University of Technology and Economics

Faculty of Transportation and Logistics

ERASMUS +

Final Project

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Study of the approach of mathematical models to Euro Standard passenger car curves for predicting the future of the market

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ABSTRACT

In Europe, vehicle emissions are regulated by the EuroStandard legislation. Governments of different countries enforce automotive industries to adapt their vehicles to comply with these standards. The legislation is regularly updated to reduce vehicle emissions and control the issue of greenhouse gas emissions.

The objective of this study is to examine previous regulations and adapt three different mathematical models to their market curves. With the information collected propose three possible predictions for the future Euro Standard. This will allow for anticipation of future regulations and enable adaptation to the demands of the future market such as autonomous vehicles.

To clonclude, there will be a brief explanation of autonomous vehicles and the obstacles needed to overcome for this technology to become a feasible future for the automotive industry.

Keywords: Euro Standard, mathematical model, prediction, autonomous vehicles.

RESUMEN

En Europa, las emisiones de los vehículos son reguladas mediante la normativa conocida como EuroStandard. Los gobiernos de los distintos países exigen a las industrias automovilísticas que adapten sus vehículos para cumplir con dichos estándares. Con cierta regularidad, se actualiza esta normativa con el fin de reducir las emisiones de los vehículos, lo que a su vez contribuye a mitigar el problema del efecto invernadero.

El propósito de este estudio consiste en analizar las normativas previas adaptar tres modelos matemáticos a las curvas de mercado de dichas regulaciones. Con la información recolectada, se propondrán tres posibles predicciones para la curva del futuro estándar. De este modo, se pretende estar preparados para las futuras normativas y ser capaces de anticiparse a las exigencias del mercado futuro como los vehículos autónomos.

Por último, habrá una breve explicación de los coches autónomos y los obstaculos necesarios a superar por esta tecnología para que sea un futuro factible para la industria automotriz.

Palabras clave: Euro Standards, modelo matemático, predicción, vehículos autónomos.

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CHAPTER 1. INTRODUCTION

1.1 Purpose of the thesis

The aim of this thesis is to study the approach of three mathematical models to the Euro Standard sales curves of passenger cars and make three possible predictions for the future Euro Standard curve.

The study will be focused on the Euro Standard curves 3,4,5 and 6.

The tool used to achieve this will be Microsoft Excel.

Once this is explained, here are the main points:

- To get along with Microsoft Excel environment.
- Understand these mathematical models:
    - Logistics Model
    - Gompertz Model
    - Gaussian Distribution Model

Euro Standard curves represent the amount of sold passenger vehicles which accomplish the emissions restrictions in a range of time.

In addition to this analysis, a small review of the future vehicle technologies concerning autonomous vehicles will be made.

1.2. Justification of the thesis

Thanks to Erasmus + program, I have been gifted with the chance of analyzing a field which I would not have considered in my hometown.

In my exchanging program I have become part of the department of Transportation and Logistics.

Nowadays vehicle emissions are an issue which is important to regulate to avoid environmental problems such as global warming.

Forecasting the future of the market of vehicle industry concerning Euro Standards is a useful field which automotive manufacturers could use to anticipate to the change required.

The following final project will be part of a major thesis of a student from the University of Technology and Economics from Budapest.

1.3. Structure of the Thesis

The project is divided in 11 chapters. Likewise, each chapter is divided into subsections to make the project more comprehensive.

Chapter 1. This chapter is the introduction to the final project. Firstly, it makes a short summary of the project; afterwards, it explains why this topic has been selected and finally how the project structure is going to be.

Chapter 2. It explains what Euro Standards regulations are and their importance. Besides, it explains the evolution of the different Standards regulations.

Chapter 3. It explains the latest regulations known for the future Euro Standard 7.

Chapter 4. It describes the three mathematical models. In addition to this, the Excel Solver tool from Microsoft Excel is presented.

Chapter 5. The approximation to the Logistics Model is explained in detail. Also, the approximation of the other models explained.

Chapter 6. It explains the procedure of the three predictions for the future Euro Standard sales curve.

Chapter 7. Discussion of the obtained results.

Chapter 8. Brief explanation of autonomous cars, their futures and what is needed to become feasible.

Chapter 9. Economic aspect of Euro Standards.

Chapter 10. Budget.

Chapter 11. Bibliography

CHAPTER 2. EURO STANDARDS

European emission standards were introduced in the European Union (EU) in 1992.

The widespread use of personal vehicles for daily use becoming a necessity for many people, makes transport responsible for about 20% of CO_2 emissions. Which is a significant signal of the environmental problem involved with automotive industry.

Therefore, Europe set regulations for the automotive industry to control this problem.

Euro Standards regulate the amount of exhaust emissions released by vehicles sold in the EU.

These regulations are designed to become more stringent over time.

The aim of these is to reduce the environmental impact of vehicles by regulating:

- Nitrogen oxides (NO_x)
- Carbon monoxide (CO)
- Hydrocarbons (HC)
- Particulate matter (PM)

NO_x: this term is used to refer to nitric oxide (NO) and nitrogen dioxide (NO_2). The composition of fuel primarily consists of hydrocarbons, which means they are not made of nitrogen. However, air composition is made of 78% of nitrogen. For this reason, these chemical products inevitably appear during combustion at high temperatures.

NO_x is a highly reactive substance that can interact with other organic substances generating ozone (O_3) at low heights. Ozone at low heights is harmful to human beings, it can cause irritations in the respiratory system.

Additionally, it is one of the causes of acid rain generating nitric acid.

CO: this compound appears because of incomplete combustion. This chemical is colourless and odourless and it is harmful to human beings. During breath, it attaches to haemoglobin in the bloodstream reducing the amount of oxygen.

In low concentrations, symptoms can include nausea or headaches, while in high concentrations, it can even cause death, commonly known as “sweet death”.

In addition, it also contributes to generating tropospheric ozone.

HC: their main impact is the greenhouse effect. Also, they contribute to generating ground-level ozone, causing respiratory problems to people. Moreover, it harms crops and reduced visibility by creating a fog.

PM: it consists of solid and liquid particles that are suspended in the air. These can replicate health problems and also affect the environment producing smog, fires or dust storms.

Petrol and diesel engines produce different types of emissions. That is the reason why the regulations are different depending on the type of engine.

In conclusion, Euro Standard is a crucial instrument to mitigate air pollution and improve air quality, which improves human health conditions. Also, it reduces carbon footprint and combats climate change.

Furthermore forcing motor companies to make cleaner engines reduces the dependence on fossil fuels and advances in the transition to greener modes of transportation

The following table 1 presents the different Euro Standards regulations.

1993	Euro 1 emission limits (petrol)	Euro 1 emission limits (diesel)
	• CO – 2,72 g/Km • HC+NO_X – 0,97 g/Km • PM – No limit	• CO – 2,72 g/Km • HC+NO_X – 0,97 g/Km • PM – 0,14 g/Km
1997	Euro 2 emission limits (petrol)	Euro 2 emission limits (diesel)
	• CO – 2,2 g/Km • HC+NO_X – 0,5 g/Km • PM – No limit	• CO – 1,0 g/Km • HC+NO_X – 0,7 g/Km • PM – 0,08 g/Km
2001	Euro 3 emission limits (petrol)	Euro 3 emission limits (diesel)
	• CO – 2,3 g/Km • HC – 0,20 g/Km • NO_x – 0,15 • PM – No limit	• CO – 0,64 g/Km • HC+NO_X – 0,56 g/Km • NO_x – 0,50 g/Km • PM – 0,05 g/Km
2006	Euro 4 emission limits (petrol)	Euro 4 emission limits (diesel)
	• CO – 1,0 g/Km • HC – 0,10 g/Km • NO_x – 0,08 g/Km • PM – No limit	• CO – 0,50 g/Km • HC + NO_x – 0,30 g/Km • NO_x – 0,25 g/Km • PM – 0,025 g/Km
2011	Euro 5 emission limits (petrol)	Euro 5 emission limits (diesel)
	• CO – 1,0 g/Km • HC – 0,10 g/Km • NO_x – 0,06 g/Km • PM – 0,005 g/Km (direct injection only)	• CO – 0,50 g/Km • HC + NO_x – 0,23 g/Km • NO_x – 0,18 g/Km • PM – 0,005 g/Km • PM – 6,0x10^11/Km

2015	Euro 6 emission limits (petrol)	Euro 6 emission limits (diesel)
	• CO – 1,0 g/Km • HC – 0,10 g/Km • NO_x – 0,06 g/Km • PM – 0,005 g/Km (direct injection only) • PM – 6,0x10^11/Km (direct injection only)	• CO – 0,50 g/Km • HC + NO_x – 0,17 g/Km • NO_x – 0,08 g/Km • PM – 0,005 g/Km • PM – 6,0x10^11/Km

Table 1. Euro Standards limits for petrol and diesel passenger cars

Source [1]

The following figure 1 shows the reduction in emissions achieved thanks to these regulations from Euro 1 to Euro 6.

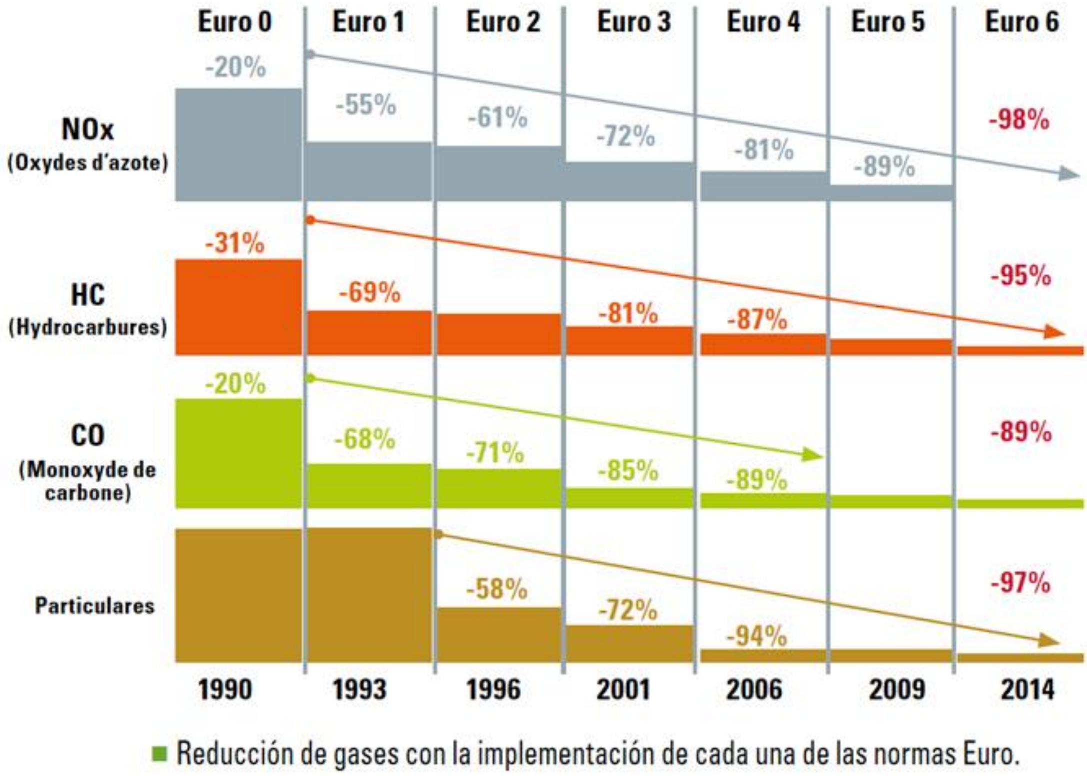

Figure 1. Euro Standards emissions reduction

Source [2]

CHAPTER 3. EURO STANDARD 7

[24] Euro Standard 7 will come into effect on 2025.

