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Analysis of Bus Transportation Mode in Central Europe

Ammar Al-lami

Misan university, College of Engineering, Department of Civil Engineering, north entrance of AL-Amarah Misan, Misan, Iraq
ammarcivil.allamy@gmail.com

Abstract: Buses belong to the most important means of public transportation that significantly impact the economic and environmental aspects of people in different countries. This study has focused on studying the relationship between buses and their effect on GDP, road networks and population in Hungary, Poland, Czech and Slovakia. We evaluated the number of buses and the GDP per capita for each country for different years and examined the changes over time and the effect of increasing GDP per capita on the number of buses for these countries. We evaluated the transportation system for each country in terms of the number of buses, the area of the country, the paved road network, and the number of inhabitants with income levels there. Poland excels in the number of buses compared to its vast area and high population, but it is lagging in GDP per capita. Slovakia is the smallest in terms of its population and area but has the highest GDP per capita. The Czech Republic is the best in caring for the road network, constantly updating it, and adding newly paved roads and expressway sectors.

Keywords
Buses, GDP, Population, Area, Paved Road.

1. Introduction:

Public transportation, especially buses (fuel or electric) , is one of the leading mobility modes in the world due to the services it provides that are commensurate with the population's economic situation and the world's trends towards sustainability and reducing pollution and congestion. The level of service provided by buses and the amount of demand for them is directly related to several influencing factors, including the income level of the individual and the countries' policies in developing buses in line with the requirements of the population and the changes that occur to it, since the relationship is inverse between the income level of the individual and the demand for using buses for transportation (Egercioğlu & Doğan, 2016). Therefore, there must be a direct interest in developing the bus transportation system commensurate with the country's area, the number of residents and their welfare. As a result, transportation and mobility play a crucial part in urban economics and quality of life (Nanaki et al., 2017).

One of the main tasks of public passenger transport is to satisfy the transport requirements of the area served. The importance of proper coordination of public passenger transport is particularly evident in the development of cities and suburban areas and in the effort to reduce environmental pollution. Transport must meet the transport requirements of society, but it must also contribute to its economic development and to raising the living standards of the population (Konecný et al., 2021)

In most countries, the government is involved in supplying public transportation services. In most cases, it provides substantial subsidies for the operation of the services to increase the equality of accessibility and financial efficiency of the system (Pucher and Renne, 2013). In recent decades, numerous countries have introduced reforms in their public bus services. This has been based mainly on budgetary considerations against the background of inefficient spending by bus companies, and a decline in revenue, due to a steady decrease in the number of passengers (Ida and Talit, 2018).

So, for Central European countries like Hungary, Poland, Czech and Slovakia, these four countries share many social and historical characteristics. However, they differ in terms of area, population, infrastructure, economic level of each country, and public transport system, so we need a comprehensive evaluation comparison of the bus transportation system in these countries and the impact of GDP per capita on it. Moreover, evaluating the road network that serves each country and its proportionality with the number of buses, the country's size, and the population will be explored, because of the important location of these countries in Central Europe. Where it is considered a link between eastern and western Europe and plays an important role in terms of economic and tourism.

2. Methodology

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The following types of general data were collected for the four countries from publicly available databases (Eurostat, Nation Master):

- The number of public transport buses registered for each country from 2013 until 2019.
- Population and area of each country.
- The length of paved roads for each country.
- Average annual GDP per capita.

The length of paved roads were considered as constant in the investigation period (from 2013 to 2019), because there is no clear, transparent, robust database for the Visegrad countries for each years.

The relationship between the number of buses for each country was compared with the four variables (area [km^2], length of paved road network [km], GDP [EUR/capita] and number of buses) and comparing them with each other in order to show the extent to which the number of buses is proportional to the area of each country, the number of paved roads served, and the extent to which the economic level of the individual or the state affects the number of buses, and thus the percentage of use of public transport by buses for each country. The raw data are given in Table 4 at the end of this study.

2.1. Study Area

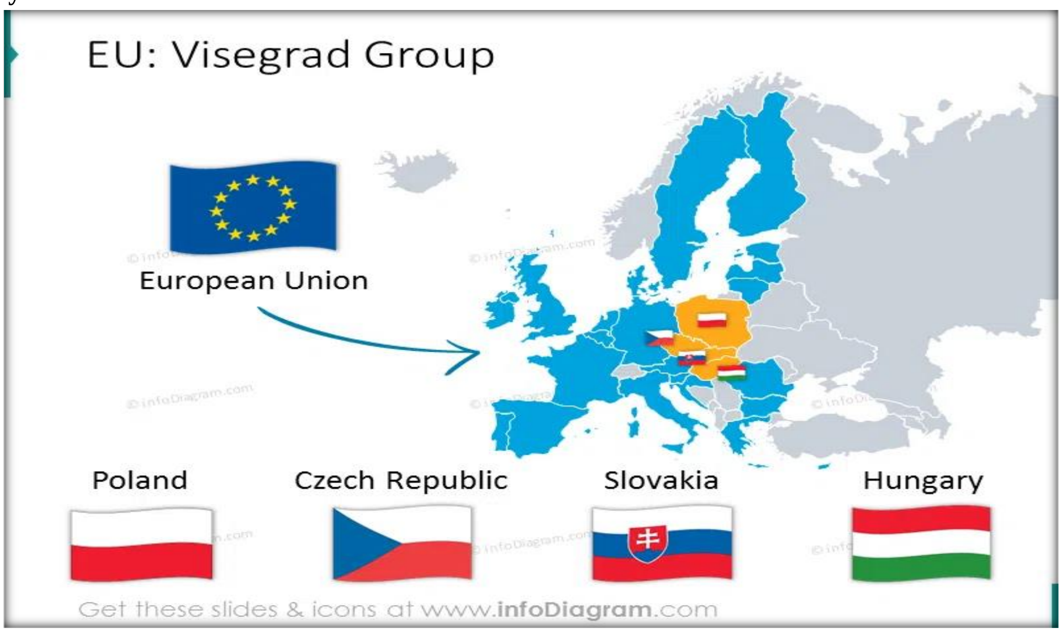

Fig.1. *Location of case study countries(www.infodiagram.com)*

Hungary is a landlocked country in Central Europe. The area of around 93,030 km^2 of the Carpathian Basin is bordered by Slovakia to the north, Ukraine to the northeast, Romania to the east and southeast, Serbia to the south, Croatia and Slovenia to the southwest, and Austria to the west. Hungary has a population of nearly 10 million (Horváth, 2000).

Poland is located at a geographic crossroads that links the forested lands of northwestern Europe to the Atlantic Ocean Sea lanes and the Eurasian frontier's fertile plains. The total area of 312,679 km^2 is the seventh biggest country on the continent. The Polish population is over 38,5 million people. Poland borders seven countries: Germany on the west, Czech Republic and Slovakia on the south, Ukraine, Belarus and Lithuania on the east, and Russia on the north.(Rdzany, 2014).

The Czech Republic or Czechia is a landlocked country in Central Europe. It is bordered by Austria to the south, Germany to the west, Poland to the northeast, and Slovakia to the southeast. The Czech Republic has a hilly landscape covering an area of 78,871 square kilometers and over 10 million people (Divíšek et al., 2014).

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Slovakia is a landlocked country in Central Europe. It is bordered by Poland to the north, Ukraine to the east, Hungary to the south, Austria to the southwest, and the Czech Republic to the northwest. Slovakia's mostly mountainous territory spans about 49,000 km^2, with a population of over 5.4 million (Ištok and Plavčanová, 2015).

These four countries, which make up the so-called Visegrád Group, are located in the center of Europe, share boundaries, and have the same characteristics of society. They are also landlocked countries except for Poland, which has a larger population density and a larger area.

3. Result and discussion

Firstly, we can arrange the countries depending on the area as follows: Poland, Hungary, Czechia, and Slovakia. Furthermore, depending on the population as following Poland, Czechia, Hungary and Slovakia.

Table 1

Summary data in 2019

country	Total Buses	Bus/capita	Bus/km²	Bus/km	Bus/GDP
Poland	91052	0.0023874	0.2911707	0.299513	6.581
Czechia	21484	0.0020345	0.272408	0.386035	1.016
Hungary	19500	0.0020093	0.2096211	0.278373	1.3
Slovakia	8974	0.0016445	0.1830121	0.235631	0.518

https://ec.europa.eu .

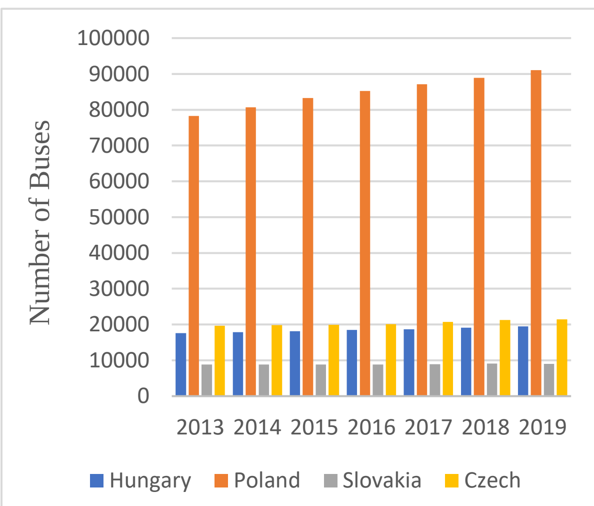

Fig. 2 No of buses

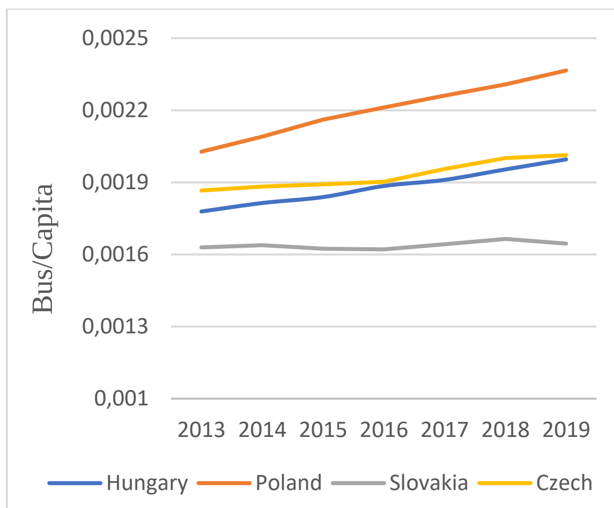

Fig. 3 Bus/ capita

Figure 1 shows that Poland has more buses than the other countries. This is expected because of its vast area and population, and Czechia in the second level before Hungary and finally Slovakia. Hungary's area is more than that of Czechia by 15%, but the Czech Republic has more buses. Figure 3 shows the percentage of buses per capita in each country. Poland takes the lead, followed by the Czech Republic, Hungary, and Slovakia. The Czech Republic is superior to Hungary in the bus/capita figure, despite the similarity in the population of both countries, considering the area of Hungary, which is 15% more than that of Czechia.

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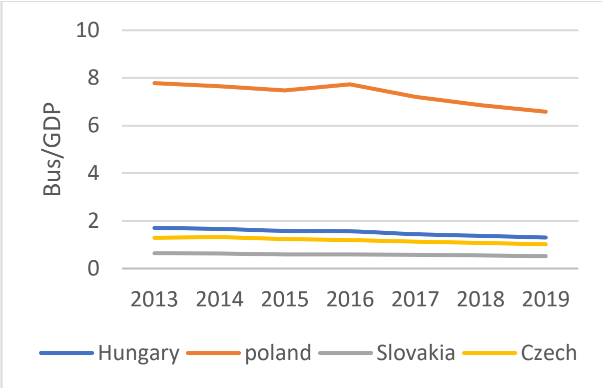

Fig.4 Bus/GDP

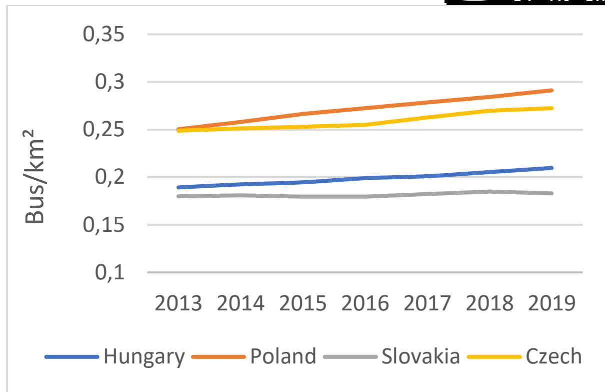

Fig. 5 Bus/ Km²

Figure 4 demonstrates how GDP per capita is correlated with the number of buses for these four countries. Poland has the highest Bus/GDP value due to the high number of buses and low GDP per capita, but generally, it decreases by 15% from 2013 to 2019. Slovakia has the lowest percentage of Bus/GDP because it has higher GDP, which affects the number of buses: it leads to a decrease in the use of buses as a mode of transportation, and thus the number of buses decreases due to the lack of use. To increase the use of buses in countries with higher GDP per capita, the performance of bus transportation must be improved in terms of reducing the waiting time, increasing the number of stations and facilitating access to them, and using modern buses that provide sufficient comfort factors.

