked in miliseconds before being presented to the user as result. In this context, data concepts need to be named and defined, with their relationship to each other established. For example, brakes would consist of several data concepts that together constitue the term ”breaks” These concepts are collected in ”knowledge graphs”, which are the realm of interrelated data concepts. (SCANIA AB, 2019)

Data remains in normal storage and is only mirrored as a digital twin. There information are transmitted and avaible. For each question posed, new knowledge graphs are formed. The ”Digital Twin” concept can be used to develop more sophisticated, long-term realions with customers. In other words, to extend business model. (SCANIA AB, 2019)

BIBLIOGRAPHY

Aktuální cena benzínu, cena nafty [online]. Praha: kurzy.cz, 2022 [cit. 2022-03-13]. Dostupné z: https://www.kurzy.cz/komodity/benzin-nafta-cena/

AUTOVRAKY: Jak se likvidují autovraky?. *TŘÍDĚNÍODPADU.cz* [online]. © 2007 - 2022 [cit. 2022-03-12]. https://www.trideniodpadu.cz/autovraky?fbclid=IwAR00KudosiBO_XmytxSjGo1AwauuH1buvdGZkv6yvaS0BDkwT7p5JUNQgLw

Co dělat při registraci nového auta [online]. Online: Finance.cz, 2020 [cit. 2022-03-10]. Dostupné z: https://www.finance.cz/475236-jak-na-registraci-noveho-auta/

Common Causes of Inspection Failure-Personal Vehicles I dmv [online]. DC.gov, 2022 [cit. 2022-03-10]. Dostupné z: https://dmv.dc.gov/service/common-causes-inspection-failure%E2%80%94personal-vehicles

Daň z elektřiny [online]. Praha: INNOGY, 2022 [cit. 2022-03-13]. Dostupné z: https://www.kurzy.cz/komodity/benzin-nafta-cena/

Digital Twin takes predictive maintenance to the next level [online]. online: SCANIA AB, 2019 [cit. 2022-03-13]. Dostupné z: https://www.scania.com/group/en/home/newsroom/news/2019/digital-twin-takes-predictive-maintenance-to-the-next-level.html

Elektronická dálniční známka [online]. Online: Státní fond dopravní infrastruktury, 2022 [cit. 2022-03-10]. Dostupné z: https://edalnice.cz/

Ford Strives for 100% Uptime for Commercial Vehicles with Predictive Usage-Based Maintenance Solution [online]. online: Field Service Connect, 2020 [cit. 2022-03-13]. Dostupné z: https://fieldserviceconnecteu.wbresearch.com/blog/ford-strives-for-100-uptime-for-commercial-vehicles-with-predictive-usage-based-maintenance-solution

Internal materials of ŠKODA AUTO a.s.

JANDOVÁ, Ing. Vilma, Mgr. Ivo DOSTÁL, RNDr. Leoš PELIKÁN PH.D. a Ing. et Ing. Libor ŠPIČKA. *STUDIE O VÝVOJI DOPRAVY Z HLEDISKA ŽIVOTNÍHO PROSTŘEDÍ V ČESKÉ REPUBLICE ZA ROK 2020* [online]. 2021, 194 [cit. 2022-03-12]. Dostupné z: https://www.mzp.cz/C1257458002F0DC7/cz/doprava/$FILE/OOO-Studie_doprava_2021-20220117.pdf

JANDUSOVÁ, Martina. Kam s ním aneb Jak postupovat při likvidaci starého vozidla?. *Průmyslová ekologie.cz* [online]. 2021, 2.3.2021 [cit. 2022-03-12].

https://prumyslovaekologie.cz/info/kam-s-nim-aneb-jak-postupovat-pri-likvidaci-stareho-vozidla-

Kalkulačka zdanění pohonných hmot: Nafty, benzínu, CNG a LPG I Finance.cz [online]. Internet Info, 2022 [cit. 2022-03-10]. Dostupné z: https://www.finance.cz/nahled-sekce/dane-a-mzda/kalkulacky-a-aplikace/kalkulacka-zdaneni-pohonnych-hmot-nafty-benzinu-cng-a-lpg/