The new rules will set the same limits regardless of wether the vehicle uses petrol, diesel, electric drive-trains or alternative fuels.

In November of 2022, the european commission published a press realease explaining the futures of Euro Standard 7.

Better control emissions of air pollutants from all new vehicles: by broadening the range of driving conditions that are covered by the on-road emissions tests. Including conditions such as temperatures of up 45ºC or short trips of daily commutes.

Update and the tighten the limits for pollutant emissons: the limits will be more stringent for trucks and buses while the lowest existing limits for cars and vans will now apply regardless the fuel used by the vehicle. Previously unregulated pollutants sich as nitrous oxide from heavy-duty emissions will now be regulated.

Regulate emissions from brakes and tyres: the Euro 7 stantdard rules will be the first worldwide emissions standards to limit particulate emissions from brakes and rules on microplastic emissions from tyres. These rules will be applied to all vehicles.

Ensure that new cars stay clean for longer: cars and vans regulations will be checked until these vehicles reach 200.000 kilometres and 10 years of age. This doubles the latest requirements. Similar increases will take place for buses and lorries.

Support the deployment of electric vehicles: the new rules will regulate the durability of batteries installed in cars and vans in order to increase consumer confidence in electric vehicles. This will also reduce the need for replacing batteries early in the life of a vehicle.

Make full use of digital possibilities: using sensors inside the vehicle will allow to measure the vehicle emissions troughout the lifetime of a vehicle.

CHAPTER 4. MATHEMATICAL MODELS

4.1 Logistics Model

This mathematical model is used to describe the growth of a population over time.

It is determined by a non-linear equation, presented in the next mathematical expression 1:

$$N(t) = \frac{N_0 \cdot K}{N_0 + (K - N_0) \cdot e^{-rt}}$$

Mathematical Expression 1. Logistics Model Formula

Source [3]

Where:

- **N(t):** is the population at time t.
- **N_0:** is the initial population at time 0.
- **K:** the carrying capacity of the environment which is the maximum amount of individuals that can coexist at the same time.
- **r:** is the population growth rate.

In the beginning, the development of the population is fast, however as the population approaches the carrying capacity of the environment, the growth decreases. Eventually, it reaches an asymptotic growth.

Limitations of the model:

- **Constant growth rate:** assumes that the growth rate is constant in time.
- **Constant carrying capacity:** the model assumes that the parameter K is constant in the time. However, depending on the environmental context or in our case in the market context this may change.
- **Assuming a growth which depends on density:** however there are other factors which could affect such as economic crisis.

This graph, figure 2 shows the typical shape of a Logistcs Model.

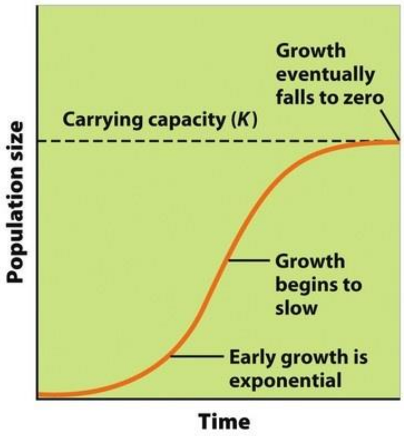

Figure 2. Logistics Model

Source [4]

4.2 Gompertz Model

As Logistcs Model, this model is used to describe the population of a population over the time.

The next mathematical expression 2 shows the Gompertz Model Formula.

$$f(t) = a \cdot e^{-be^{-ct}}$$

Mathematical Expression 2. Gompertz Model Formula

Source [5]

Where:

- **a:** is an asymptote, the maximum value that it can reach.
  b and c are positive numbers:
- **b:** affects the speed of the curve and is related to the initial growth rate.
- **c:** affects the shape of the curve and establishes the decay rate.

  The Gompertz function describes an exponential growth rate that decreases over time. As time increases, the growth rate of the function decreases.

The next figure 3 shows the typical shape of the function.

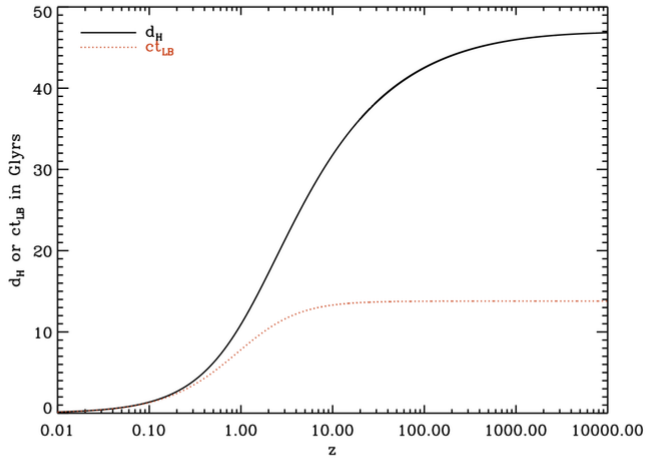

Figure 3. Gompertz Model

Source [6]

At first sight, Logistics and Gompertz Model could appear to be equal.

However, there are several differences between the models:

There are variations not only in mathematical equations but also in their ability to fit different context scenarios:

The former model has a better approximation to data when the population approaches the upper limit, the carrying capacity, whereas the latter approaches better when the growth rate decreases as the population size increases.

4.3 Gaussian Distribution of Probability

Normal distribution is the most basic statistic distribution. This model is symmetric about the mean, the central value. Data near the mean is more frequent in occurrence than data far from the mean.

Its main two parameters are the mean and the deviation. Regardless, the analysis will not be focused in a statistics context, so these parameters will not be explained extensively.

Mean (μ): the sum of the values divided by the total amount of values.

Deviation (σ): This factor measures how far are the individual values of a group of data from the mean. It is measured in the same units as the data.

$$f(t) = a \cdot e^{(-b\cdot(x-c)^2)}$$

Mathematical Expression 3. Gaussian Distribution of Probability Formula

Source [7]

Where:

- **a:** this parameter represents the amplitude or height of the Gaussian bell. It represents the maximum probability of the random variable.
- **b:** it determines how wide the bell is. If b grows up, the bell shrinks and it gets more sharp, meaning that there are more values around the mean.
- **c:** defines the central position of the bell. If it grows the bell will be moved to the right and vice versa.

The next figure 4 shows the gaussian distribution model.

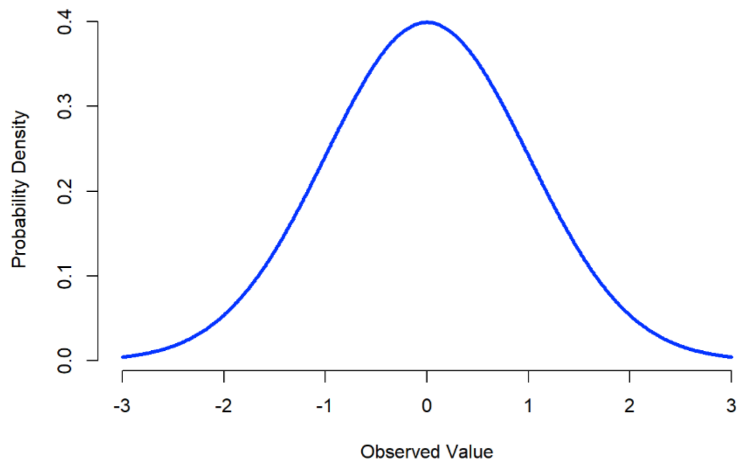

Figure 4. Gaussian Distribution Model

Source [8]

4.4 Microsoft Excel Solver tool

To achieve the approximation of these mathematical methods Excel Solver tool will be used.

Figure 5 explains the main functions of this tool that will be required for the analysis.

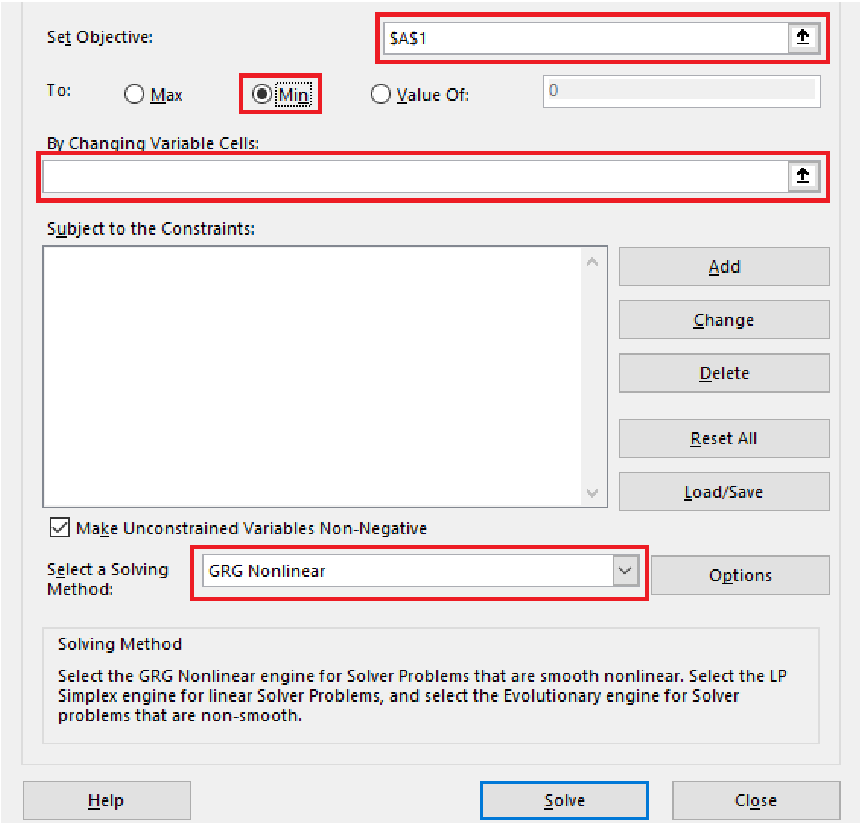

Figure 5. Solver tool

Source [9]

This instrument has the ability to change the value of a cell by changing other cells.

The idea is to calculate the error which exists between the mathematical approach for each year to the real value of the curve.

Then ask the Solver to minimize the cell which contains the sum of the errors by changing the model parameters.

The selected method to do this is "Generalized Reduced Gradient" (GRG) Nonlinear as our study case is a non-linear problem.

It is known that this tool has a better performance when asking to minimize the squared errors. Consequently, the approach will be made with the squared errors as shown in the ME 4.

$$\Sigma \text{ Squared errors} = (\text{real value} - \text{approximated value})^2$$

Mathematical Expression 4. Squared errors Formula

Source [10]

Chapter 5. APPROACH TO MATHEMATICAL MODELS

5.1 Real Euro Standard curves 3,4,5 and 6.

The study will be focused on the Euro Standards 3,4,5 and 6.

The following table 2 shows the percentage of new passenger cars registered that accomplish the different standards each year. The information collected goes from 2001 until 2020.