Also, Figure 5 shows that the area covered by buses in Poland is high compared to other countries like Slovakia, which has the smallest area has a low Bus/km^2 value.

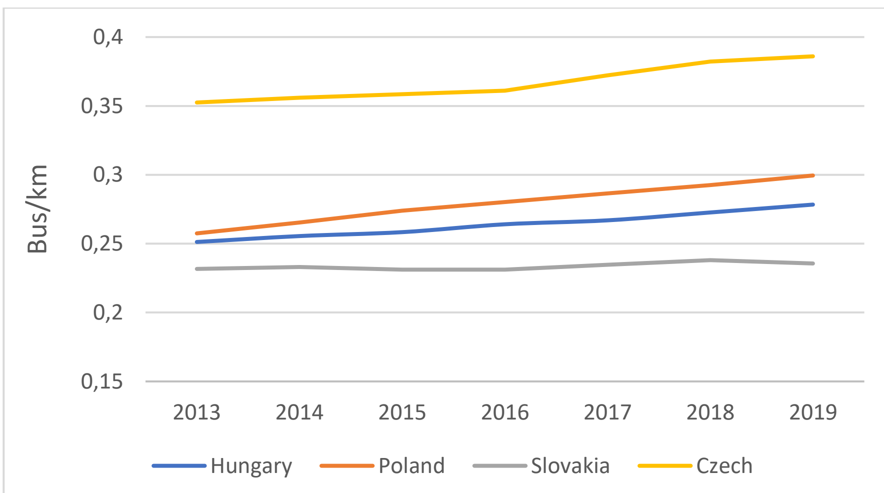

Fig. 6 Bus/ Km

Table. 2
Area and paved road.

Country	Czechia	Slovakia	Poland	Hungary
Area	78,867 km²	49,035 km²	312,710 km²	93,025 km²
Length of paved roads	129, 411 km	38,085 km	307,066 km	77,942 km
%km/km^2	1.64	0.77	0.97	0.83

https://www.nationmaster.com/

Figure 6 illustrates that Czechia has the highest percentage for Bus/km and it has the longest road network km/km^2, while Poland is the second and Slovakia is the last. In contrast, Slovakia has a high GDP and low area level compared with the other countries.

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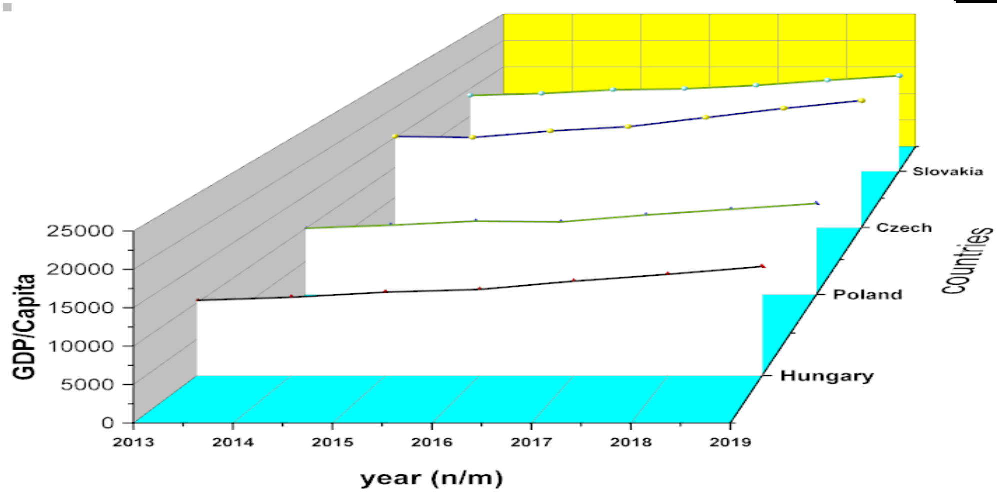

Fig. 7 The relationship between GDP and Capita

GDP/capita: The statistical description of the available data shows that the GDP/capita is inversely proportional to the demand for public transportation and, thus, the number of buses in each country. Poland has the highest number of buses and buses per capita and high Bus per GDP capita value but has the lowest income level (GDP). In contrast, Slovakia has a low population, small area, and high GDP. This leads to the lowest number of buses if income welfare is high (GDP/per capita), this shows that the increase GDP per capita is not linked to an increase in the number of buses or an increase in dependence on public transportation by buses.

Bus / km and Bus/ km²: Czechia has a better bus/km percentage than Poland, Hungary, and Slovakia. That means the paved road network in Czechia covers the country area very well, regarding to figure 6 it is suitable for transport services. With respect to the number of buses compared to the area of the country, Czechia comes in second after Poland, which needs to expand the transportation network and increase the number of buses in it to suit the number of residents and the area of the country. Also, this applies to Slovakia and Hungary to a lesser extent**.**

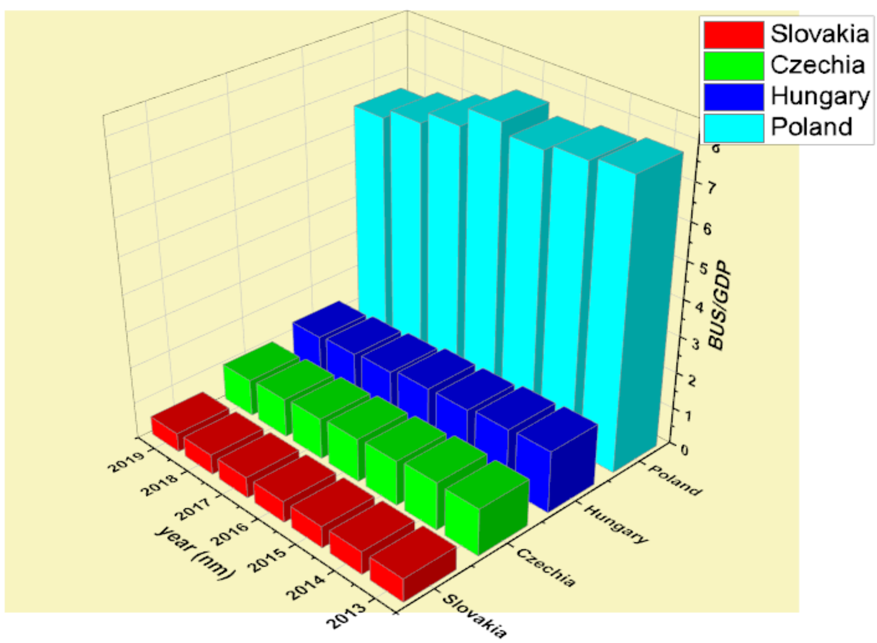

Fig. 8 The relationship between BUS and the GDP per capita

4. Conclusion and Recommendations

- Poland has the largest number of buses but that s offset by a low GDP per capita.

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- Czechia has largest Bus/km percent and suitable Bus/capita percent.
- Hungary has good level regarding the proportionality of the number of buses with the number of the population and the coverage of buses from the area of the country.
- Slovakia is the highest in the GDP of its citizens and the lowest in terms of the number of buses, Bus/km, Bus/km^2 and Bus/GDP.
- For future work should be Focusing on the sustainability of public transport by buses by studying the percentage of emissions in these countries and their change with the increase or decrease in the number of buses in general and the extent of changes in the rates after increasing the number of electric buses.

Table 4. All data in our case study (2013–2019).

country	year	Population	GDP (country)	GDP per capita	No. of buses	Bus/capita	Bus/km²	Bus/km	Bus/GDP
Hungary 93025 km² 70,050 km	2019	9771796	146,526.1	14,994.79	19500	0.001995539	0.2096211	0.2783726	1.300451
	2018	9776358	136,054.6	13,916.69	19100	0.001953693	0.2053212	0.2726624	1.372452
	2017	9788941	127,024.7	12,976.34	18700	0.001910319	0.2010212	0.2669522	1.441083
	2016	9815104	116,255.7	11,844.57	18500	0.00188485	0.1988713	0.2640971	1.561897
	2015	9844246	112,791.0	11,457.55	18100	0.001838638	0.1945714	0.2583869	1.579744
	2014	9867901	106,263.8	10,768.63	17900	0.001813962	0.1924214	0.2555318	1.662235
	2013	9894639	102,239.7	10,332.83	17600	0.001778741	0.1891965	0.2512491	1.703307
Poland 312710 km² 304000 km	2019	38493601	532,504.7	13,833.59	91052.00	0.00236538	0.2911707	0.2995132	6.58195
	2018	38521457	499,004.1	12,953.92	88907.00	0.002307986	0.2843113	0.2924572	6.863325
	2017	38532812	465,772.6	12,087.68	87122.00	0.002260982	0.2786032	0.2865855	7.207499
	2016	38532113	424,735.3	11,022.89	85205.00	0.002211272	0.2724729	0.2802796	7.729823
	2015	38553146	429,834.6	11,149.14	83304.00	0.002160758	0.2663938	0.2740263	7.471784
	2014	38581872	406,412.5	10,533.76	80659.00	0.002090593	0.2579355	0.2653257	7.657184
	2013	38607353	388,356.4	10,059.13	78280.00	0.002027593	0.2503278	0.2575	7.781985
Slovakia 49035 km² 38,085 km	2019	5454147	94,437.5	17,314.80	8974.00	0.001645354	0.1830121	0.2356308	0.518285
	2018	5446771	89,874.7	16,500.54	9066.00	0.001664472	0.1848883	0.2380465	0.549436
	2017	5439232	84,669.9	15,566.51	8937.00	0.001643063	0.1822576	0.2346593	0.574117
	2016	5430798	81,265.2	14,963.76	8804.00	0.001621125	0.1795452	0.2311671	0.588354
	2015	5423801	80,126.0	14,773.03	8804.00	0.001623216	0.1795452	0.2311671	0.595951
	2014	5418649	76,354.5	14,091.05	8876.00	0.001638047	0.1810136	0.2330576	0.629903
	2013	5413393	74,492.8	13,760.83	8821.00	0.001629477	0.1798919	0.2316135	0.641022
Czechia 78867 km² 55,653 km	2019	10671870	225,613.5	21,140.95	21484.00	0.002013143	0.272408	0.3860349	1.016227
	2018	10629928	210,970.5	19,846.84	21271.00	0.002001048	0.2697072	0.3822076	1.071757
	2017	10594438	194,132.9	18,324.03	20719.00	0.001955649	0.2627081	0.372289	1.1307
	2016	10566332	177,438.5	16,792.81	20097.00	0.001901985	0.2548214	0.3611126	1.196762
	2015	10546059	169,558.2	16,077.87	19950.00	0.001891702	0.2529575	0.3584712	1.240836
	2014	10525347	157821.30	14994.40	19808.00	0.001881933	0.251157	0.3559197	1.321026
	2013	10514272	159461.50	15166.20	19619.00	0.00186594	0.2487606	0.3525237	1.293601

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Hungarian agricultural pathways revealing climate-related challenges

Kinga Biro
Dept. of Department of Environmental Economics and Sustainability
Budapest University of Technology and Economics
Budapest, Hungary
biro.kinga@gtk.bme.hu

Otto Toldi
Climate Policy Institute
Mathias Corvinus Collegium
Budapest, Hungary
toldi.otto@mcc.hu

Abstract
The agricultural sector is highly exposed to the expected impacts of climate change, such as more frequent extreme weather events, prolonged and intensified heat waves, and water shortages, which present new challenges to farmers. Innovation is becoming increasingly important in European and Hungarian agricultural policy, and it plays a key role in the decarbonization of the sector. Innovative technologies improve the three dimensions of sustainability, and contribute to food security and increase the profitability of agricultural production. The research aims to analyze the greenhouse gas emission trends and forecast future emissions from the agriculture sector in Hungary and give a brief overview of the emission scenarios reported in the National Clean Development Strategy. Descriptive statistics are used to analyze emissions data. Chebyshev's inequality is used to predict future EU and domestic GHG emissions. Agriculture is one of the most conservative sectors from a climate perspective and it is already visible that the conventional approach will not be enough, but it has effective tools to achieve climate neutrality by 2050.