KOMBINOVANÝ VÝPIS AUTOSERVISŮ (S AUTORIZACÍ I BEZ). *Autoservis Advisor* [online]. © 2014 – 2022 [cit. 2022-03-12]. https://autoservisadvisor.cz/seznam/autoservisy?fbclid=IwAR3SVV1cci8j9W3ppsOm4hGgkpC-AaJBFubf94T92ommzfAVOncjcoVoXTM

LPG stanice [online]. online: levnelpg.cz, 2022 [cit. 2022-03-13]. Dostupné z: https://www.levnelpg.cz/lpg-stanice/

Maintenance, Wear & Tear and Service Packages [online]. online: Porsche, 2022 [cit. 2022-03-13]. Dostupné z: https://www.porsche.com/central-eastern-europe/en/accessoriesandservice/porscheservice/serviceandmaintenance/maintenance/

MAN TeleMatics®. Providing maximum efficiency. [online]. Munich: MAN Truck & Bus, 2014 [cit. 2022-03-13]. Dostupné z: https://www.truck.man.eu/man/media/et/content_medien/doc/business_website_truck_master_1/TeleMatics_Broschuere_2014.pdf

Mapy zpoplatněných pozemních komunikací [online]. Online: Ředitelství silnic a dálnic, 2019 [cit. 2022-03-10]. Dostupné z: https://mytocz.eu/cs/vymezene-useky-silnic/mapy?TSPD_101_R0=08fb7d7aa5ab2000dfc4fb0b16168a8f46012e32aaa845a7ec16d21702c4fef97351ce782c0d9ce10825b025ac14300030af16bed294fc6c8f4b584d4ab9a9285600e9d5d8c0ab4f1504b87aa56fca060375425460a98177eec66530858826ce

Nabíjecí stanice pro elektromobily [online]. online: seznam.cz, 2022 [cit. 2022-03-13]. Dostupné z: https://mapy.cz/zakladni?x=14.4968060&y=50.3744000&z=11&q=nab%C3%ADjec%C3%AD%20stanice%20pro%20elektromobily

Přehledy z informačního systému o silniční a dálniční síti ČR [online]. Praha: Ředitelství silnic a dálnic ČR, 2021 [cit. 2022-03-13]. Dostupné z: https://www.rsd.cz/wps/portal/web/Silnice-a-dalnice/delky-a-dalsi-data-komunikaci

Recyklace vozidel aneb Stručný přehled zákonných opatření. *ŠROTY.cz* [online]. 2015 [cit. 2022-03-12]. Dostupné z: http://www.sroty.cz/recyklace-vozidel-aneb-strucny-prehled-zakonnych-opatreni?fbclid=IwAR1uHAqr97etcIKjYMZuVjOX3qgYq0vUTBOyR1MXSO4s57bxGKBfweAC0CA

Sazba DPH ve státech Evropské unie [online]. Online: STORMWARE, 2021 [cit. 2022-03-13]. Dostupné z: https://portal.pohoda.cz/dane-ucetnictvi-mzdy/dph/sazba-dph-v-eu/sazby-dph-ve-statech-evropske-unie/

Silniční daň za rok 2021 a v roce 2022 I Kurzy.cz [online]. online: Kurzy.cz, spol. s r.o., AliaWeb, spol. s r.o., 1996 - 2022 [cit. 2022-03-10]. Dostupné z: https://www.kurzy.cz/dane-danova-priznani/dan-silnicni.htm#sazba

Složení vozového parku 2020. *Www.autosap.cz* [online]. Česká republika: autosap.cz, 2020, 24.6.2021 [cit. 2022-03-12]. Dostupné z: https://autosap.cz/wp-content/uploads/2021/06/vozovy-park.pdf

Stanice CNG [online]. online: cng.cz, 2022 [cit. 2022-03-13]. Dostupné z: https://www.cng.cz/stanice

Vyhláška č. 211/2018 Sb. In: . Praha: Ministry of Transportation, 2018, ročník 2018, číslo 211. Dostupné také z: https://www.zakonyprolidi.cz/cs/2018-211

Zdanění PHM v Česku a dalších zemích EU [online]. Praha: ČAPPO, 2021 [cit. 2022-03-13]. Dostupné z: https://www.cappo.cz/cisla-a-fakta/zdaneni-phm-v-cesku-a-dalsich-zemich-eu

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