Year	Euro 3	Euro 4	Euro 5	Euro 6
2001	68,0%	24,0%		
2002	67,0%	28,0%		
2003	64,0%	33,0%		
2004	55,0%	43,0%		
2005	39,0%	60,0%		
2006	16,0%	84,0%		
2007	7,0%	93,0%		
2008	3,0%	95,0%	2,0%	
2009	1,0%	86,0%	13,0%	
2010	0,5%	61,0%	38,5%	
2011		23,0%	77,0%	
2012		8,5%	90,5%	1,0%
2013		0,5%	95,0%	4,5%
2014			82,0%	18,0%
2015			40,0%	60,0%
2016			10,0%	90,0%
2017			4,0%	96,0%
2018			3,0%	97,0%
2019			1,0%	35,0%
2020			0,5%	20,5%

Table 2. New PC registration percentage.

Source [11]

In addition, the next table 3 shows the total amount of new passenger cars registered from 2001 to 2020.

Year	Total new PC registration (EU 27)
2001	15.366.229
2002	15.013.826
2003	14.936.521
2004	15.237.555
2005	15.275.153
2006	15.443.071
2007	15.596.339
2008	14.338.100
2009	14.091.605
2010	13.305.479
2011	13.117.185
2012	12.008.247
2013	11.825.400
2014	12.513.670
2015	13.699.408
2016	14.645.165
2017	15.161.447
2018	15.086.636
2019	15.467.336
2020	11.658.884

Table 3. New PC registration.

Source [11]

With this information, the number of new PC which meet the different Euro Standards each year can be calculated by multiplying the table 2 with the table 3.

Vehicles are indivisible entities, hence decimals do not make sense. That is the reason of why the numbers presented in the document will be rounded to the nearest multiple of ten thousand. This is not a big deal considering that this is a prediction where precise numbers are not required.

The results obtained are presented in table 4.

Year	Euro 3	Euro 4	Euro 5	Euro 6
2001	10.450.000	3.690.000		
2002	10.060.000	4.200.000		
2003	9.560.000	4.930.000		
2004	8.380.000	6.550.000		
2005	5.960.000	9.170.000		
2006	2.470.000	12.970.000		
2007	1.090.000	14.500.000		
2008	430.000	13.620.000	290.000	
2009	140.000	12.120.000	1.830.000	
2010	70.000	8.120.000	5.120.000	
2011		3.020.000	10.100.000	
2012		1.060.000	10.870.000	120.000
2013		60.000	11.230.000	530.000
2014			10.260.000	2.250.000
2015			5.480.000	8.220.000
2016			1.460.000	13.180.000
2017			610.000	14.550.000
2018			450.000	14.630.000
2019			150.000	5.410.000
2020			60.000	2.390.000

Table 4. New PC registration Euro Standards.

Source [11]

Graphics are more visual than numbers. The results are plotted in figure 6:

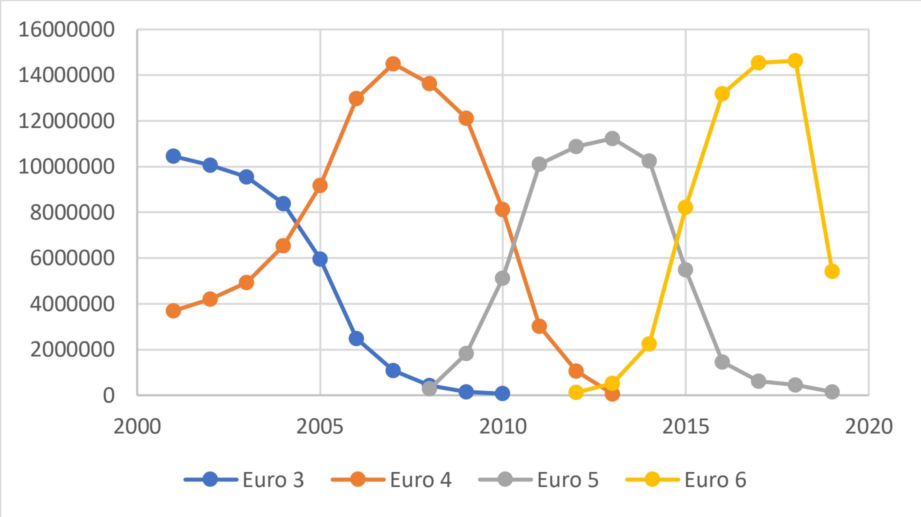

Figure 6. New PC registrations Euro Standards

Source [11]

It is noticeable that the drawn curves have a shape similar to a bell.

5.2 Logistics Model approximation

Hereunder, the calculation process for the approach to Euro Standard 3 curve will be explained.

It is important to remark that the process is equivalent for the other curves.

Moreover, the process is analogous for the other mathematical models.

The aim is to adjust the Logistics Model to the actual data.

EURO STANDARD 3	
YEAR	**Passenger cars registration**
2001	10.450.000
2002	10.060.000
2003	9.560.000
2004	8.380.000
2005	5.960.000
2006	2.470.000
2007	1.090.000
2008	430.000
2009	140.000
2010	70.000

Table 5. Euro Standard 3 Passenger cars registered

Source [11]

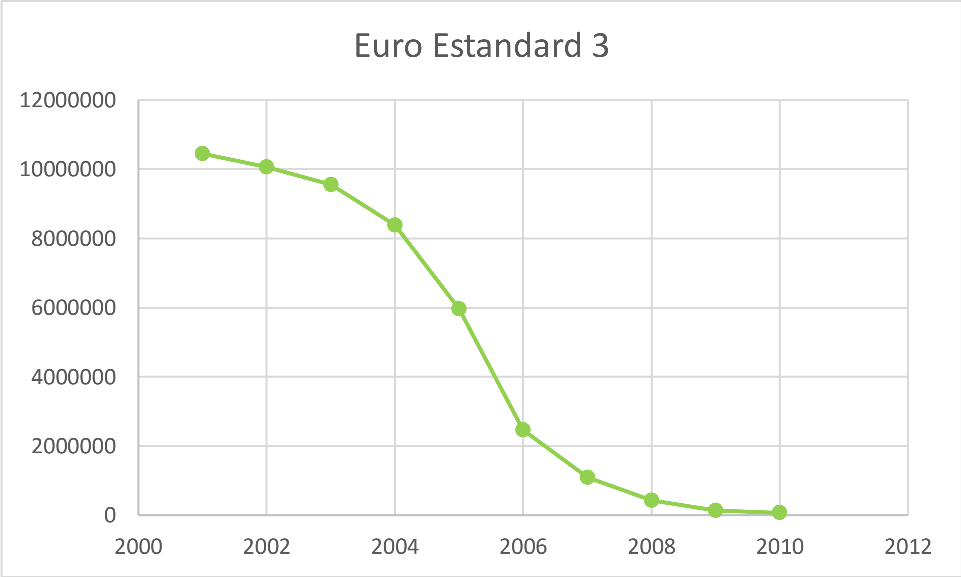

Figure 7. Euro Standard 3

Source [11]

Logistics graph,Figure 2, and Euro Standard 3, figure 7 ,are similar. The Euro curve is like the logistics model but backwards.

To execute the approximation, the data is going to be rearranged backwards. As shown in figure 8.

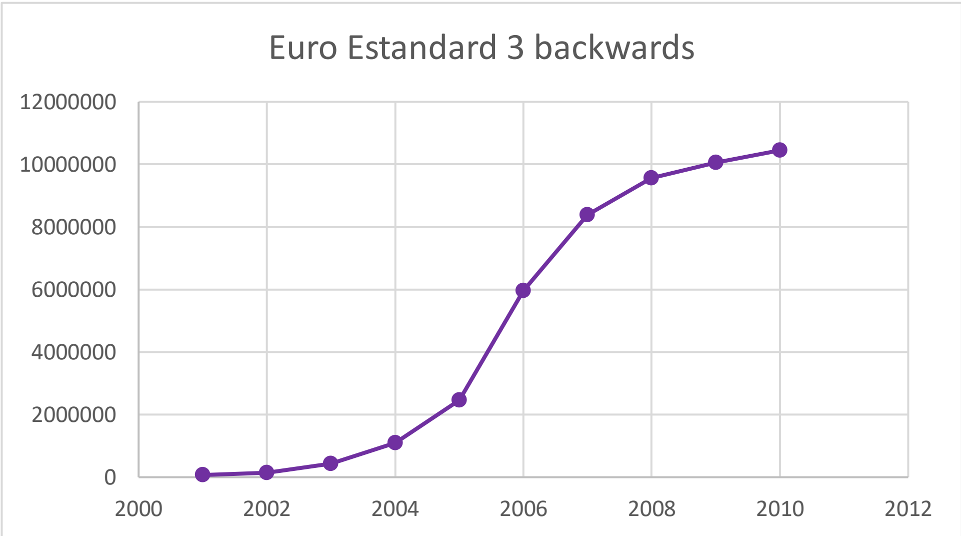

Figure 8. Euro Standard 3 backwards

Source [12]

As explained before, the Logistics Model has the following mathematical formula; ME 1:

$$N(t) = \frac{N_0 \cdot K}{N_0 + (K - N_0) \cdot e^{-rt}}$$

Mathematical Expression 1. Logistics Model Formula

Source [3]

Three parameters can be distinguish: N_0, K and r.

To achieve this, at first growth rate will be equal to 1.

As shown in table 6, the value which was the final value for the Euro 3 original curve, now it will be taken as the initial value for the Logistics Model approximation, and vice versa with the initial value.

		Euro 3	Euro 3 backwards
N_0	70.000	Value from 2010	Value from 2001
K	10.450.000	Value from 2001	Value from 2010
r	1		

Table 6. Logistic Model Euro 3 parameters

Source [12]

One remarkable aspect is that when talking about Logistics Model, the approach will start at year 0, this is owe to its mathematical equation; ME 1. In contrast, for the other models the starting year will be year 1.

Another important point is the fact that in order for the Solver Excel tool to function optimally, the initial year for the calculations will be set to either 1 or 0, depending on the mathematical model. Subsequently, the data will be organized accordingly, aligning the actual year with each correspondign value.

The upcoming table 7 shows the starting point of approximation of the Logistics Model.

It is noticeable that the starting year corresponds with the initial value of the Euro 3.

YEAR		N(t)	$\mathbf{Error^2}$
2001	0	70.000	12.058.985,49
2002	1	190.000	2.227.696.108
2003	2	500.000	4.337.948.371
2004	3	1.250.000	23.984.620.049
2005	4	2.810.000	1,16494E+11
2006	5	5.230.000	5,32995E+11
2007	6	7.640.000	5,46606E+11
2008	7	9.210.000	1,25388E+11
2009	8	9.950.000	10.911.553.471
2010	9	10.260.000	34.906.612.424
		Σ	1,39786E+12

Table 7. Logistic Model first approximation to Euro 3

Source [12]

The next step is to use the Microsoft Excel Solver tool. The approximation is achieved by asking Excel Solver tool to minimize the cell which contains the squared errors by modifying the parameters of Logistics Model.

Logistics Euro Standard 3	
N_0	25.723,98661
K	10.336.192,02
r	1,244430014

Table 8. Logistic Model Euro 3 parameters

Source [12]

Table 9 shows the final estimations of the Logistics Model for the Euro 3 curve backwards.

YEAR		N(t)	$\mathbf{Error^2}$
2001	0	30.000	1.600.000.000
2002	1	90.000	2.500.000.000
2003	2	300.000	16.900.000.000
2004	3	970.000	14.400.000.000
2005	4	2.740.000	72.900.000.000
2006	5	5.750.000	44.100.000.000
2007	6	8.410.000	900.000.000
2008	7	9.690.000	16.900.000.000
2009	8	10.140.000	6.400.000.000
2010	9	10.280.000	28.900.000.000
		Σ	2,055E+11

Table 9. Logistic Model approximation to Euro 3

Source [12]

It is important to remember that the curve was set backwards, so the data must be rearranged again. Once that is done, the approximation to the real curve is achieved.