Keywords
Agricultural pathways, Climate change, Innovation, Scenarios, Greenhouse gas emission trends

1. Introduction

The paradox of the agricultural sector is that agriculture can decouple itself from the adverse effects of climate change by increasing the intensity of farming (irrigation, use of plant stress tolerance fertilizers, growth regulators, pesticides, large-scale livestock production, etc.), which, together with increasing the profitability of agricultural production and crop safety, increases GHG emissions. Achieving climate neutrality by 2050 will also require a contribution from the agricultural sector, and we can already see that we need to step out of our comfort zone to achieve this, as the traditional approach will not deliver the desired results. The goal for Hungarian agriculture is to produce more, realize its potential, and fulfill its historic mission in global food markets while reducing greenhouse gas and other pollutant emissions. This is the sustainable intensification of agricultural production and Hungary has all the tools at its disposal to achieve this. An integrated approach should be adopted, which requires assessing the negative externalities and potential adaptation trajectories for Best Available Techniques (BAT) (Ndue and Goda, 2022). Furthermore, we must base the development on innovation, and smart, energy-efficient, renewable energy-based, waste-free, and environmentally friendly agriculture must become a reality by 2030. Innovative solutions and businesses have a pivotal role in solving sustainability, climate change, and achieving low GHG emissions in the sector and precision farming and Agriculture 4.0 toolbox are the innovative tools in this process. The aim of precision farming is to reduce the use of pesticides, fertilizers, and water-use, and improve soil productivity. In livestock production, as in crop production, more sustainable management is based on targeted interventions.

Agricultural policy plays an important role in supporting Sustainable Development Goals (SDGs). SDG-2 aims to eliminate hunger in the world and in this regard, agriculture has a dual role: the Common Agricultural Policy (CAP) guarantees the availability of safe, nutritious, and sustainably produced food for all, and food exports contribute to food security, thereby promoting the growth of the domestic agro-industry. The agricultural policy also contributes to several other SDGs, including

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Goal 1 (no poverty), Goal 8 (decent work and economic growth), Goal 12 (responsible consumption and production), Goal 13 (climate action), and Goal 15 (life on land) (United Nations, 2015).

Innovative technologies and business are the key solutions to sustainability and climate change. Innovative tools contribute to solving social challenges, but they can also have negative externalities (Csete, 2022). Innovation improves the 3 scopes of sustainability: enhance incomes, decrease the risks and environmental pressures, and reduce critical labor deficit (Szőke et al., 2021). Sustainable management tools and solutions can be linked to business, innovation, and agriculture and the issues must consider maintaining or improving the quality of life and strengthening the processes of cognitive sustainability (Zöldy et al., 2022).

2. Literature review

2.1 Agriculture map

Hungary produced 2.1% of the EU's agricultural output in 2020, according to Hungarian Central Statistical Office (KSH) data (KSH, 2020). Hungary accounted for 4.9% of EU cereal production, including 11% of maize. In industrial crops, Hungary contributed 5.8% to the EU's output, mainly related to the production of oilseed crops. National poultry production accounted for 4.4% of total EU production in 2020. Among the countries with significant agricultural production, the Central and Eastern European and Southern European countries, including Greece, Romania, and Hungary, typically have the largest share of agriculture in gross value-added production, with a share of over 4%. In contrast, Germany and Belgium have shares of less than 1%. The different economic structures are also reflected in the fact that, although Germany and France together account for one-third of the EU's agricultural output, agriculture makes only a small contribution to their economic performance. The KSH carried out a comprehensive agricultural census in 2020. Data collection covering all municipalities in the country takes place every ten years, and last year was the eighth in the history of Hungarian agricultural statistics. According to the first preliminary data, the number of farms has fallen by two-thirds to 234,000 since 2010 (KSH, 2021). The concentration of holdings has increased, with the reduction in the number of holdings leading to an increase in the amount of land per holding in all cultivated branches, for example, in the case of vines, the area of land per holding has more than doubled. The use of digital tools is most common among young managers. The most frequently used tool is the crop health monitoring system. The results also show that the higher the farmers' education, the more often they use expert help (Juhász and Horváth-Csikós, 2021). Based on their main activities, two-thirds of farms were mainly engaged in crop production in 2020 a significant change compared to 2010, when the share of livestock and crop production was 41-46%. At the same time, the share of farms with a mixed profile has also decreased, thus increasing specialization (KSH, 2021).

2.2 Overview of the sector

Agricultural production is highly exposed to constantly changing weather patterns, average temperature increases, and changes in precipitation patterns due to climate change. Within Europe, the Carpathian Basin is the region most exposed to climate change, along with the southern countries (Gaál et al. 2014, Pálvölgyi and Csete, 2012; Biró and Csete, 2021b; Hadnagy et al. 2013). Climate change also has a significant impact on agriculture in our country because weather extremes, periods that are too cold or too hot, too wet, or too dry, and periods of excessive precipitation or drought, reduce the reliability of crops and production. In the short term, the average yields of our main arable crops may not yet be significantly threatened by climate change, but from 2050 onwards we can expect a significant reduction in yields of up to 30%, which will require adaptation techniques such as drip irrigation, construction of reservoirs, soil protection, drought-tolerant crops, use of stress-tolerant propagation materials, water-saving and low-GHG agro-techniques, climate-smart husbandry or the energy-efficient agrotechnological tools.

What we cannot currently estimate in the long term is the changing composition of disease and damage due to climate change, not only because the environment is changing, but also because the composition of the living communities surrounding our crops and livestock is changing, including new pathogens and vector organisms that pose a risk to plant and animal health. What we do know is that current trends in plant and animal health are not very promising for the future. Climate change is leading to the increasing emergence of pathogens and vectors from southern Europe and even tropical regions, but indigenous pathogenic organisms will not disappear in the short term.

2.3 Emission trends

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The agricultural sector is a major sector of the economy, but also a major emitter of GHGs. According to the National Inventory Report 2022 (UNFCCC, 2022), the energy sector is the largest emitting sector, contributing 71% of domestic GHG emissions, with agriculture accounting for 11.6%. A closer look at the trend of GHG emissions from agriculture shows that GHG emissions have been increasing in Hungary since 2010, mainly due to the significant increase in fertilizer use and beef cattle population, which is the result of the domestic agricultural support system. The European Green Deal, the European Commission's "Go 55%!" package of proposals, and the RRF introduced in the 2021-2027 programming period confirm the importance of this dissertation and show that this topic is a high priority in the green transition. The total greenhouse gas emissions in Hungary in 2020 were 62.8 million tonnes of CO_2-e without the Land Use, Land-Use Change and Forestry (LULUCF) sector (UNFCCC, 2022). Considering the largely decarbonizing processes in the LULUCF, Hungary's emission in 2020 was 56.0 million tonnes of CO_2-e. Hungarian emissions per capita are around 6 tonnes below the European average. Figure 1 shows the trend in net and gross GHG emissions in Hungary between 1985 and 2020. GHG emissions from agriculture decreased by 39% over the whole period 1985-2020, but increased steadily between 2010 and 2018, due to an increase in inorganic fertilizer use, cattle, and dairy production (UNFCCC, 2022). In 2020, Hungary's GHG emissions will fall by 2.7% compared to the previous year, back to 2016 levels. The reduction in travel restrictions under COVID-19, and tourism, and business travel have strongly contributed to the decrease in emissions. According to the National Inventory Report, the agricultural sector accounted for 11.6% of total domestic GHG emissions in 2020 (UNFCCC, 2022).

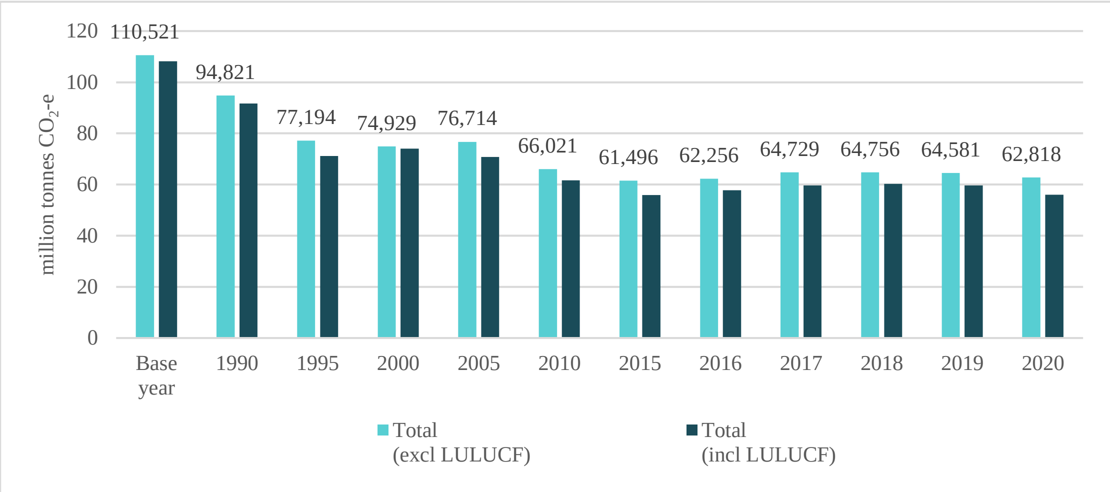

Figure 1 Total GHG emissions in Hungary 1985-2020 (including and excluding Land Use, Land-Use Change and Forestry (LULUCF)) (Source: data based on UNFCCC, 2022)

Agriculture mainly emits N_2O (from arable land, and manure management) and methane (from livestock production) into the atmosphere. Trends in aggregate GHG emissions can be assessed based on Global Warming Potential (GWP). Methane has a global warming potential (GWP) of 25 times (GWP_{CH4}=25), and nitrous oxide 298 times (GWP_{N2O} = 298) compared to carbon dioxide over the hundred-year period (IPCC, 2006). 86% of total N_2O emissions were from agriculture in 2020 (UNFCCC, 2022).

It can be concluded that agriculture is of great importance for our country in terms of the national economy, employment, and nature, but it is also a very sensitive sector exposed to climate change, so the application of mitigation and adaptation techniques are essential tools to preserve its role.

3. Methods

The research aims to analyze GHG emission trends in Hungary and forecast future emissions. Descriptive statistics are used to summarize and interpret GHG emissions data, which support inferences about a population by estimating the value of unknown population (population is the same as the sample) parameters using a single point and a graphical representation. The graphical representation is used to illustrate the relative magnitude of the data. The time series representation of GHG emission data is presented as a line graphs. Univariate analyses look at the distribution of cases according to a single variable

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to describe it. By variable, we mean a selected numerical property of the phenomenon under study. The size of the statistical population is usually large, so it is important to be able to characterize the data collected well with a few numbers. These numbers are called statistical indicators. Dispersion indicators show how much the data deviate from the mean, i.e., how much the data are skewed around the average. The following descriptive statistics were applied to the data series collected in the research:

- Average: one of the most popular statistical items that measure the central tendency of a sample of observations.

(1) $$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n}$$

- Standard deviation: the mean squared deviation of each value from the average. It shows how much the values differ from the mean on average, i.e., how heterogeneous the sample is. A standard deviation is always a non-negative number (positive or zero).

(2) $$\sigma = \sqrt{\sigma^2} = \sqrt{\frac{\sum_{i=1}^{N}(x_i-\mu)^2}{N}}$$

- Variance: emphasizes the variance because of the quadratic function.

(3) $$\sigma^2 = \frac{\sum_{i=1}^{N}(x_i-\mu)^2}{N}$$

- Skewness: is a measure of the degree of asymmetry of the frequency distribution. The skewness of a symmetric distribution is 0.
- Kurtosis: is a measure of the flatness of the frequency distribution. Positive values indicate a relatively peaked distribution, while negative values indicate a relatively flat distribution.

The skewness and kurtosis of a sample can be determined from equations (4) and (5) (Casella and Berger, 2002):

(4) $$sk(X) = E\left[\left(X - E(X)\right)^3\right] \cdot Var(X)^{-3/2}$$

(5) $$kr(X) = E\left[\left(X - E(X)\right)^4\right] \cdot Var(X)^{-4/2}$$

According to the definition of descriptive statistics, the expected value is the first moment of the probability variable, the variance is the second moment of the probability variable, the third moment measures skewness, i.e., how non-symmetric the distribution is, and the fourth moment measures flatness (kurtosis), i.e., how peaked the distribution is.

The Chebyshev inequality is used to estimate the range of values within which greenhouse gas emissions from agriculture are expected to range in the next ten years (2020-2030) and is examined at the EU and national levels. Chebyshev's inequality can use the expected value and standard deviation to estimate the probability that a probability variable will deviate from the expected value by more than a given amount. In other words, it can be used to estimate the probability that the time series treated as a probability variable will deviate from the expected value with a large standard deviation. Greater certainty will, of course, lead to greater variance. The Chebyshev inequality does not require knowledge of the distribution and can be applied to any probability variable with finite variance. Let X be a probability variable with variance σ(X). Then for any real number a > 0:

(6) $$P(|X - E(X)| \geq \varepsilon) \leq \frac{D^2(X)}{\varepsilon^2}$$

where,

X is the estimated value,
E(X) is the expected value of the probability variable X,
D2(X) is the variance,
ε is the probability of estimation.

The study presents EU and domestic agricultural emissions based on the EEA (2022) database, followed by a statistical analysis of the data. According to the National Clean Development Strategy, we also demonstrate the emission reduction scenarios to assess the measures to reduce the GHG emissions in Hungary.

4. Results and discussion

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On average, emissions in the agricultural sector have been decreasing year by year in EU member states, while our GHG emissions from agriculture have been increasing since 2010 (EEA, 2022) (Figure 2). The standard deviation of CO_2 emissions from agriculture is large, so the sample does not show a normal distribution. The kurtosis values are around 3, so the distribution is flat. The skewness values range from 1.7 to 2 (Table 1), i.e., the distribution curve is skewed to the right and the data are not normally distributed.

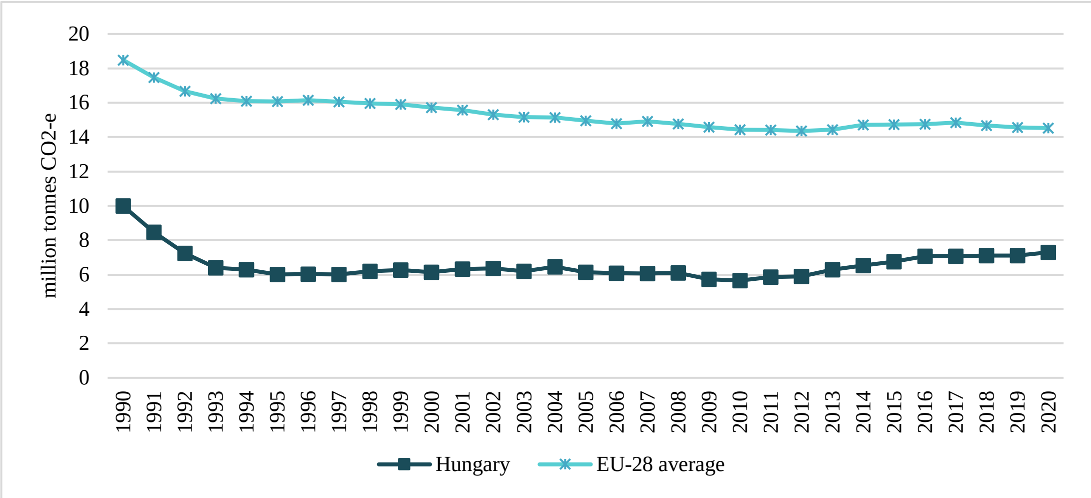

Figure 2 GHG emission trends from agriculture in the EU (average) and Hungary, 1990-2020 (Source: data based on Eurostat and EEA, 2022)

Table 1 Statistical analysis of EU greenhouse gas emissions from agriculture sector based on EEA database (million tonnes CO_2e)

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Average	18,49	17,47	16,67	16,24	16,09	16,07	16,14	16,06	15,97	15,92	15,72	15,58	15,31	15,16	15,15	14,95
Standard deviation (σ)	21,43	20,41	20,05	19,85	19,92	20,03	20,26	20,21	20,29	20,38	20,42	20,23	19,78	19,54	19,45	19,20
Variance (σ^2)	459,25	416,75	401,86	393,99	396,66	401,37	410,35	408,30	411,58	415,14	416,95	409,06	391,30	381,82	378,20	368,77
Kurtosis	2,14	2,60	2,75	2,75	2,63	2,70	2,63	2,71	2,70	2,77	3,21	3,37	3,40	2,95	3,08	3,09
Skewness	1,66	1,74	1,78	1,78	1,76	1,77	1,77	1,78	1,79	1,81	1,89	1,92	1,92	1,85	1,87	1,87
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	
Average	14,79	14,92	14,77	14,58	14,44	14,42	14,36	14,43	14,71	14,73	14,76	14,85	14,68	14,56	14,52	
Standard deviation (σ)	18,99	19,19	19,05	18,97	18,73	18,65	18,63	18,62	19,07	19,01	18,85	18,93	18,64	18,40	18,14	
Variance (σ^2)	360,74	368,08	362,81	359,83	350,72	347,66	347,05	346,77	363,79	361,30	355,24	358,52	347,36	338,67	329,04	
Kurtosis	3,17	3,19	3,65	3,59	3,55	3,45	3,54	3,46	3,53	3,52	3,30	3,19	3,06	3,01	2,64	
Skewness	1,88	1,88	1,96	1,96	1,96	1,94	1,96	1,95	1,96	1,96	1,92	1,89	1,86	1,86	1,79	

The histogram (bar chart) shows the frequency of GHG emissions from the EU agricultural sector. The horizontal axis shows the emissions in million tonnes of CO_2 equivalent and the vertical axis shows the frequency (Figure 3). 868 values are included in the sample, so the data have been grouped. The histogram shows that nearly 80% of EU Member States emitted 16 million tonnes of CO_2-equivalent GHG from the agricultural sector in 2020.

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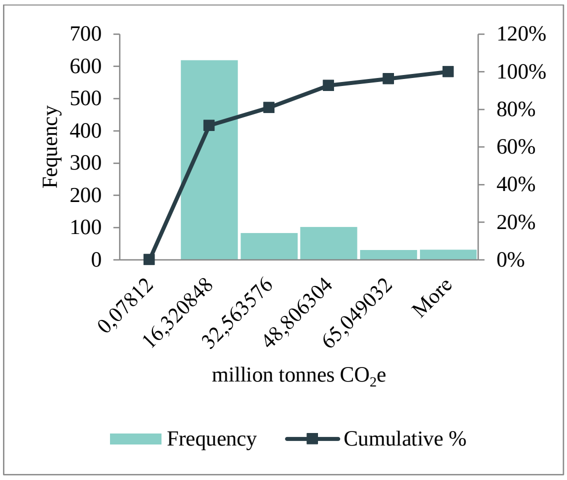

Figure 3 Histogram of EU GHG emissions from agriculture, 2020 (Source: based on EEA 2022 database)

Chebyshev's inequality was used to assess the values within which GHG emissions from agriculture can vary over time. The expected trend in GHG emissions for the EU (in million tonnes of CO_2 equivalent) between 2020 and 2030 with a confidence interval of 95%, based on the actual data and their standard deviation. EU GHG emissions are expected to be between 0 and 42 million tonnes of CO_2 equivalent in 2030 (Figure 4). Hungary's GHG emissions from agriculture are also projected between 2020 and 2030. Emissions are expected 2030 to be between 0-19 million tonnes of CO_2 equivalent with a confidence interval of 95% (Figure 5).

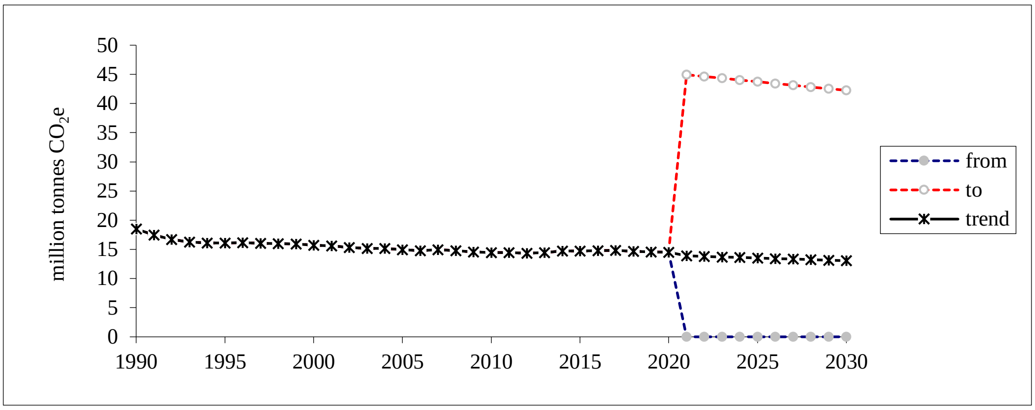

Figure 4 Projected GHG emissions from agriculture in EU, 2020-2030 (Source: based on EEA 2022 database)

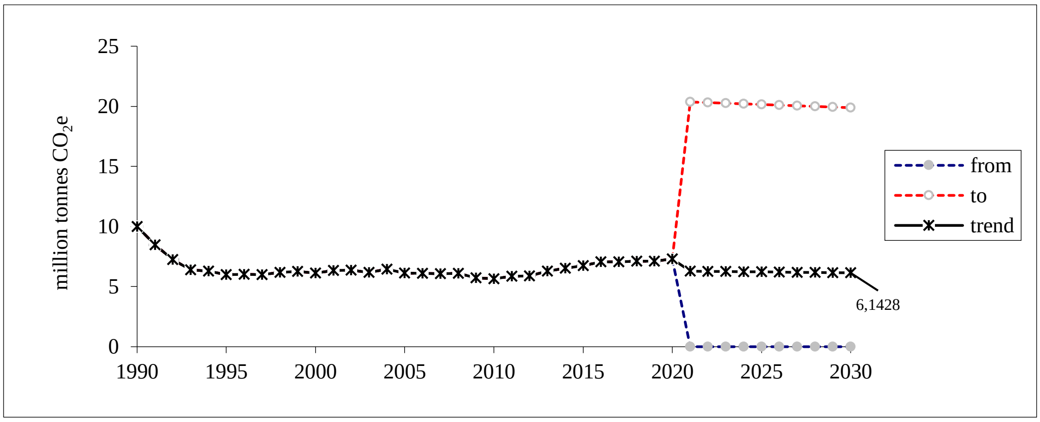

Figure 5 Projected GHG emissions from agriculture in Hungary, 2020-2030 (Source: based on EEA 2022 database)

The National Clean Development Strategy serves as a roadmap for achieving climate neutrality in Hungary by 2050, setting out sectoral targets and tasks. For agriculture, two different production and emission reduction scenarios (Business-As-Usual and the Early Action scenario) for the future were examined (ITM, 2021). The Business-As-Usual (BAU) scenario of the

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Strategy is based on the implementation of measures to reduce greenhouse gas emissions from agriculture in the past and by the end of 2020. The scenario assumes that the present free trade agreements stay in place, the embargo against Russia is ended in 2025 and there is no significant change in eating habits. The scenario is predicated on a gradual increase in livestock numbers on a market basis, together with the use of nitrogen fertilizers. The scenario projects a continuation of the slow, steady increase in emissions until 2050. Emissions projected for 2050 are expected to be 7.679 million tonnes of CO_2-e per a year which is still a lower value compared to 1985 emissions (Figure 6). Precision farming and Agriculture 4.0 tools are gaining ground through subsidies and market-based approaches. In livestock production, as in crop production, the tools of precision farming and Agriculture 4.0 are emerging. The Early Action (EA) climate neutrality scenario contains measures and innovative technologies that are at an investigational or experimental stage but could be implemented if appropriate EU and national legislation are in place. Such actions could be included restricting to the use of nitrogen fertilizers by increasing prices, eliminating subsidies for beef cattle, stricter regulation of fertilizer use, and subsidized cattle selection schemes. Also included campaigns to reduce meat and milk consumption and to raise awareness. According to Business-As-Usual, the sector's output would increase by 8% at the end of 2050 (Figure 6). In contrast, under the Early Action scenario, the sector's GHG emissions are projected to decrease by 70% until 2050 (ITM, 2021).