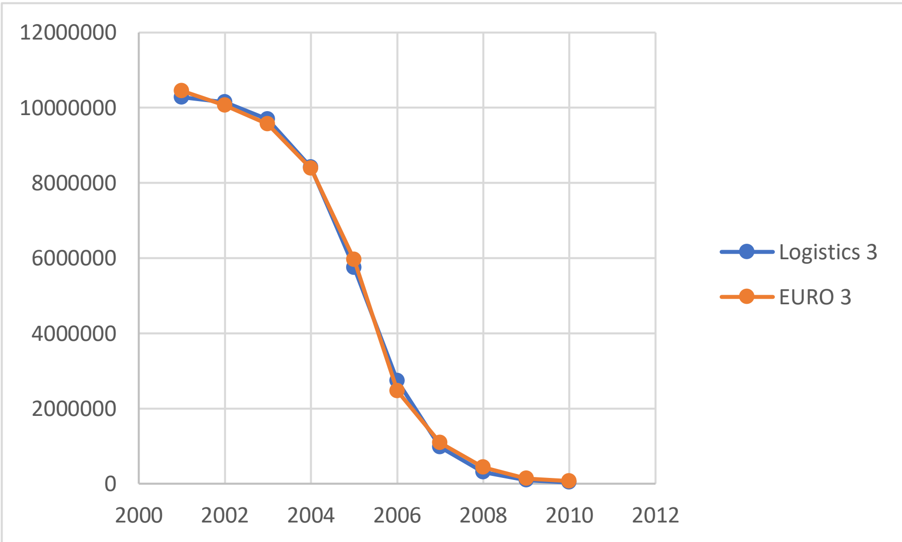

Figure 9. Logistic Model Approximation to Euro Standard 3

Source [12]

Unlike the other curves, in the data collected, Euro Standard 3 curve is half the other standards as the other curves have a complete bell shape.

However the process followed to approximate the mathematical models to these curves is similar to the explained one.

To reach the approximation for these curves, they have been splited into two curves at the maximum value.

Afterwards, the Logistics Model approach has been done twice. One for the first mid bell and the another one for the second mid bell.

As the first mid bell already had the form of the model, it did not require to rearrange the data.

Lastly, as the peak value is reapeted in both Logistics Model aproximations, the avarage value for the summit has been considered in order to take into account both approaches.

Year	Euro 3	Euro 4	Euro 5	Euro 6
2001	10.280.000	3.040.000		
2002	10.140.000	4.080.000		
2003	9.690.000	5.430.000		
2004	8.410.000	7.160.000		
2005	5.750.000	9.310.000		
2006	2.740.000	11.910.000		
2007	970.000	14.620.000		
2008	300.000	13.840.000	260.000	
2009	90.000	12.160.000	1.470.000	
2010	30.000	7.970.000	5.480.000	
2011		3.190.000	9.690.000	
2012		890.000	11.040.000	60.000
2013		210.000	11.340.000	390.000
2014			10.030.000	2.300.000
2015			5.610.000	8.210.000
2016			1.440.000	13.190.000
2017			240.000	14.480.000
2018			40.000	14.650.000
2019			10.0 00	5.600.000
2020			900	2.150.000

Table 10. Logistic Model Approximation to Euro Standards 3,4,5 and 6

Source [12]

The figure 10 represents the real Euro curves and the approximations of the Logistics Model.

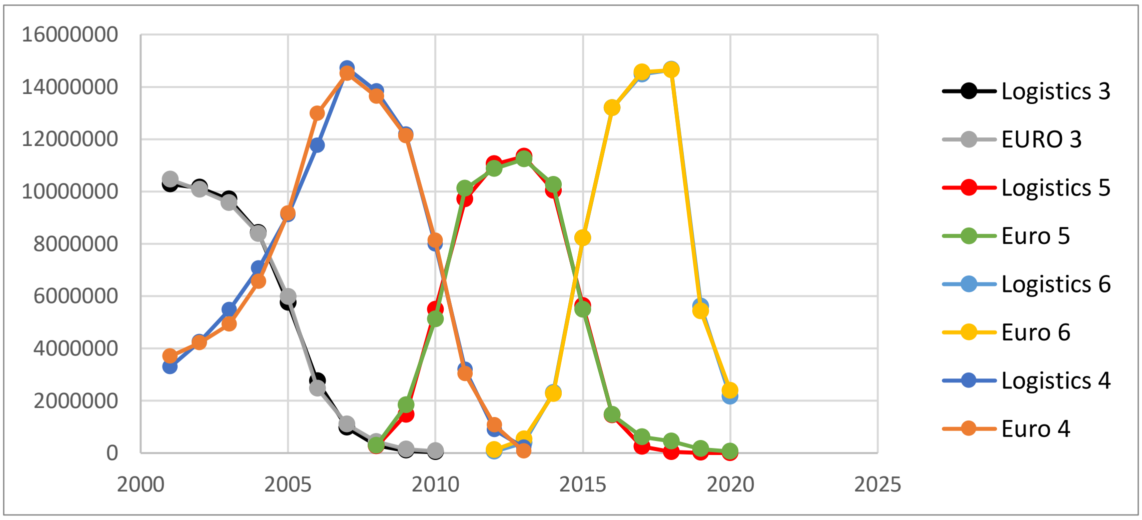

Figure 10. Logistic Model Approximation to Euro Standards 3,4,5 and 6

Source [12]

The next tables 11 and 12 show the values obtained after the approximation to the Logistics Model.

FIRST MID-BELL				
Parameters	Euro 3	Euro 4	Euro 5	Euro 6
N_0		3.035.460,49	263.559,24	59.163,4247
K		46.338.102,3	11.343.926,2	14.735.272,3
r		0,31936445	1,83467595	1,91428373

Table 11. Logistic Model Approximation to Euro Standards 3,4,5 and 6

parameters from first mid-bell

Source [12]

SECOND MID-BELL				
Parameters	Euro 3	Euro 4	Euro 5	Euro 6
N_0	25.723,9866	214.699,848	864,408805	2.146.524,32
K	10.336.053	14.441.380,7	11.661.882,1	26.900.682.156
r	1,24394825	1,46738949	1,88711659	0,95881283

Table 12. Logistic Model Approximation to Euro Standards 3,4,5 and 6

parameters from second mid-bell

Source [12]

5.3. Gompertz Model approximation

The process explained before is equal to the approach made for the Logistics model.

Here are the results obtained collected in table 13:

Year	Euro 3	Euro 4	Euro 5	Euro 6
2001	10.490.000	3.030.000		
2002	10.170.000	4.100.000		
2003	9.500.000	5.470.000		
2004	8.190.000	7.180.000		
2005	5.900.000	9.290.000		
2006	2.880.000	11.860.000		
2007	590.000	14.760.000		
2008	20.000	13.720.000	20.000	
2009	9	11.810.000	1.470.000	
2010	0	8.170.000	5.860.000	
2011		3.290.000	9.310.000	
2012		350.000	10.870.000	0
2013		1.400	11.475.000	20.000
2014			9.750.000	2.100.000
2015			5.850.000	8.530.000
2016			1.220.000	12.810.000
2017			10.000	14.420.000
2018			0	14.780.000
2019			0	5.490.000
2020			0	0

Table 13. Gompertz Model Approximation to Euro Standards 3,4,5 and 6

Source [12]

It stands out the fact that the initial values are zero.

Here in tables 14 and 15 are the values obtained for the parameters:

FIRST MID-BELL				
Parameters	Euro 3	Euro 4	Euro 5	Euro 6
a		914.415.661	11.748.200,7	15.134.618,0
b		6,03	18,60	80,43
c		0,05465988	1,09574985	1,23577359

Table 14. Gompertz Model Approximation to Euro Standards 3,4,5 and 6 parameters from first mid-bell

Source [12]

SECOND MID-BELL				
Parameters	Euro 3	Euro 4	Euro 5	Euro 6
a	10.767.774,2	15.199.988,4	12.455.999,9	17.139.546,52
b	67,2501427	22,88	641,41	59,54
c	0,78609587	0,90171014	1,12412894	1,978383628

Table 15. Gompertz Model Approximation to Euro Standards 3,4,5 and 6 parameters from second mid-bell

Source [12]

Figure 11 plots the approximations of Gompertz Model to Euro Standard curves.

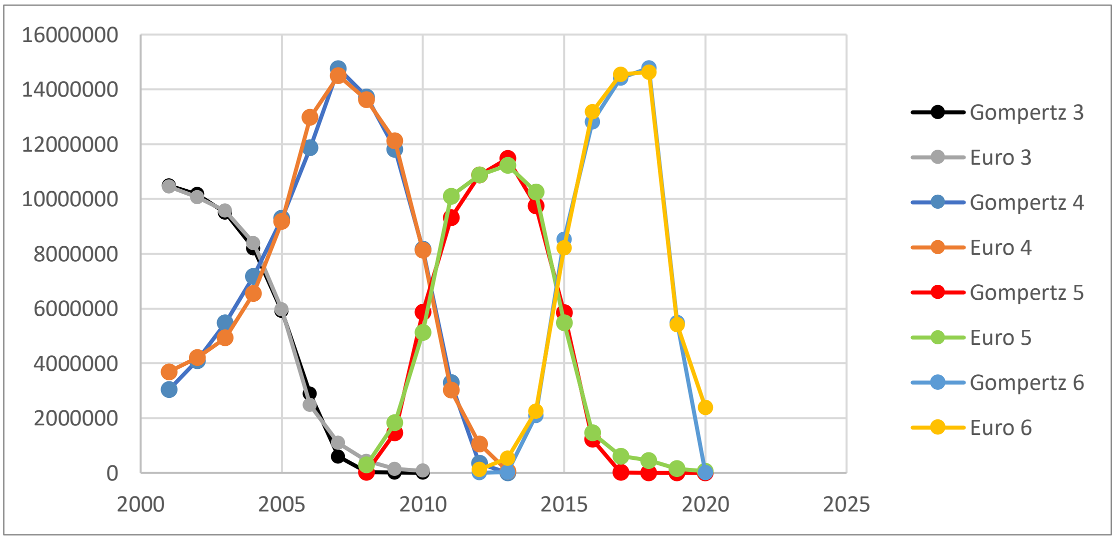

Figure 11. Gompertz Model Approximation to Euro Standards 3,4,5 and 6

Source [12]

5.3 Gaussian Ditribution Model approach

The approach of the Gaussian distribution to the curve is easier as the model already has a bell shape form. Because of this, in this case it is only asked the Solver Excel tool to minimize the cell which contains the squared errors by changing the model parameters.

That is to say, using only once the Solver the estimation is completed.

Year	Euro 3	Euro 4	Euro 5	Euro 6
2001	9.960.000	1.030.000		
2002	10.720.000	2.290.000		
2003	9.880.000	4.410.000		
2004	7.810.000	7.350.000		
2005	5.280.000	10.600.000		
2006	3.060.000	13.220.000		
2007	1.520.000	14.270.000		
2008	650.000	13.330.000	750.000	
2009	240.000	10.770.000	2.250.000	
2010	70.000	7.530.000	5.130.000	
2011		4.550.000	8.900.000	
2012		2.380.000	11.770.000	110.000
2013		1.080.000	11.870.000	680.000
2014			9.120.000	2.740.000
2015			5.340.000	7.380.000
2016			2.380.000	13.230.000
2017			810.000	15.840.000
2018			210.000	12.650.000
2019			40.000	6.740.000
2020			6000	2.390.000

Table 16. Gaussian Approximation to Euro Standards 3,4,5 and 6

Source [12]

Table 17 collects the parameters obtained for the Gaussian distribution after applying the Excel Solver tool.

Parameters	Euro 3	Euro 4	Euro 5	Euro 6
a	10.719.541,5	14.273.777	12.229.621,7	15.848.336,25
b	0,07733152	0,07242987	0,13574992	0,20241533
c	1,97546516	7,02700773	5,52941142	5,94388946

Table 17. Gaussian Distribution Model Approximation to Euro Standards 3,4,5 and 6 parameters

Source [12]

Figure 12 plots the results obtained and compares the Gaussian approach to the real curves.

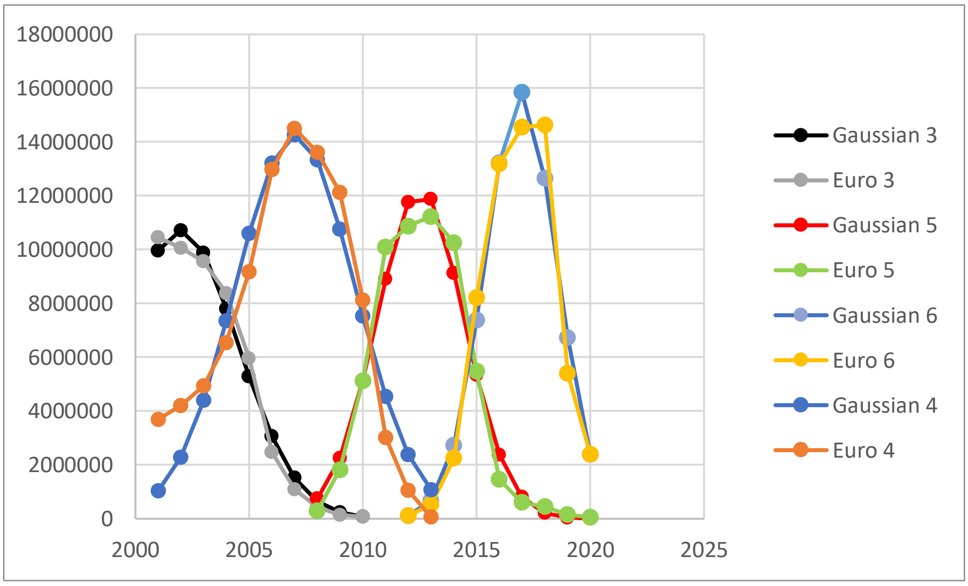

Figure 12. Gaussian Distribution Model Approximation to Euro Standards 3,4,5 and 6

Source [12]

Chapter 6. PREDICTION

6.1. Duration

Euro Standards regulations do not have deadlines. For this reason, it is difficult to determine how much time will the future Euro Standard last.

The only information it can guide us is the duration of the previous curves.

For this reason, the average value of the duration of the Standards will be considered the duration for the future standard.

	Euro 3	Euro 4	Euro 5	Euro 6	Euro 7
Duration	9	13	9	13	11

Table 18.Euro Standards duration.

Source [12]

The future Euro Standard 7 will be assume to last eleven years.

6.2. Covid-19 pandemic impact

In 2019 the world was overwhelmed by SARS-CoV- 2.

Not only Covid-19 pandemic affected humanity health, but also shook the economy worldwide. The automotive industry was not an exception.

Governments adapted different medical strategies to avoid the rapid spread of the illness.

Because of this, people were forced to confine themselves at home.

Teleworking became a reality and as a result, there was a growth in the computer market and other devices such as smartphones.

Semiconductors are required by these technologies for their microchips.

The factor of citizens remaining at home, stopped production of semiconductor manufacturers.

After overcoming this crisis, there was a consumerist spirit raise.

However, this growth in demand could not be sustained by the semiconductor manufacturers which resulted in a crisis.

The automotive industry was affected by this, as cars require semiconductors.

Therefore there was a recession in vehicle production which affected the market.

In the folowing table 19, year 2019 is highlighted, the recession in 2020 is clear.

Year	Passenger car registrations
2001	15.000.000
2002	15.000.000
2003	15.000.000
2004	15.000.000
2005	15.000.000
2006	15.000.000
2007	16.000.000
2008	14.000.000
2009	14.000.000
2010	13.000.000
2011	13.000.000
2012	12.000.000
2013	12.000.000
2014	13.000.000
2015	14.000.000
2016	15.000.000
2017	15.000.000
2018	15.000.000
2019	15.000.000
2020	12.000.000

Table 19. PC registration.

Source [11]

The European Standards vehicle market statistics as of today, goes from 2001 to 2020.

There is no more further information regarding european standards passenger car registrations.

Nevertheless, European Automobile Manufacturers' Association (ACEA) has recorded the latest registrations of passenger cars.

Year	Passenger car registrations
2021	11.000.000
2022	11.000.000

Table 20. PC registration 2021-2022

Source [13]

Moreover, ACEA has recorded the passsenger car registrations from the first two months of 2023.

A comparisson between the start of the year of 2023 and 2022 was made allowing to obtain some results. Showed at table 21.

Year	January	February	Rise %
2022	798.049	778.777	11,77697
2023	892.035	877.204	12,63866

Table 21. PC registration January-February 2022-2023 comparisson

Source [13]

The average of the sales rise in this two months is 12,2%; rounding: 12%.

There is an improvement showing that previous numbers could be reached again. This percentage is going to be assumed as reasonable as a yearly improvement until the average registrations of passenger cars before the pandemic crisis is reached again.

The mean of passenger cars registrations until the year of 2019 is 14.322.546, rounding 14.000.000.

As explained before, Euro Standard 7 is meant to be introduced in 2025. Previous calculations say that it will last 11 years. From 2025 until 2025.

Year	PC registrations
2021	11.000.000
2022	11.000.000
2023	12.000.000
2024	14.000.000
2025	14.000.000
2026	14.000.000
2027	14.000.000
2028	14.000.000
2029	14.000.000
2030	14.000.000
2031	14.000.000
2032	14.000.000
2033	14.000.000
2034	14.000.000
2035	14.000.000

Table 22. PC 2021- 2035

Source [12]

The hypothesis says that in 2024 the previous mean will be reached again. It will be assumed that there will not be any other recession in the automotive industry in the following years.

6.3. Estimation of the initial and maximum value of PC registrations

Euro Standard curves have a bell shape form. In the next graphic, figure 13, it is shown the colour code followed to represent a curve.

The darkest green represents the value of the summit. As the values get away from the peak value the green becomes lighter. Finally, the initial and near values use a blue colour code.

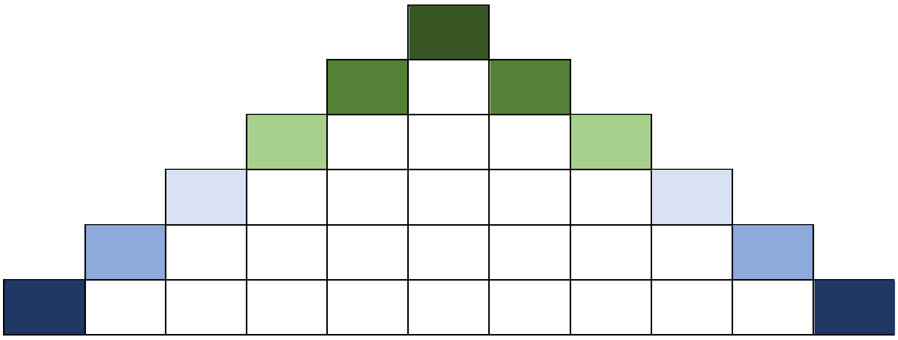

Figure 13. Euro Standards bell colour code

Source [12]

Year	Euro 3	Euro 4	Euro 5	Euro 6
2001	68,0%	24,0%		
2002	67,0%	28,0%		
2003	64,0%	33,0%		
2004	55,0%	43,0%		
2005	39,0%	60,0%		
2006	16,0%	84,0%		
2007	7,0%	93,0%		
2008	3,0%	95,0%	2,0%	
2009	1,0%	86,0%	13,0%	
2010	0,5%	61,0%	38,5%	
2011		23,0%	77,0%	
2012		8,5%	90,5%	1,0%
2013		0,5%	95,0%	4,5%
2014			82,0%	18,0%
2015			40,0%	60,0%
2016			10,0%	90,0%
2017			4,0%	96,0%
2018			3,0%	97,0%
2019			1,0%	35,0%
2020			0,5%	20,5%

Table 23. PC registration percentage.

Source [11]-[12]

Figure 14 shows each Euro curve known point with the colour code explainded before.

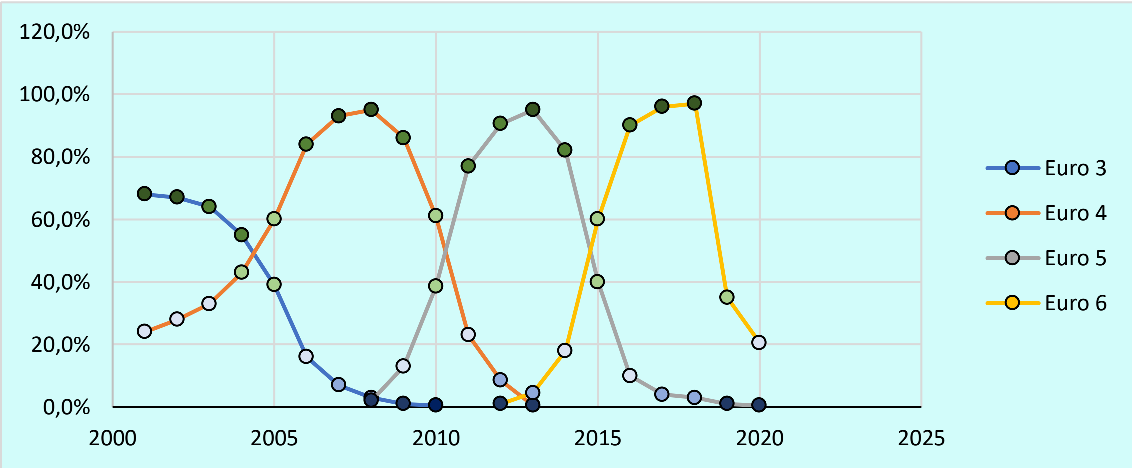

Figure 14. PC registration percentage.

Source [11]-[12]

Predicting the future curve has a lot of variables. Assuming a similar behaviour of the previous Standards is something reasonable and allows to simplify.

The average values of the curves are presented in the following table 24.

Mean	87,3%	78,6%	47,1%	20,6%	5,0%	0,93%

Table 24. PC registration mean percentage

Source [12]

To simplify the analysis, Euro Standard 7 curve is going to be assumed to be symmetrical.

Based on the predictions for the year of 2025, there will be 14.000.000 of new passenger car registrations.

Multiplying this number with the 0,93% estimated states and initial value of: 130.000.

The peak value will be reached in 2030. As exposed before, in the year 2030 the amount of newly registered cars will be 14.000.000.

Multiplying this value with the calculated percentage, gives us 12.222.000; rounding: 12.000.000.