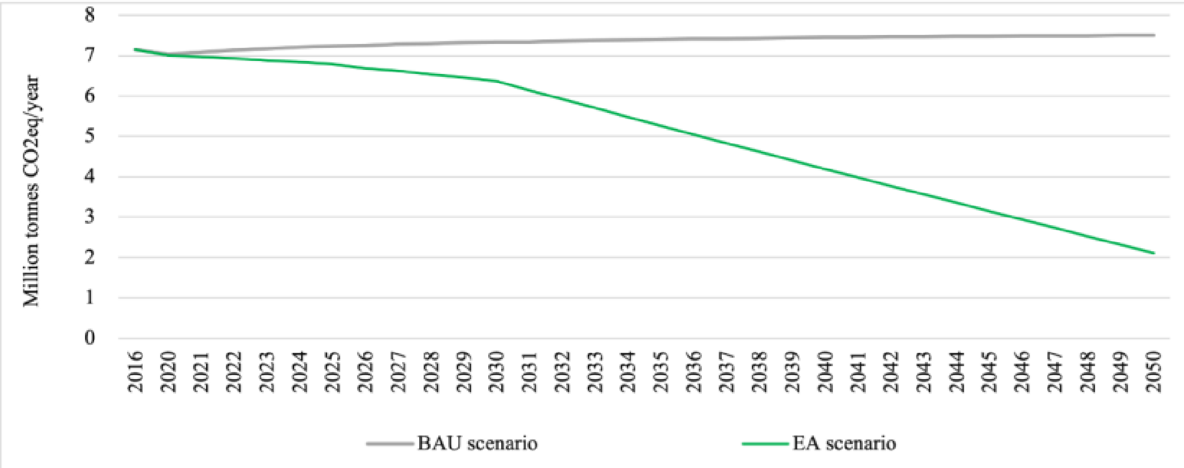

Figure 6 The projected GHG emissions in the agricultural sector under the two scenarios (CO_2-e/year) (Source: ITM, 2021)

In the Early Action scenario, the largest emission reductions are caused by a very significant structural transformation. 30% of the feed materials for feed production are planned to be produced in closed industrial fermenters using biomass and renewable energy, which will also help the livestock sector to produce feedstock by using carbon-neutral technologies. Further GHG emission reductions are expected in soil emissions. According to the Ministry of Agriculture, fertilizers are mainly needed on arable land to replenish nutrients. The right management of organic materials is an essential requirement for competitive and sustainable production, so it is important to know how farmers handle in practice the waste of production, such as manure. The impact of biomass energy use on soil nutrient replenishment has direct and indirect implications for farmers. If soil nutrient replenishment is not ensured, soil biological activity and biota are not maintained, and humus extracted by crop production is not improved, the soil will not be able to renew itself, and in the long-term yields will fall drastically as a result. The European Union's Farm to Fork strategy has set a target of a 20% reduction in fertilizer use by 2030, with demand for organic fertilizers in the sector expected to increase (European Commission, 2020). Within the agricultural sector, the smallest reduction in emissions can be expected in animal husbandry, but with precision farming and the use of Agriculture 5.0 tools, emissions can be reduced even with the growing number of animals.

It can be assumed that our perdition using Chebyshev's inequality yields the values of the Early Action (EA) scenario outlined in the National Clean Development Strategy. The expected GHG emission trend will be around 6 million tonnes of CO_2 equivalent by 2030. This is a climate-neutrality vision, where innovative tools play a key role, leading to a profound structural transformation of the sector. From the early 2030s, we will increasingly see the dawn of the digital era of agriculture, with near-zero GHG and other pollutant emissions, circular material flows, and zero waste based on the use of Agricultural 5.0 tools such as robotics, drones, molecular farming, functional fertilizers, bio-pesticides. Innovation has the potential to increase the sustainability and intensification of agricultural production, thus growing the global food supply.

5. Conclusions

Thinking through the diversity of development paths that the agricultural sector could potentially take: all projections are wrong; the question is how wrong. The most optimistic scenario that Hungarian agriculture could realize would be to fully exploit the agricultural potential in the future. Conversely, the most pessimistic scenario would be to be locked into production and price competition with many developing agricultural countries, resulting in production far below what is possible. Anything between these two scenarios is possible. The research aimed to analyze GHG emission trends and forecast future emissions in Hungary. Descriptive statistics were used to analyze the emissions data, and they were presented in a time series. The result shows that the prediction using Chebyshev's inequality approximates the values of the Early Action (EA) scenario and a climate-neutral vision in which innovation has a major role. From a climate perspective, agriculture is perhaps the most conservative sector, with no marketable and significant emission reduction technologies yet in sight. Nevertheless, wherever we are in 2030, agriculture will have two powerful tools at its disposal to achieve climate neutrality: it can even reduce its current emissions by planting carbon-climate crops on marginal land and by basing agriculture on renewable energy.

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Real Driving Emissions from Vehicle Fuelled by Petrol and Liquefied Petroleum Gas (LPG)

Ante Vučetić, Vjekoslav Sraga, Boris Bućan, Krunoslav Ormuž,
Goran Šagi, Petar Ilinčić, Zoran Lulić

University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture,
Laboratory for IC Engines and Motor Vehicles, Ivana Lučića 5, 10000 Zagreb
Zagreb, Croatia

Abstract

In recent years, in addition to laboratory tests to determine emissions from road motor vehicles, tests in real driving conditions RDE (Real Driving Emissions) with the use of portable measuring equipment PEMS (Portable Emissions Measurement System) have been conducted. The paper presents the results of the emission research conducted on a vehicle Dacia Duster 1.0 TCe 100 ECO-G fuelled by petrol Eurosuper 95 and liquefied petroleum gas (LPG). The aim of the research was to determine the emissions of harmful substances and carbon dioxide, i.e. fuel consumption, in accordance with the prescribed RDE procedure and their comparison for the two types of motor vehicle fuel. Results clearly showed that the method used can differentiate between fuel types. The results correspond to the RDE emissions public data, which secures that the methodology used is in accordance with the procedure for measuring emissions in real driving conditions.

Keywords

Emissions of harmful substances from motor vehicles, Real driving emissions, RDE, Portable Emissions Measurement System, PEMS, Liquefied Petroleum Gas, LPG

1. Introduction

Due to the constant increase in the number of motor vehicles and their impact on global warming, the limit of the permissible values of pollutants from internal combustion (IC) engines are constantly decreasing. Consequently, the use of alternative fuels and renewable energy sources is especially encouraged.

Using alternative fuels and renewable energy sources helps reduce greenhouse gas emissions and human dependence on fossil fuels (*Hatim, 2012*). The largest share of greenhouse gases is carbon dioxide (CO_2), the main by-product of most human activities and the burning of fossil fuels (*Virt, Arnold, 2022*). As an incentive for the use of renewable sources, the European Union (EU) adopted Directive 2009/28/EC in 2009, with the goal that by the year 2020, 20% of total energy consumption and 10% of energy consumption in traffic should come from renewable energy sources (*EC, 2009*). As the goals were not achieved, a new Directive (EU) 2018/2001 (RED II) (*EC, 2018*) was adopted, which established a common framework for the promotion of energy from renewable sources in the EU and set a binding target of 32% for the total share of energy from of renewable sources until 2030.

Over the years, the limit values for emissions of harmful substances have decreased significantly *(Lončarević et al., 2022). (Rešetar et al., 2022).* Since the introduction of the first limit value, the so-called Euro 1 to the currently valid Euro 6d-Temp limit value of certain emissions of harmful substances has been reduced by more than 95% (*Zoldy, 2009*).

Modern IC engines are tested in accordance with the type approval procedures before being put on the market, and the tests are conducted in a laboratory. As all individual engines of the same series are expected to be identical, only one or a few engines of each series are tested. Tests have shown that most of the total emissions come from relatively short episodes of high emissions, such as the cold start phase of the engine.

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With the development and reduction of the overall dimensions of the measuring equipment, emission tests began to be carried out outside the laboratory in the actual operating conditions of engines and vehicles. The results of these tests showed that emissions in real working conditions are often significantly higher than in laboratory conditions. For this reason, emissions are measured in accordance with the RDE (Real Driving Emissions) test procedure and are mandatory today, i.e. measurements of emissions of harmful substances in real conditions of vehicle use are carried out. One of the most important features of measuring emissions in real conditions is a relatively fast change in driving conditions that correspond to the actual use of the vehicle (sudden and significant changes in load, acceleration, and engine speed).

It should be noted that the measurement of emissions in real conditions, the RDE procedure, is not a substitute for emission measurements carried out in laboratories but a mandatory supplement to laboratory tests. The RDE procedure is used to confirm that the vehicle's emissions of harmful substances do not exceed legally permitted limit values in real driving conditions. During RDE testing, the vehicle goes through various driving conditions and external road conditions, such as changes in altitude, temperature, additional load, driving uphill and downhill, highways and similar conditions.

The results determined by measurement in real conditions (RDE procedure) have lower repeatability than those determined in laboratory conditions and are considered good if they are within certain limits. Due to previously determined significantly higher emissions in real working conditions, the measured results are compared with the limit values for laboratory conditions increased by the Conformity factor (CF).

Driving conditions can have a significant impact on the overall result. For the measurement according to the RDE procedure, the boundary conditions for assessing the validity of driving are defined. The threshold value determines whether the vehicle’s driving was excessively aggressive, appropriate or excessively passive. At each drive and in each individual part of the drive, the limit value must not be exceeded for the drive to be considered valid. Alternative fuels are and will be part of green and sustainable mobility. Real world tests are key to define the directions of future developments to further increase sustainability levels. The goal of the presented research was to determine the emissions of harmful substances and carbon dioxide, and fuel consumption, in accordance with the prescribed RDE procedure and compare for the two types of motor vehicle fuel: petrol and LPG.

2. Measuring equipment and measurement methods

The AVL M.O.V.E portable emission measurement equipment (Portable Emissions Measurement System - PEMS) is installed on the vehicle to measure emissions of pollutants and carbon dioxide and fuel consumption in real driving conditions. This system makes the continuous monitoring of individual pollutants from the vehicle’s IC engine possible.

The PEMS is mounted on the vehicle’s towbar or in the luggage compartment and connected to the engine exhaust pipe outlet. The PEMS device is small enough in size and mass that it can be installed on the vehicle and does not significantly impact the vehicle’s dynamics.

The PEMS is a complex portable emission measuring system consisting of several different and interconnected measuring devices. All measuring devices of the PEMS system are connected to a central computer that controls the measurement and also acquires and stores measurement data.

The main elements of the PEMS are:

- gas analysers for determining the concentration of individual components in exhaust gases,
- particle counter that measures the number of solid particles in exhaust gases,
- exhaust gas mass flow meter,
- global positioning system (GPS) that determines vehicles speed and location while driving,
- meteorological station that measures the ambient temperature, pressure and humidity,
- interface to On Board Diagnostics - OBD system to acquire vehicle data from the CAN bus.

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Table 1. Technical specifications of the PEMS

Analyzer	NO/NO_2 and $CO/CO_2/N_2O$	THC/CH_4	Particle counter
Measuring method	Non-Dispersive Ultra Violet – NDUV Non-Dispersive Infrared – NDIR	Flame Ionisation Detector – FID	Advanced diffusion charger
Measuring range	NO: 0 do 5000 ppm	THC: 0 do 30000 ppmC1	from ~1500 to ~2,5 x 107 #/cm^3
	NO_2: 0 do 2500 ppm		
	CO: 0 do 5% vol.		
	CO_2: 0 do 20% vol.	CH_4: 0 do 10000 ppmC1	
	N_2O: 0 do 2000 ppm		
Zero drift/8h	NO/NO_2: 2 ppm	± 5 ppm C1/8h	
	CO: 20 ppm		
	CO_2: 0,1% vol.		
	N_2O: 20 ppm		
Accuracy		0,3% FS	

Gas concentration measurement in the exhaust is based on methods that monitor a certain physical property of a gas or reaction with working gases. Gas concentrations are calculated by comparing the signal generated by analysing the exhaust gas sample and the signal from the calibration gases at a given concentration.

3. Test vehicle

In this research, a Dacia Duster 1.0 TCe 100 ECO-G was used as a test vehicle. The main feature of the test vehicle is that it uses liquefied petroleum gas (LPG) or petrol as a fuel.

Figure 1. Test vehicle Dacia Duster 1.0 TCe 100 ECO-G

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Vehicle technical specifications are displayed in table 2:

Table 2. Technical specifications of the test vehicle

Manufacturer	Dacia
Model	Duster
Emission level	6D6
Variant	DHE2
Vehicle category	M1
Engine type	SI 4 stroke
Number of cylinders	3
Engine displacement, cm3	999
Maximum power, kW	74 at 5000 rpm
Type	Bi-fuel
Fuel	Petrol – LPG

4. Design of experiment

The method of vehicle utilisation significantly affects the total harmful emissions, and due to that, an appropriate design of experiment (DoE) was conducted. The main influencing variables are the fuel type (LPG or petrol), the cold or warm start of the IC engine and driving style. Other conditions, such as route, weather, etc. were kept as it was possible constantly. The experimental plan of the conducted emission tests is shown in table 3.

Table 3. Design of experiment

RDE Test Number	Engine fuel	Engine start
Test no. 1	Petrol	Cold start
Test no. 2	Petrol	Cold start
Test no. 3	Petrol	Worm start
Test no. 4	Petrol	Worm start
Test no. 5	LPG	Cold start
Test no. 6	LPG	Cold start
Test no. 7	LPG	Worm start
Test no. 8	LPG	Worm start

5. Vehicle emissions measurement in real driving conditions

A test drive of three parts was conducted on a public road in accordance with the RDE procedure. The first part is urban, the second part is rural, and the third part is motorway. The geographical features of the test route and the characteristic values of individual parts of the test drive are shown in Figure 2:

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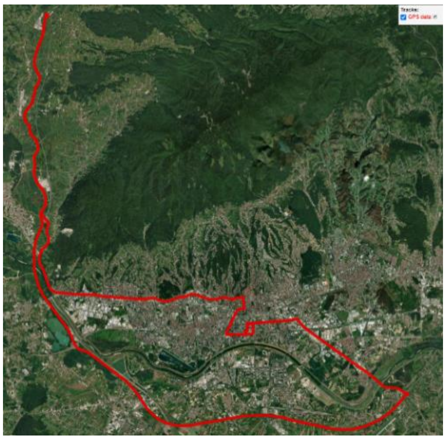

Total time		Between 90 and 120 min
Driving conditions		
Distance	Urban	> 16 km
	Rural	> 16 km
	Motorway	> 16 km
Driving share	Urban	29% - 44% of the total trip
	Rural	23% - 43% of the total trip
	Motorway	23% - 43% of the total trip
Average speed	Urban	15 - 60 km/h
	Rural	60 - 90 km/h
	Motorway	> 90 km/h (> 100 km/h minimum 5 min)

Figure 2. RDE test route around the City of Zagreb, Croatia

Before every test drive, the device calibration procedure was carried out (see Figure 4). The calibration procedure was also carried out immediately after the end of the measurement in order to determine whether, during the test drive, there were any changes in the accuracy of the measurement results (shifting of the zero point and the measuring range).

Figure 3. Test vehicle with built-in measuring equipment

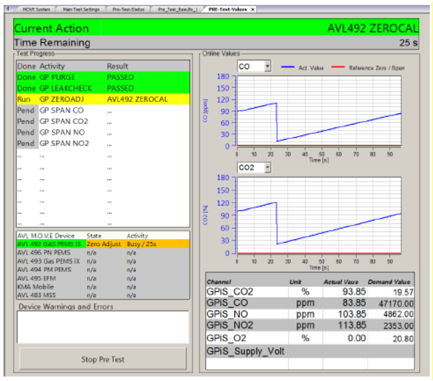

Figure 4 Program interface of the AVL M.O.V.E System Control during PEMS calibration

During the test drive, the acquired data is continuously analysed, and it is checked whether the limit conditions of the RDE test procedure are met.

6. Results and discussion

After the test was carried out in accordance with the prescribed procedure, the results were processed in the AVL Concerto software package. The results are shown in Figures 5 to 9 in the same way in all diagrams. The green bars show the values measured when driving with LPG, and the blue colour shows the results when driving with petrol.

In all the diagrams, in addition to the measured results, the values taken from the publicly available certificate of conformity of the vehicle are plotted, whereby the value during testing according to the NEDC cycle (New European Driving Cycle) is marked in purple, the value measured during testing is marked in red according to the WLTP cycle (Worldwide Harmonized Light Vehicles Test Procedure), and the value of Euro 6 d in blue.

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The mean value of fuel consumption in all cases of LPG drive is 8.4 l/100 km, and the standard deviation is 0.5 l/100 km. The results confirm the well-known fact that fuel consumption is slightly lower after a warm start. The LPG consumption measured by the PEMS device is near the limits measured by the NEDC or WLTP test procedure during the homologation tests.

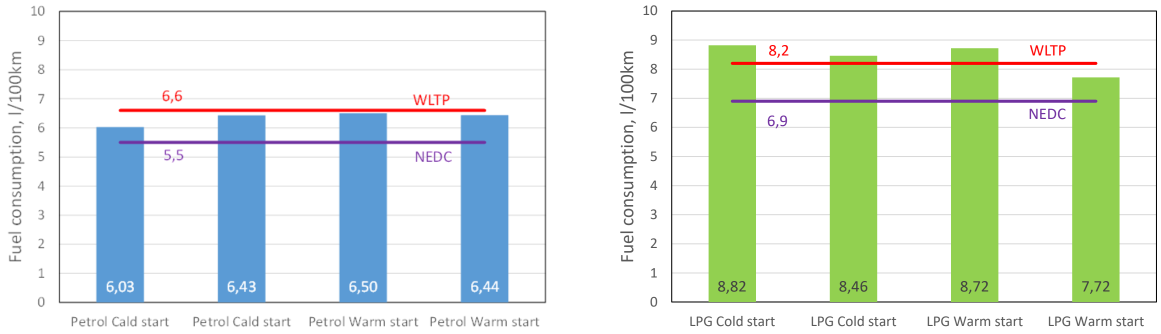

Figure 5. Vehicle fuel consumption when fueled with petrol (blue) and LPG (green)

The emission of CO_2 is directly related to fuel consumption. In Figure 6 the value trend for individual tests is the same as in Figure 5, that is, as in fuel consumption.

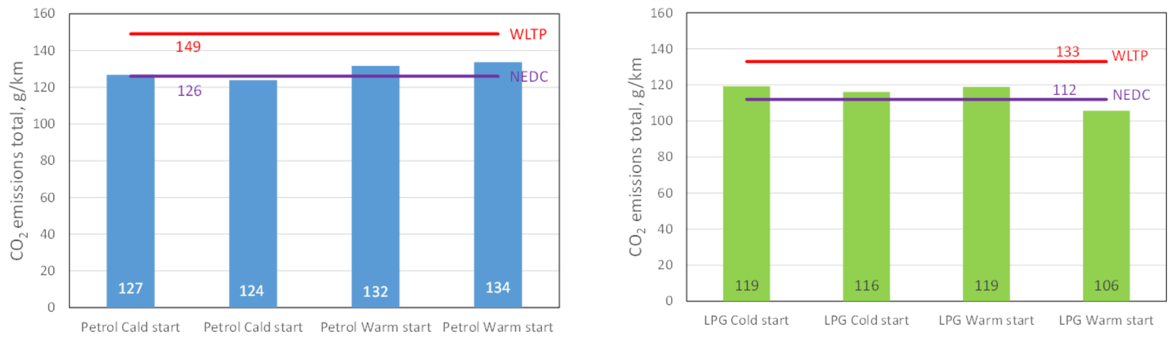

Figure 6. Vehicle CO_2 emission when fuelled with petrol (blue) and LPG (green)

The emission of carbon monoxide, CO, measured by the RDE procedure when running on petrol, is slightly lower than when running on LPG, see figure 7.

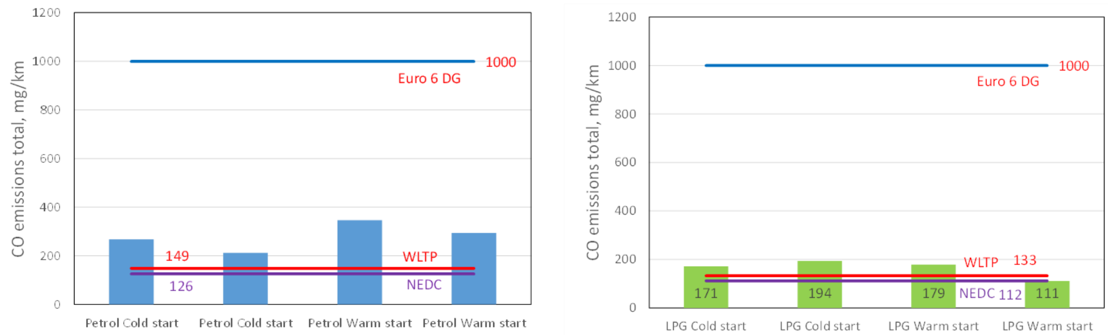

Figure 7. Vehicle CO emission when fuelled with petrol (blue) and LPG (green)

Emissions of NO_X are, in some cases, 50% lower when the vehicle is fuelled with LPG than in the case when it is fuelled with petrol. Furthermore, it is observed that during most of the conducted RDE tests, NO_X emissions are lower than in NEDC or WLTP test procedures (except the first test with petrol with a cold engine start).

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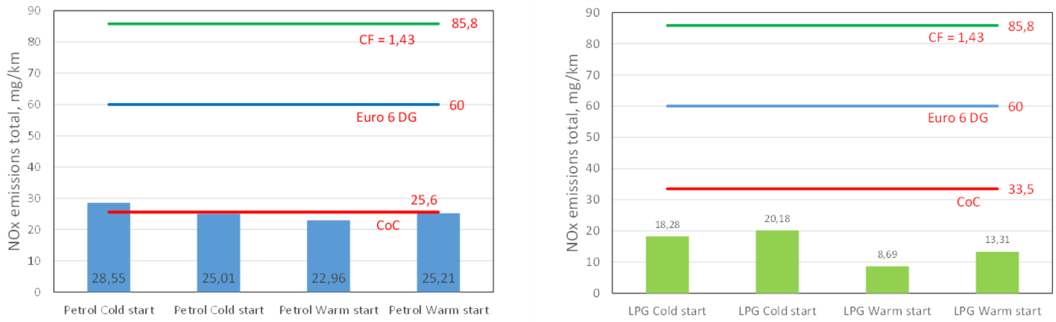

Figure 8. Vehicle NO_X emission when fuelled with petrol (blue) and LPG (green)

The measured emissions of the particles, more precisely, the number of the particles, is significantly higher when running on petrol. The significant difference in the number of particles can be explained by the fact that it is an internal combustion engine that, when powered by petrol, uses direct injection of petrol under high pressure into the engine cylinder to prepare the fuel mixture. In contrast, when powered by LPG, the mixture is prepared in the intake manifold.

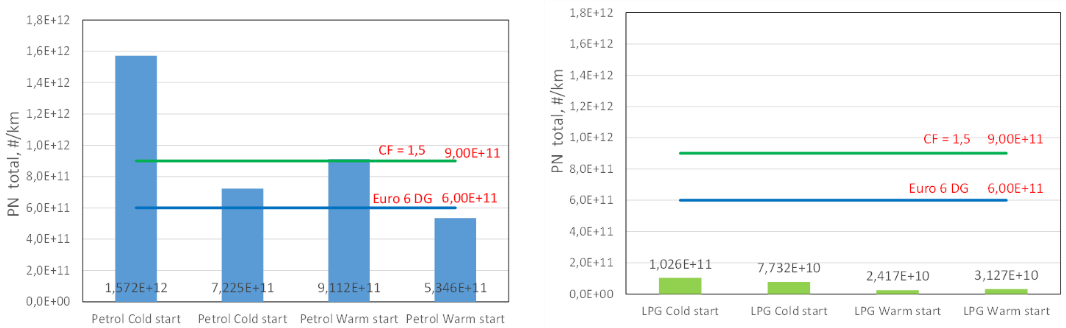

Figure 9. Vehicle particle number when fuelled with petrol (blue) and LPG (green)

Particle number in the first test with an engine fuelled by petrol on cold start is high due to the start of the regeneration process of the gasoline particulate filter (GDF), and this value is not taken into overall consideration.