Parameters	Euro 7
Initial value	130.000
Maximum value	12.000.000

Table 25. Euro Standard 7 predicted values

Source [12]

6.4. Logistics Model prediction

	FIRST MID BELL				
	Euro 3	Euro 4	Euro 5	Euro 6	MEAN
r		0,31936445	1,83467595	1,91428373	1,73878305
Duration (years)		7	6	6	6,66

Table 26. Logistics Model r parameter and duration from first mid bell

Source [12]

In the data collected, Euro Standard 3 has only registered its second mid bell. Therefore, it will not be considered for the first mid bell.

When analyzing the rest Euro Standards, there is not a clear patron between the growth rate and the time it takes to reach the peak values. For instance, it takes Euro 4 and Euro 6 7 years to reach the peak value. However, their growth rate varies a lot.

That is the reason why the mean of the “r” parameter is going to be accepted for the prediction.

	SECOND MID BELL				
	Euro 3	Euro 4	Euro 5	Euro 6	MEAN
r	1,24394825	1,467389493	1,887116588	0,958812833	1,389316793
Duration (years)	10	7	8	3	7

Table 27. Logistics Model r parameter and duration from second mid bell

Source [12]

With this data, the predictions for each mid bell are as shown in tables 28 and 29:

Year	Euro 7 First mid bell
2025	130.000
2026	700.000
2027	3.140.000
2028	8.020.000
2029	11.040.000
2030	11.820.000

Table 28. Logistics Euro Standard 7 first mid bell prediction

Source [12]

Year	Euro 7 Second mid bell
2035	130.000
2034	510.000
2033	1.800.000
2032	4.970.000
2031	8.870.000
2030	11.030.000

Table 29. Logistics Euro Standard 7 second mid bell prediction

Source [12]

Finally, the prediction for the Logistics Model will be the combination of the previous tables 28 and 29. Presented in table 30.

As it was explained before, the value for the sixth year (the summit) will be the mean of the two prognosticated values.

Year	Euro 7
2025	130.000
2026	700.000
2027	3.140.000
2028	8.020.000
2029	11.040.000
2030	11.425.000
2031	8.870.000
2032	4.970.000
2033	1.800.000
2034	510.000
2035	130.000

Table 30. Logistics Euro Standard 7 prediction

Source [12]

Results are plotted in figure 15.

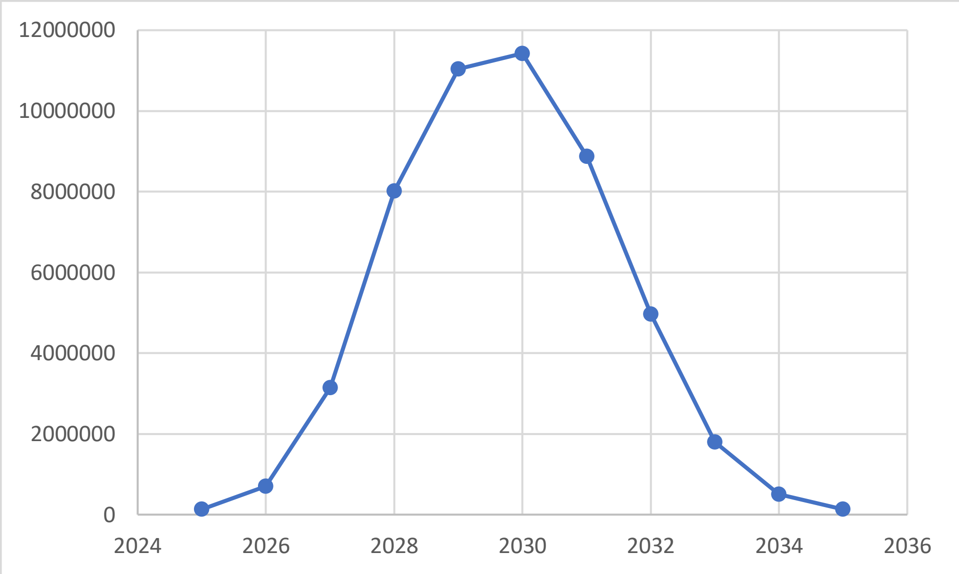

Figure 15. Logistics Euro Standard 7 prediction

Source [12]

6.5. Gompertz Model prediction

As presented before, the c parameter represents the growth rate.

For the prediction, the mean of the previous Euro Standards' "c" parameter will be treated as the possible value for the new Euro Standard 7 growth rate parameter.

	FIRST MID BELL				
	Euro 3	**Euro 4**	**Euro 5**	**Euro 6**	**MEAN**
c		0,05	1,10	1,24	0,80

Table 31. Gomperz Model c parameter

Source [12]

After analyzing the decrease in sales due to the Covid-19 crisis and the possible recovery in the future years, the initial value estimated for the next Standard will be 130.000 and the maximum value of 12.000.000.

Therefore, the "a" parameter for the prediction is 12.000.000.

The only parameter left is "b". This parameter is related with the initial growth rate.

The process followed to assume a possible value is to iterate until the initial and peak values estimated were reached, 130.000 and 12.000.000.

With this, for the initial mid bell, the value estimated is 10.

The parameters for the first mid bell are shown in table 7:

Parameters	Euro 7
a	12.000.000
b	10
c	0.8

Table 32. Gomperz Model first mid bell parameters prediction

Source [12]

Table 33 presents the prediction for the first mid bell.

Year	Euro 7 First mid bell
1	130.000
2	1.560.000
3	4.780.000
4	7.920.000
5	9.950.000
6	11.030.000

Table 33. Gomperz Model first mid bell prediction

Source [12]

The same process was repeated for the second mid bell.

	SECOND MID BELL				
	Euro 3	Euro 4	Euro 5	Euro 6	MEAN
c	0,78609587	0,90	1,12	1,98	1,2

Table 34. Gomperz Model c parameter second mid bell

Source [12]

The parameters for the second mid bell are as follows in table 35:

Parameters	Euro 7
a	12.000.000
b	15
c	1,2

Table 35. Gomperz Model second mid bell parameters prediction

Source [12]

Year	Euro 7 Second mid bell
1	130.000
2	3.060.000
3	7.940.000
4	10.590.000
5	11.560.000
6	11.860.000

Table 36. Gomperz Model second mid bell prediction

Source [12]

The prediction of the Gompertz Model is as presented in table 37 :

Year	Euro 7
2025	130.000
2026	1.560.000
2027	4.780.000
2028	7.920.000
2029	9.950.000
2030	11.445.000
2031	11.560.000
2032	10.590.000
2033	7.940.000
2034	3.060.000
2035	130.000

Table 37. Gompertz Euro Standard 7 prediction

Source [12]

The results of the Gompertz prediction are plotted in figure 16:

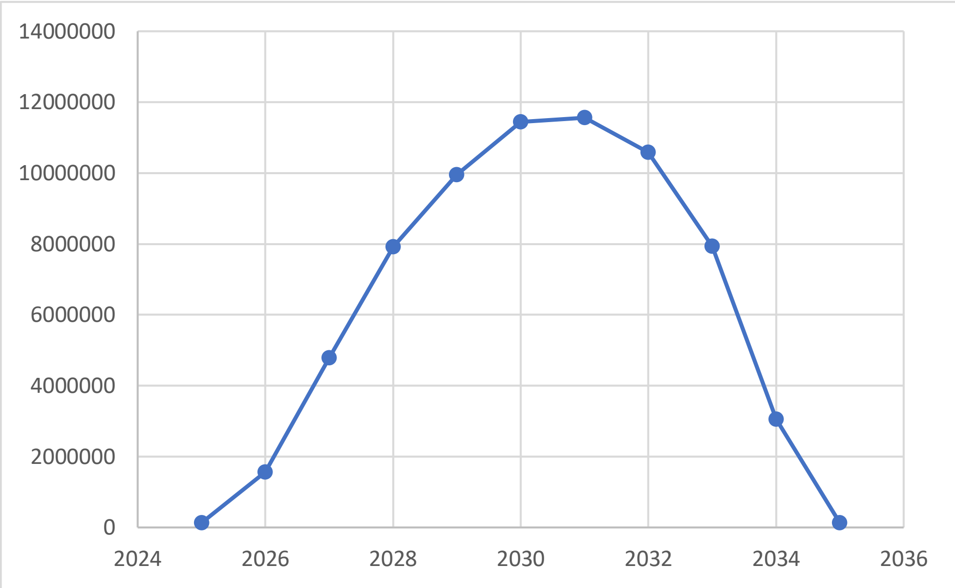

Figure 16. Gompertz Euro Standard 7 prediction

Source [12]

6.6. Gaussian Distribution Model prediction

For this model the formula is as presented in ME 3:

$$f(t) = a \cdot e^{\left(-b\cdot(x-c)^2\right)}$$

Mathematical Expression 3. Gaussian Distribution Model formula

Source [7]

The "a" parameter reperesents the maximum value reached, in this case: 12.000.000.

The "c" parameter represents when the peak value is reached. In my prediction, the future Euro Standard will last 11 years so this value will be 6.

For the "b" value the average value based on the approximation to the previous curves will be taken.

	Euro 3	**Euro 4**	**Euro 5**	**Euro 6**	**MEAN**
b	0,077331521	0,072429874	0,135749923	0,202415339	0,121981664

Table 38. Gaussian b paremeter

Source [12]

The parameter for the Gaussian Distribution Model prediction are presented in table 39:

Parameters	Euro 7
a	12.000.000
b	0,121981664
c	6

Table 39 . Gaussian Distribution Model parameters prediction

Source [12]

Here are the prediction results presented in table 40:

Year	Euro 7
2025	150.000
2026	570.000
2027	1.700.000
2028	4.000.000
2029	7.370.000
2030	10.620.000
2031	12.000.000
2032	10.620.000
2033	7.370.000
2034	4.000.000
2035	1.700.000

Table 40. Gaussian Distribution Model Euro Standard 7 prediction

Source [12]

The plotted results are presented in table 17:

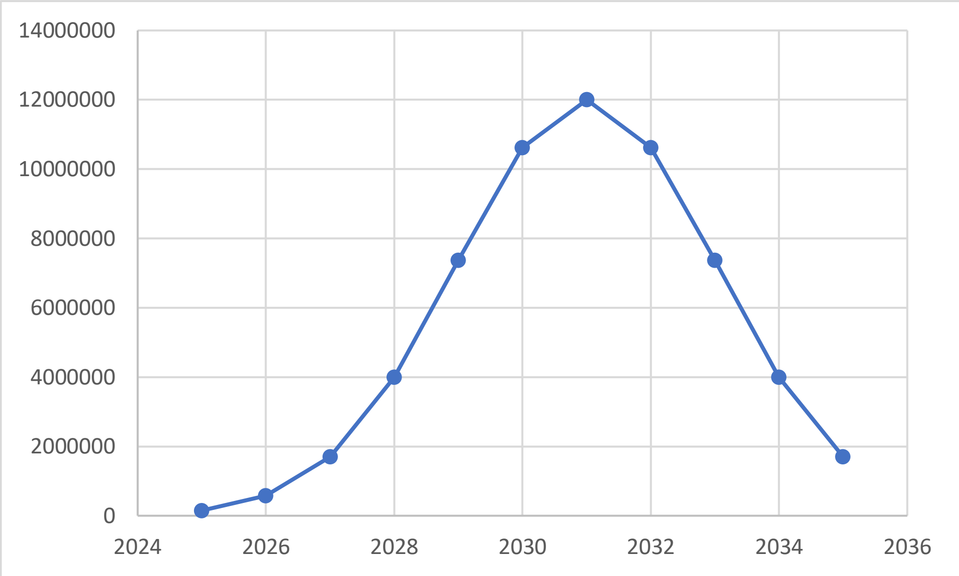

Figure 17. Gaussian Distribution Model prediction

Source [12]

Year	Logistics Model	Gompertz Model	Gaussian Distribution Model
2025	130.000	130.000	150.000
2026	700.000	1.560.000	570.000
2027	3.140.000	4.780.000	1.700.000
2028	8.020.000	7.920.000	4.000.000
2029	11.040.000	9.950.000	7.370.000
2030	11.425.000	11.445.000	10.620.000
2031	8.870.000	11.560.000	12.000.000
2032	4.970.000	10.590.000	10.620.000
2033	1.800.000	7.940.000	7.370.000
2034	510.000	3.060.000	4.000.000
2035	130.000	130.000	1.700.000

Table 41. Mathematical Model predictions for Euro Standard 7

Source [12]

The hypothesis suggested that the bell should be symmetrical, that is to say that the maximum value should be reached in 2030.