7. Conclusion

In accordance with the design of the experiment, eight measurements of the harmful emissions, carbon dioxide and fuel consumption in real driving conditions were carried out on the Dacia Duster 1.0 TCe 100 ECO-G using portable measuring equipment AVL M.O.V.E. The measurements were carried out in accordance with the prescribed procedure for measuring emissions in real driving conditions (RDE).

For the first time in the Republic of Croatia, the vehicle emissions fuelled by LPG were measured with the newly acquired measuring equipment for measuring vehicle emissions in real driving conditions and were compared with the emissions when the vehicle is fuelled by petrol.

The test vehicle, when running on petrol, uses a system that injects fuel directly into the engine cylinder, and as expected, higher particle emissions were measured than when running on gaseous fuel. Results showed that the used method can differentiate between different fuel types thus it is a valuable tool for future fuel developments.

The measured emissions correspond to the publicly published data on RDE emissions, which points to the conclusion that the measurements were carried out in accordance with the procedure for measuring emissions in real driving conditions.

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Nomenclature

CH_4	methane	NO	Nitric oxide
CO	Carbon monoxide	NO_2	Nitrogen dioxide
CO_2	Carbon dioxide	NO_X	Nitrogen oxides
HC	Hydrocarbon	PEMS	Portable emissions measurement system
IC	Internal combustion	PM	Particulate Matter
LPG	Liquefied Petroleum Gas	PN	Particle Number

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Implementation of vehicle simulation model in a modern dynamometer test environment

Tamás Koller
Multidisciplinary Doctoral School of Engineering Science
Széchenyi István University
Győr, Hungary
tamas1.koller@audi.hu

Csaba Tóth-Nagy
Department of Internal combustion Engines and Propulsion
Audi Faculty of Vehicle Engineering
Széchenyi István University
Győr, Hungary
toth-nagy.csaba@ga.sze.hu

József Perger
Head of Functional Analysis Drive/Chassis/Body
Audi Hungária Zrt.
Győr, Hungary
jozsef.perger@audi.hu

Abstract

The rapid development of digital technology makes it possible to expand the sustainability of the transport sector. With the development of digitalization, virtual tests play an increasingly important role in product design. With the development of computer technology, there is a more accurate and faster opportunity to save time, energy, and costs before the product is introduced to the market. In the early stages, vehicle simulation can be effectively used, which is a cost- and time-efficient solution. This study presents the transfer of a vehicle simulation model to an internal combustion engine dynamometer. Dynamometers allow the behavior of the real engine to be tested before the complete vehicle is available. Building the simulation model of the complete system including the dynamometer and the engine makes it possible to setup the variables of the real test environment resulting in decreased time and cost on the dynamometer. Furthermore, the system constructed in this way can be suitable for carrying out the tests that were previously carried out on the entire vehicle. With a vehicle simulation model, the level of simulation can be changed as needed during development until the developed real vehicle is fully realized.

Keywords

virtualization, virtual calibration platform, vehicle simulation, Engine-in-the-loop (EIL), Modell-in-the-loop (MiL)

1. Introduction

Today's modern software solutions offer new possibilities for expanding dynamometer tests with simulations. Petters shows an example of this by comparing different vehicle driving styles: the comparison was carried out in an office environment in order to minimize the time spent on the engine dynamometer (Petters, 2019). Cognitive Mobility (CogMob) investigates the entangled combination of the research areas such as mobility, transportation, vehicle engineering, social sciences, artificial intelligence, cognitive info-communication (Zöldy and Baranyi, 2021).

The applications cooperate using each other's advantages in order to generate timely analyses that can influence decision-making during planning. In their work, Dietrich and Rupfle created a reproducible environment on the test dynamometers, in which the selected components can be used using simulation applications (Dietrich, 2020). Pfister investigated the unification of powertrain combinations in a virtual test driving environment (Pfister, 2019). Jiang and his colleagues developed a method for creating a vehicle simulation environment in a real dynamometer environment. (Jiang et al., 2009). The present research was carried out in a test environment on an engine dynamometer. Along these aspects, the transfer of the vehicle simulation to the engine dynamometer test environment is a useful task, because the problems that may arise appear even before installation on the engine dynamometer.

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Due to the ever tightening emission regulations, internal combustion engines need more complex systems (Baranyi and Csapo, 2010). Nyerges and Zöldy (2020) show an example of the role of modeling and simulation of an internal combustion engine.

When creating a vehicle simulation model, the dynamics, aerodynamics, kinematics, and the driving of the vehicle must be described in detail, translated into machine language. A basic requirement is that a model is created that can determine the engine load in real time. With this data, the dynamometer is able to load the engine as if it were in a real vehicle. The purpose of the dynamometer is to load the engine in real time depending on the input data of engine load, similar to that in a vehicle. The conversion and modification of the signals used to automate the test dynamometer and the processing of the signals of the intermediate systems are carried out by several software programs, which provide the control signals for all the elements in the automation circuit. The goal is for the engine load to be exactly the same in real time on the engine dynamometer as if it were operating in a passenger vehicle. This requires a vehicle simulation in which all elements are mapped that are not physically present at the engine dynamometer. The vehicle properties must be modeled in sufficient detail depending on the test objective (e.g. kinematics, aerodynamics, virtual track, maneuvers, driving style – driver, engine, transmission, drive parameters, tires, brakes, suspension, ambient temperature and pressure).

With a real engine, the engine's torque and speed can be directly, physically measured, , as well as the consumption and emissions of the internal combustion engine. During the validation, the simulation results may be compared to the measured results. During the rechecking (validation) of the results, the operation of the main parts that are present in the applied system, but different from a real vehicle, must be examined. The disadvantage of real testing is that urban conditions are always changing, so it is impossible to reproduce the results, which makes comparisons difficult. For example, the status of traffic lights, the traffic situation or the strength of wind gusts are constantly changing. Therefore, vehicle measurements on public roads cannot be reproduced.

The problem of reproducibility can be overcome, by using vehicle simulation on a dynamometer, for example. With this solution, different engines can be tested on the dynamometer under the same conditions, so there is a basis for their comparison. Vehicle simulation can be used effectively in the early stages of development, which is a cost-effective and quick solution. The behavior of the real engine can be tested even before the complete vehicle is available. The system constructed in this way can be suitable for carrying out the tests that were previously administered on the entire vehicle. With a vehicle simulation model, the level of the simulation can be applied as needed until the real vehicle under design is fully realized. Thereby, already in the early stages of development, partial results are available that have an influence on the direction of development.

When making decisions, more and more emphasis is placed on the processing of data created by vehicle simulation. An example of this is written by Bauer and his colleagues, where the effects of the vehicle configurations on emissions were investigated (Bauer et al., 2019). With the help of vehicle simulation, the development time is reduced, and fewer real tests are required. Therefore, the introduction of the product to the market can be accelerated. Moreover, the development cost and the environmental impact per unit of product is reduced. The raison d'etre of vehicle simulation is time, since shortening the product life cycle and reducing development costs is one of the basic conditions for the sustainability of competitiveness.

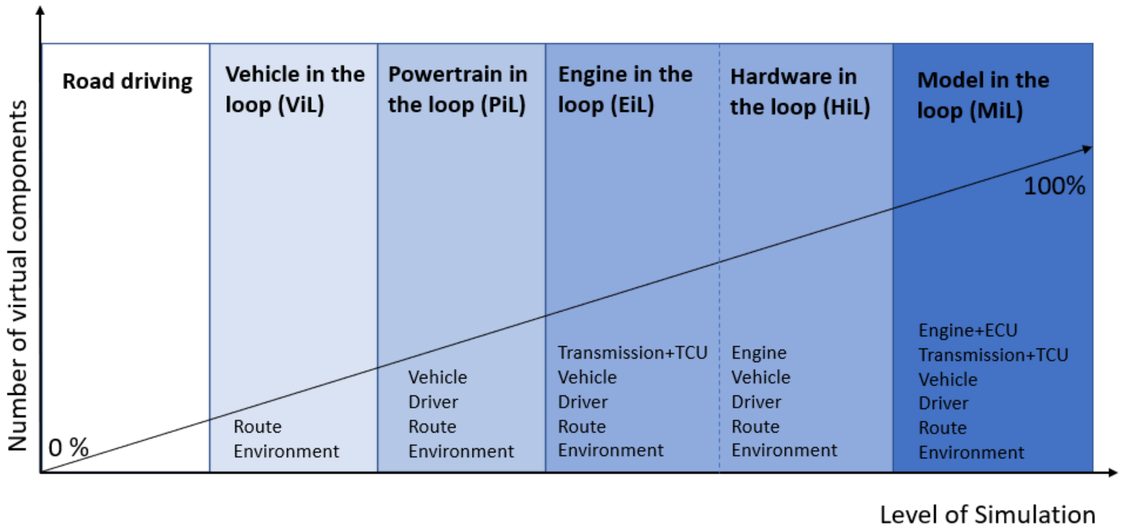

Figure 1. Overview of test environments (based on Jung et al., 2019).

The engine is in the test structure named EiL – Engine-in-the-loop, in which the control circuit provides an efficient environment where exact repeatability of the measurements is possible. Figure 1 shows how the level of simulation of the

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development process grows with the use of simulation models and the need for the presence of physical elements during the tests. In the MIL (Modell-in-the-loop) phase, a completely virtual vehicle is tested, there are no physical devices at all during the virtual test. During the analysis, the engine control unit (Electronic Control Unit, ECU), the engine (Engine), the gearbox control unit (Traction Control Unit, TCU), the drivetrain, the driver, the drive track and the environment are modelled in detail. For the HiL (Hardware-in-the-loop) process, the tests are supplemented with the engine control unit, for EiL with the engine controller and the engine, i.e. real physical elements. In the further stages of testing, they are replaced with real components according to the level of simulation in Figure 1, until finally a test carried out on completely real equipment (Jung et al., 2019).

The purpose of this article is to describe the transfer of model in-the-loop (MiL) vehicle simulation to the dynamometer environment (EiL). Such a simulation produces results exactly as if the engine were with the real vehicle. With this solution, it is possible to prepare tests that previously required the presence of the entire vehicle.

2. Methodology

The creation of the internal combustion engine dynamometer test environment helps to validate the vehicle simulation, as well as to prepare for the real engine dynamometer test, since it is possible to carry out the preparations earlier. Thus, problems can be solved in advance, before they become apparent during the actual engine dynamometer testing. The transfer of the vehicle simulation model was carried out in the test environment of the engine dynamometer, where neither the internal combustion engine nor its controller are physically present. The vehicle simulation used in the engine dynamometer test environment includes the driver, track, vehicle (drivetrain, engine, gearbox) and environment models.

Figure 2 shows the general structure of the test environment the Model-in-the-Loop (MiL) system created in this way. A four-cylinder in-line gasoline engine is virtually integrated. The vehicle simulation and the test engine dynamometer fitting are done through a real-time simulation platform, which can connect simulation with real hardware: this is a co-simulation platform. Teuschl and his colleagues (2021) applied a similar model. Based on the entire vehicle model, the accelerator pedal control algorithm works in real time on the co-simulation platform, it transmits signals to the virtual dynamometer. The value of the gas pedal position determined by the vehicle simulation and the speed of the virtual engine are sent via the platform to the environment of the engine dynamometer test, on the basis of which a virtual torque is calculated and returned to the vehicle simulation model.

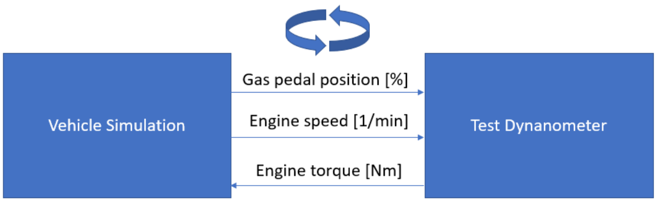

Figure 2. Control signals between vehicle simulation and the test dynamometer.