The predictions are similar, altough there are some differences.

The Logistics Model and Gompertz Model estimate an initial and final value of sales equal which supports one of the initial hypotheses, the symmetry of the bell.

In contrast, The Gaussian Distribution Model, has a great difference between the sales value of 2025 and the value of 2035.Based on this, the approach of the Gaussian Model could be rejected.

Logistics and Gaussian predictions have a similar growth rate until the expected maximum value of 2030 is reached. However,the Gaussian Model reaches the maximum value on 2031, one year after the expected.
On the other hand, Gompertz Model differs in how the sales rate grows, increasing less gradually than the other models.

Focusing on the sum of the cuadratic errors, the Logistics Model showed a better performance approaching the curve to the standard curves. Based on this argument, the better prediction is the Logistics Model.

Notwithstanding these predictions are based in the previous data collected. Therefore, future could be unpredictable and perform in a different way.

The Euro Standard regulations play a crucial role in regulating the emissions of vehicles.

This project had the aim to forecast the future Euro Standard 7 curve.

As time progresses, technology continues to advance rapidly. Currently, we are witnessing the integration of electric vehicles into the automotive industry.

It is expected that future technologies such as hydrogen cars or autonomous cars will emerge and become part of the vehicle sector. Euro Standard curves will have to adapt their regulations to these changes.

The next chapter is focused on autonomous cars and will explain briefly their advantages.

CHAPTER 8. AUTONOMOUS CARS

8.1. Introduction

Autonomous cars are an emerging technology which is expected to be seen in the near future.

There are different levels of automation as presented in figure 18.

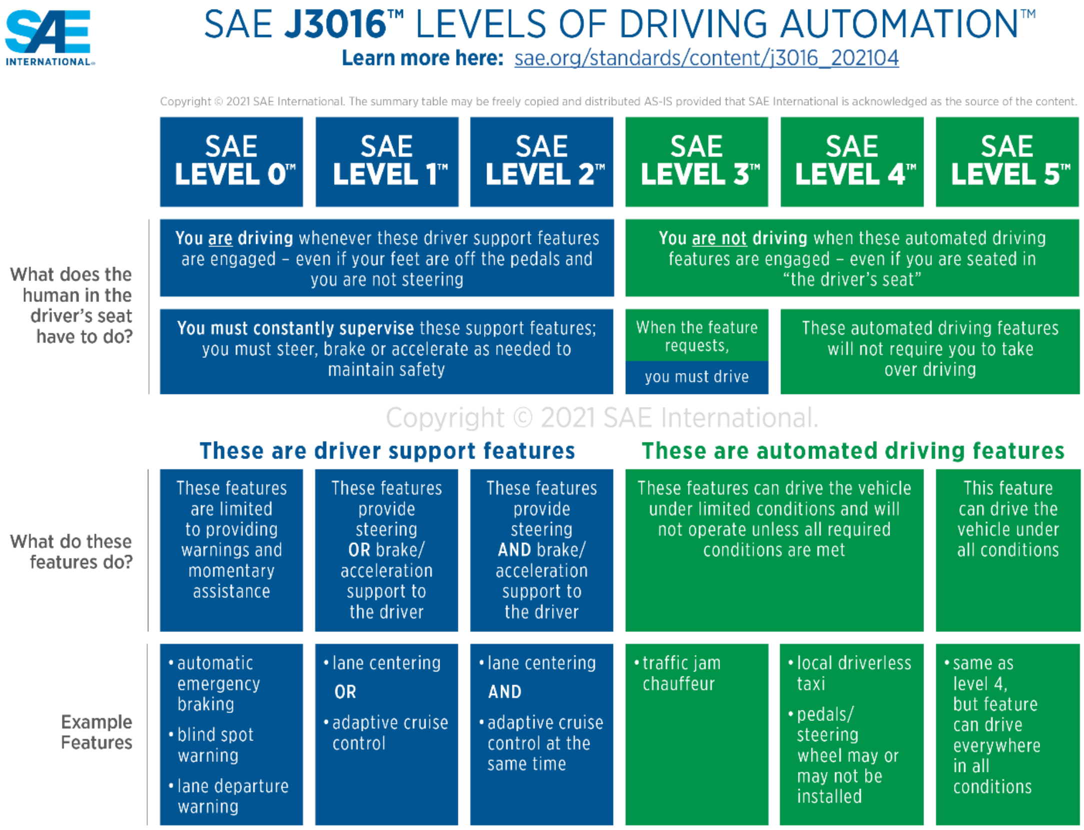

Figure 18. Levels of driving automation

Source [14]

Three different levels of automation can be appreciated.

Assisted driving:

• The driver is at the wheel and must constantly supervise the vehicle and intervene when necessary.

• The system provides steering, acceleration and braking support.

Figure 19. Assisted driving

Source [15]

Automated driving:

• The system is able to cope with all dynamic driving tasks within its operational design domain (ODD) without driver supervision.

• It will transition to the driver, offering sufficient lead time, when these conditions are not met.

• The driver may perform non-driving related tasks.

• The driver must be promptly available for safe transition of control.

Figure 20. Automated driving

Source [15]

Autonomous driving

• The system drives the vehicle under all conditions.

• No driver input is required.

• All vehicle occupants are effectively passengers.

Figure 21. Autonomous driving

Source [15]

8.2. Benefits

Road safety

Automated driving is expected to reduce the human error in driving. Thereby it contributes to the EU goal of zero road fatalities by 2050.

Assisted driving

Up until now some vehicles have already addapted this technology.

Assisted driving helps the driver in some situations such as: parking or keeping the vehicle in the lane.

Connectivity

Exchanging safety critical vehicles and infrastructure makes pissible to reduce accidents.

Vehicle communication will foresee possible dangerous situations.

Other possibilities include: impose variable speed limits or open or close traffic lanes when needed.

Freight transport

Automated driving, in combination with connectivity, is also revolutionising the transport of goods. Today, with platooning, trucks can be linked together into a convoy through connectivity technology and ADAS. The driver in the truck at the head of the platoon acts as the leader. The following trucks react and adapt to changes in the leader's movement, with little to no action required from the drivers. Tomorrow's trucks will be autonomous, transporting goods all over Europe without the need for drivers, providing shippers with a competitive advantage as well as reinventing the logistics structures of today.

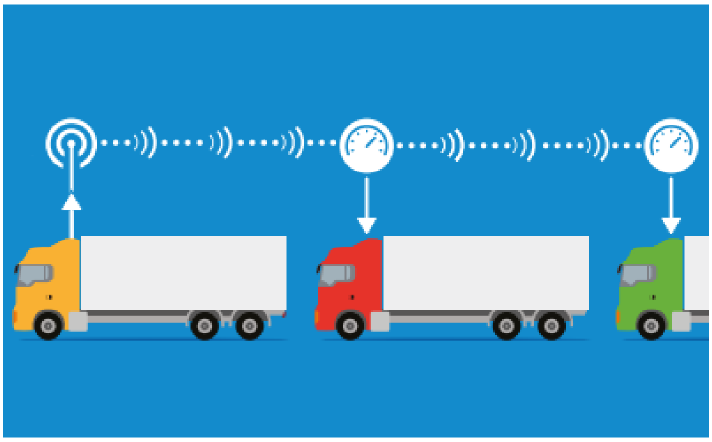

Figure 22. Platooning in freight transport

Source [15]

Accessibility and social inclusion

Driving without person assistance will be more comprehensive with people with reduced mobility and the elderly.

Figure 23. Accessibility and social inclusion

Source [15]

Efficiency and environment

Traffic congestion will be reduced and it will increase the efficiency of transport system.

This will lead to a decrease in fuel consumption and emissions improving air quality.

Freedom and comfort

Automation will increase freedom of drivers allowing them to perform other activities during driving trips.

Figure 24. Freedom and confort autonomous car

Source [15]

8.3. What is needed to become feasible

Strengthen cooperation between all stakeholders and get political support to promote its wide-scale introduction is crucial. Moreover, there are other factors to consider.

Legally

It will be crucial to adapat the legal framework in order to regulate this technology.

Physically

Adapt digital road infrastructure and make it suitable for automated driving.

Security

It is essential go gurantee safe, secure and trusted communication between vehicles and the digital infrastructure.

User adoption

Automated driving will not success unless it is socially accepted.

People fear of things wich are not familiar to them. Therefore, governments must e needed educate the public.

Artificial intelligence

AI enables autonomous vehicles to perform in complex traffic environments.

Testing

Large-scale testing and validation of automated driving systems on open roads is vital to furthering their development and deployment.

8.4. Up today

In this subchater, some examples about different levels of automation are going to be commented.

LEVEL 2

The stablished level of driving automation up today is level 2.

For instance, Tesla with its Tesla Autopilot implements this technology.

Some advances are:

The car has the ability to steer, accelerate and brake automatically within its lane. Nevertheless, this features require driver supervision.

Navigate on autopilot

Not only it will suggest changes in route in order to optimize the time but also it will automatically steer the vehicle towards highway interchanges and exists based on destination.

Self parking

The vehicle is capable of parking on its own. Besides, it can get back to the road exiting the parking zone without human intervention.

Figure 25. Tesla Model S

Source[16]

LEVEL 3

The first legally approved car has been introduced in the state of Nevada in United States.

This vehicle belongs to Mercedes and implements Drive Pilot system.

As presented before, this level allows the car to drive itself undeer some conditions.

An aspect to remark is that the maximum speed reached is 65 Km/h.

In addition to this, the car will also react to unexpected traffic situations.

Figure 26. Mercedes with Drive Pilot system

Source[17]

Level 4

In August of 2022, a company named DeepRoute.ai tested a car with Level 4 of automation during an hour in the city of Shenzen, China. The test was a success.

Despite being many hurdles to overcome before autonomous cars are feasible, all these advances demonstrate that eventually they will become doable in the near future.

CHAPTER 9. ECONOMIC ASPECT OF EURO STANDARD EMISSIONS

Europe has several instruments to fight against climate change by regulating green house gases.

European Standards are one of these instruments but there are other instruments such as European Union Allowance (EUA) which is the biggest market of tradable emissions units in the world within the framework of European Union Emissions Trading System (EU ETS).

EUAs stand as the right of an entity to emit a certain amount of carbon dioxide or other gases within th elimits of EU ETS.

The price of EUAs varies based on supply and demand in the market. It is quoted in euros per ton of CO_2 equivalent (€/tCO_2 e) which is a measurement of the carbon footprint.

Besides this, it is necessary to explain what Global Warming Potential (GWP) is. This term is adimensional, it is a measure of how much infrared thermal radiation a greenhouse gas added to the atmosphere would absorb over a given time frame, as a multiple of the radiation that would be absorbed by the same mass of added carbon dioxide.

$$CO_{2\,equivalent} = gas\ mass \cdot GWP$$

Mathematical Expression 5. CO_2 equivalent

Source [-]

The idea is to estimate the price of the emissions produced by passenger vehicles which belong to the Euro Standards 3,4,5 and 6.

To do this calculations, some elements explained before are going to be used, to avoid unnecessary repetitions are just going to be cited.

- Table 1: Euro Standards limits for petrol and diesel passenger cars
- Table 4: PC registration Euro Standards

Additionally, it is going to be needed the average distance travelled by passenger vehicles each year as presented in table 42:

Year	Average distance travelled by car Km
2001	13.076
2002	13.020
2003	13.008
2004	13.089
2005	12.789
2006	12.737
2007	12.700
2008	12.415
2009	12.329
2010	12.161
2011	11.935
2012	11.626
2013	11.532
2014	11.674
2015	11.676
2016	11.716
2017	11.545
2018	11.547
2019	11.313
2020	11.079

Table 42. Average distance travelled by car

Source [20]

By multiplying the amount of registered passenger cars which accomplish Euro Standards with the average value of distance travelled by car each year, an estimation of the amount of Kilometers travelled by car yearly by each Euro Standard can be done. Presented in table 43.

Year	EURO 3	EURO 4	EURO 5	EURO 6
2001	1,36644E+11	48.250.440.000		
2002	1,30981E+11	54.684.000.000		
2003	1,24356E+11	64.129.440.000		
2004	1,09686E+11	85.732.950.000		
2005	76222440000	1,17275E+11		
2006	31460390000	1,65199E+11		
2007	13843000000	1,8415E+11		
2008	5338450000	1,69092E+11	3.600.350.000	
2009	1726060000	1,49427E+11	22.562.070.000	
2010	851270000	98.747.320.000	62.264.320.000	
2011		36.043.700.000	1,20544E+11	
2012		12.323.560.000	1,26375E+11	1.395.120.000
2013		691.920.000	1,29504E+11	6.111.960.000
2014			1,19775E+11	26.266.500.000
2015			63.984.480.000	95.976.720.000
2016			17.105.360.000	1,54417E+11
2017			7.042.450.000	1,6798E+11
2018			5.196.150.000	1,68933E+11
2019			1.696.950.000	61.203.330.000
2020			664.740.000	26.478.810.000

Table 43. Average distance travelled by new registered cars from Euro Standards 3,4,5 and 6

Source [12]

The calculations are not going to consider old passenger cars, just the new registrations.

Besides, it is going to be assumed that every new registered car is going to emmit the maximum amount of allowed emissions for the year studied.

Having explained this, by multiplying the amount of distance travelled with the different gas emissions regulations, the result is the amount of emissions yearly.

Just one table with the results is going to be attached, the procedure is analogous for the other gas regulations.

One remarkable aspect is the fact that CO emissions due to their short lifecycle (1 to 2 months) are not going to be considered. This is also going to be the case of PM as they do not have a GWP.

Once again, the results are going to be rounded.

Here in table 44 stands the results obtainted for HC emissions for petrol passenger cars.

TONS OF HC FOR PETROL PASSENGER CARS				
Year	**EURO 3**	**EURO 4**	**EURO 5**	**EURO 6**
2001	27.000	5.000		
2002	26.000	5.000		
2003	25.000	6.000		
2004	22.000	9.000		
2005	15.000	12.000		
2006	6.000	17.000		
2007	3.000	18.000		
2008	1.000	17.000		
2009	300	15.000	2.000	
2010	200	10.000	6.000	
2011		4.000	12.000	
2012		1.000	13.000	
2013			13.000	1.000
2014			12.000	3.000
2015			6.000	10.000
2016			2.000	15.000
2017			1.000	17.000
2018			1.000	17.000
2019			200	6.000
2020			100	3.000

Table 44. Emissions of HC (tons) from Euro Standards 3,4,5 and 6

Source [12]

The next step is to multiply the tons of emissions with the GWP required for each gas.

Clarifications:

- HC: these comprehend methane, ethane, propane and butane among others. Nevertheless, CH_4 is the most abundant, therefore its GWP is going to be conisedered as the GWP for the HC emissions.
- NO_x: equally, the most abundant compound is NO_2.
- Diesel emissions regulate a category which petrol cars does not, HC+NO_X.
  For these emissions, the GWP will be considered as the average value of CH_4 and NO_2 GWP.

COMPOUND	GWP
CH_4	25
CO	-
NO_2	298
PM	-
$HC+NO_x$	161,5

Table 45. GWP

Source [21]

After the proper calculations , the next step is to multiply the $CO_{2equivalent}$ tons with the estimated price for CO_2 emissions set by EUA.

Table 46 collects this prices:

Year	€/ton CO_2
2001	
2002	
2003	
2004	
2005	
2006	
2007	
2008	22,02
2009	13,06
2010	14,32
2011	12,89
2012	7,33
2013	4,45
2014	5,96
2015	7,68
2016	5,35
2017	5,85
2018	15,88
2019	24,84
2020	24,75

Table 46. EUA €/ton CO2

Source [22]

The price for the CO2 emissions will be the average value: 12,6 €/ton CO_2.

Finally, the price (millions of euros) for the HC and NOx emissions for petrol and diesel cars is presented in table 47:

Year	EURO 3	EURO 4	EURO 5	EURO 6
2001	495,6147	90,1404		
2002	475,8957	101,7198		
2003	454,4568	119,4039		
2004	397,6497	160,8768		
2005	276,2109	217,6839		
2006	117,369	309,8592		
2007	51,0174	346,6323		
2008	21,4389	319,4037	6,54066	
2009	6,63516	280,2807	29,5785	
2010	2,95785	188,1054	86,7006	
2011		68,7015	169,6464	
2012		23,4738	179,5059	1,082844
2013		0,976248	181,5408	5,72922
2014			169,6464	24,1038
2015			92,4903	88,2756
2016			23,7888	136,4832
2017			10,76796	150,7275
2018			6,85566	154,4823
2019			2,37888	56,0322
2020			0,964152	26,1387

Table 47. Emissions price for Euro Standards (Millions of euros)

Source [12]

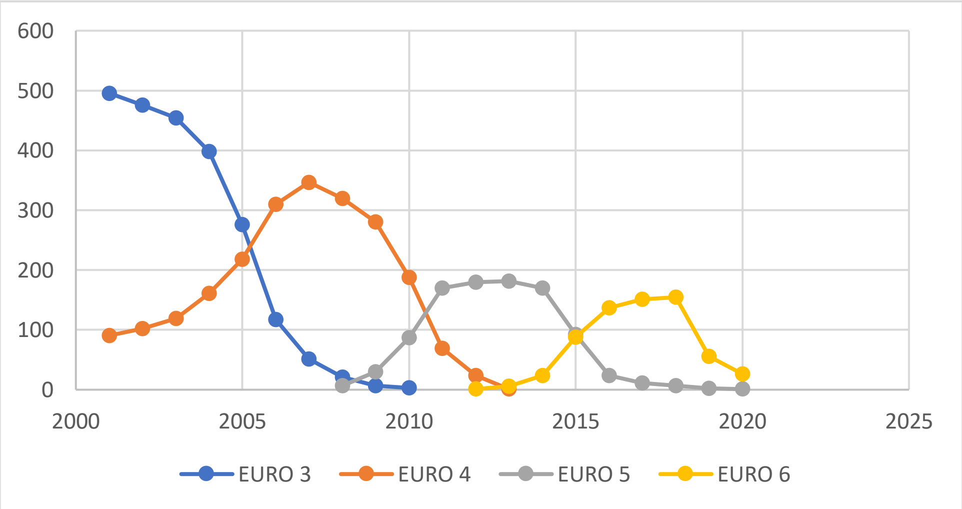

Figure 27 . Emissions price for Euro Standards (Millions of euros)

Source [12]

There is a notorious decrement in the emissions prices for each Euro Standard.

New Euro Standards on the whole, have less emissions prices.

CHAPTER 10. BUDGET

In this section the aim is to evaluate the total cost of this analysis.

The budget will be divided into two sections:

- Category 1: Machinery and intangibles.
- Category 2: Labour.

To develop this project, it was needed a computer with Microsoft 365 as computer programs such us Microsoft Excel or Microsoft Word were required.

The price for an anual Microsoft 365 sucription is 70 €/year.

The computer was bought in 2019 with a price of of 700 €. Besides, its lifetime is estimated to be 5 years.

Additionally, the tools have been used for 4 months.

The computer is classifies as machinery. This kind of assets suffer depreciation over the time. The reason behind this is that due to wear, usage and technological obsoloscence assets lose value.

Based on the International Accounting Standards (IAS), the depreciation of a computer could be done by the linear method.

$$Yearly\ Depreciation = \frac{Initial\ Cost}{Life\ time\ of\ the\ asset}$$

Mathematical Expression 6. Linear depreciation

Source [23]

The yearly depreciation is: 140 €/year.

The residual value at the end of each year is as is follows:

- Year 1 (2019-2020): 560 €.
- Year 2 (2020-2021): 420 €.
- Year 3 (2021-2022): 280 €.
- Year 4 (2022-2023): 140 €.
- Year 5 (2023-2024): 0 €.

The project started in February 2023. Therefore it is important to take into account its depreciation suffered before this date.

In the year 5, the starting price is estimated as 140 €, furthermore, at the end of the year the estimated price is 0 €.

$$Year\ 5\ monthly\ depreciation = \frac{140 - 0}{12} = 11{,}66\ €$$

$$Computer\ depreciation = 7{,}5 \cdot 4 = 46{,}64\ €$$

For the software used, the amortization cost will be:

$$Software\ amortization = 70 \cdot \frac{4}{12} = 23{,}3\ €$$

The cost of the asset during the project is the sum of the depreciations.

$$Machinery\ and\ intangibles = 23{,}3 + 46{,}64 = 69{,}94\ €$$

Based on the National Institute of Statistics of Spain “Insituto Nacional de Estadística” (INE), the annual salary of a person who works in transport and logistics is around 25.000 €/year

which is equivalent to 13 €/h.

The student has spent around 4h per day and worked around 20 days per month, which gives a total of 80h per month. Moreover, there will be an estimation of indirect costs of 13%.

All in all, this is the estimated budget is presented in table 48:

Work:	Final Project					
Budget						
Code	Type	Unit	Summary	Quantity	Price (€)	Cost (€)
Final Project	Chapter					
01	Chapter		MACHINERY AND INTANGIBLES			
001		Unit	Computer Machinery	1,00	46,64	46,64
002		Unit	Microsoft Office Intangibles	1,00	23,30	23,30
			01		69,94	69,94
02	Chapter		LABOUR			
003		h	Student author Labour	320,00	13,00	4.160,00
			02		4.160,00	4229,94
03			INDIRECT COSTS			
			Indirect costs	13%	4229,94	549,89
			Total amount			4779,83

Table 48. Project Budget (€).

Source [12]

The final budget amounts to a total of FOUR THOUSAND SEVEN HUNDRED AND SEVENTY-NINE EUROS WITH EIGHTY-THREE CENTS.

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