Figure 3 shows the MiL system created by integrating the virtual system, as a result of which the vehicle simulation model integrates the virtual vehicle into the virtual engine model integrated on the dynamometer of the test engine. For the dynamometer test station, the characteristic curve of the virtual engine is defined in the form of a look-up table.

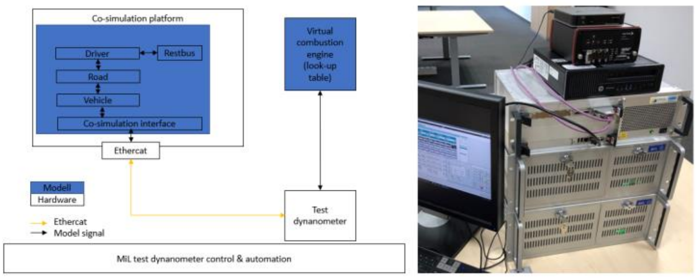

Figure 3. Conceptual diagram and actual environment of the test dynamometer at AUDI HUNGARIA Zrt..

By making settings in advance, it becomes possible to completely design the engine dynamometer test environment for the purpose of testing the vehicle simulation, and the fine-tuning can be much more prepared for the real engine dynamometer operation.

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Yao and his colleagues have integrated MATLAB-based vehicle simulation into an environment that is also used on the engine dynamometer. In the MATLAB/Simulink environment, the CANoe communication module is added to the model through the CANoe-MATLAB interface. MATLAB starts the CANoe, then tracks the changing trends of each signal of the control model in CANoe. The accuracy of the control allocation algorithm is verified by co-simulation in CANoe-MATLAB (Yao et al., 2014).

The modelling and simulation starts in Simulink, by defining the model setting up the differential equations that describe the behavior of the system. These rules of behavior are formulated relying on the laws and principles of physics (Simulink). CANoe is an open environment for software development purposes, developed by Vector Informatik GmbH. Both the software and the associated necessary hardware are provided by Vector. CANoe allows to develop tests, analyze data and simulate each ECU (Electronic Control Unit), even in a dynamometer environment. CANoe is one of the programs that MATLAB can work with. Simulink is able to work together with programs written in CANoe, which also means that the vehicle model built in Simulink can also be used for software testing (Vector).

Vectrobox VN8900 is a high-speed system controller, which runs the simulation models and controls the test engine dynamometer, which is the central part of the MiL system (Vectorbox). Vectorbox VN8900 sends control commands to accelerator pedal position and engine speed at a rate of 1000 Hz. The vehicle and driver models, as well as the brake and accelerator control algorithms, were developed using MATLAB®/Simulink/Stateflow® MATHWORKS products in the form of a model block on the host computer. The S-functions of the system hardware and function modules were developed and incorporated into the block diagram. S-functions (system functions) provide a powerful mechanism for extending the capabilities of the Simulink® environment (Mathworks).

A user interface was created in AVL Puma Open 2 (AVL) software on the test environment of the engine dynamometer, where the most important information is available from the point of view of checking the operation of the vehicle simulation. The vehicle simulation was implemented in a completely virtual environment in the simulation environment on the dynamometer.

3. Results and discussion

Engine tests according to method EiL were prepared by defining the data to be measured, editing the user interface, preparing (virtual testing) the dynamometer program, and finalizing the CAN messages between the vehicle simulation and the test engine dynamometer, as well as checking the operation of the vehicle simulation model in the dynamometer test environment.

In order to analyze any errors that may arise during a real internal combustion engine dynamometer test, it is necessary to have information directly available in the test environment of the engine dynamometer, where communication data processing can be detected immediately. Complementing the Model-in-the-loop procedure, this facilitates the transition to the Engine-in-the-loop dynamometer test method. The secondary purpose of the user interface is, as can be seen in Figure 4, to make the process unified at the different test levels during the development of subsequent engine dynamometer tests (engine dynamometer, vehicle dynamometer, etc.). During the dynamometer measurements supplemented with vehicle simulation, the method of running the tests and the evaluation of the data should also be applied in a unified manner.

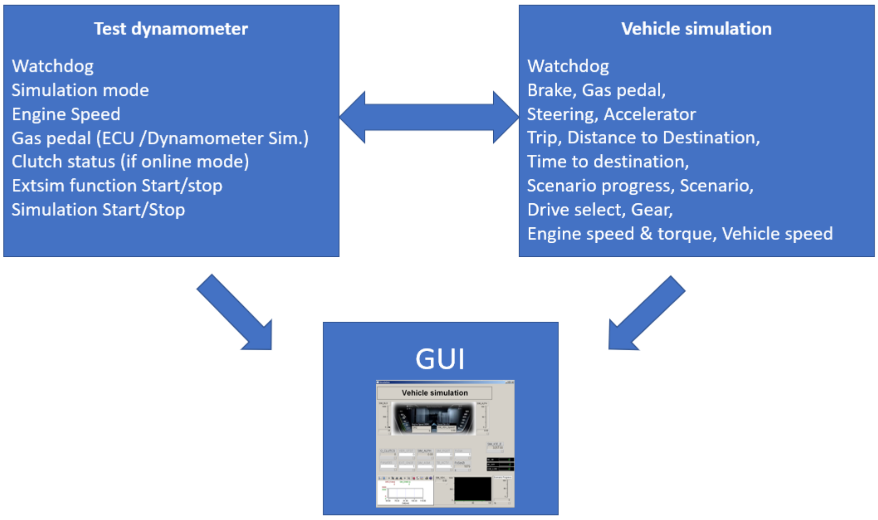

Figure 4. Vehicle simulation dialog – concept (GUI).

During its implementation, minimal modification is required to realize the transition from a fully virtual environment to an engine dynamometer.

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Figure 5 illustrates the success of implementing the vehicle simulation on the virtual dynamometer. Validation and evaluation of the vehicle simulation and presentation of its results are not the goal of the present study. As Figure 5 demonstrates, the speed of the virtual engine and the speed of the vehicle simulation follow each other well, the implementation was successful.

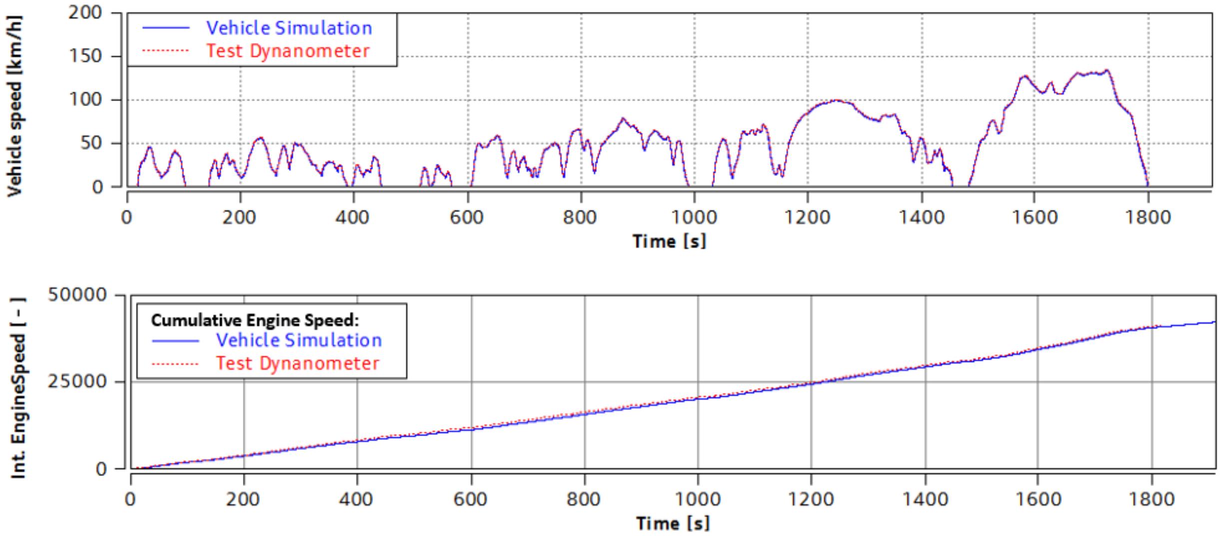

Figure 5. The result of implementing vehicle simulation on a test engine dynamometer.

By transferring the vehicle simulation of the test engine to the dynamometer, the time spent at the real dynamometer was reduced.

Based on tests performed in the engine dynamometer test environment, over 80% of the dynamometer settings can be used to carry out tests because of the application of the method EiL. It is also possible to implement the vehicle simulation in the engine dynamometer test environment with the help of a co-simulation platform.

The settings can be fine-tuned, the vehicle simulation can be operated in the test environment, and the operation description of the vehicle simulation can also be prepared for the motor dynamometer operator. Its application brings profit for later tests on a real engine dynamometer.

4. Conclusion

The application of the dynamometer test developed during this project is increasingly coming to use. It becomes possible to try different development alternatives even before the main components are physically available. The joint automation platform strategy effectively supports the implementation of shorter development processes. The unified automatization strategy between different levels of vehicle simulation makes transitions simpler and more efficient, while also supporting the integration of new methods and their applications. This significantly increases the utilization of the engine test dynamometer used in this way. Furthermore, due to the possibility of carrying out the tests earlier, the development time is reduced. The application of digital models further decreases development expenses, which increases the sustainability of the transportation sector.

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Software:

Simulink – URL: https://www.mathworks.com/products/simulink.html; (Downloaded: 11 August 2022)

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Production of Anhydrous Ethyl Alcohol from the Hydrolysis and Alcoholic Fermentation of Corn Starch

Edmilson Cipriano[1] , Tchilene Major[1], Benevides Pessela[1], António André Chivanga Barros[1,] ✉

Department of Engineering and Technology (DET),
Higher Polytechnic Institute of Technologies and Sciences (ISPTEC),
Avenida Luanda Sul, Rua Lateral S10, Talatona, Luanda, Angola

Abstract: Ethyl alcohol is an organic substance that contains a functional group, the hydroxyl, attached to the ethyl radical. It is a substance used for sterilization and as an alternative fuel to fossil fuels, especially gasoline. It is obtained by the alcoholic fermentation of biomass containing fermentable sugars, based on the use of yeasts; alternatively, microorganisms in the yeast convert the sugars into ethyl alcohol through aerobic metabolism. In this context, this research aims to produce ethyl alcohol by hydrolysis and alcoholic fermentation of corn starch and to purify the resulting products by distillation. For this, experimental tests were carried out using equipment on a laboratory scale. Alcoholic fermentation tests were carried out with strict control of ºBrix, specific mass and viscosity. After the fermentation, the resulting products with a reduced percentage of alcohol were purified by conventional and extractive distillation, ensuring increased purity and commercial value for the alcohol produced. The results obtained were satisfactory, and the phenomenological analysis of the operations ensured the understanding of the performance of each operation involved, with emphasis on hydrolysis, fermentation and fractional and extractive distillations, which involve strong interaction between the phases in each operation. With this methodology's implementation, it proved possible to produce alcohol with a high degree of purity, known as anhydrous alcohol.

Keywords: hydrolysis, fermentation, ethanol, distillation, extractive distillation

1. Introduction

In developed countries, the ethanol production process has been the object of scientific studies to establish the most relevant parameters used in the microbiological conversion of sugars into alcohol. Understood as a renewable energy source, it is an alternative to fossil fuels. It has been increasingly incorporated into the internal combustion system of engines, and it can be used in several proportions mixing ethanol to gasoline, composing a mixture with fossil fuels, or using pure, without any mixture (Santos, Kugelmeier et al., 2013).
Raw materials rich in sugars or starch are explored to produce ethanol, especially sugarcane and corn. They are the alternatives most adopted in agro-industrial plants. In Angola, maize is one of the promising products in producing fermented beverages. In this context, the Castel Group has shown interest in cultivating corn to produce fermentable beverages, especially beer, to minimize the import of raw materials.
The main carbohydrate in corn is starch, a polysaccharide composed of two macromolecules: amylose and amylopectin. It can be hydrolyzed by acid or enzymatic pathways. Starch is a carbohydrate polymer of glucose. Amylose is formed by glucose units joined by α-1,4 glycosides bonds, which results in the formation of a linear chain. Glucose units form amylopectin joined in α-1,4 and by α-1,6 bonds, thus resulting in a branched structure (Luz et al., 2020; Carvalho et al., 2016).
The analysis of corn's physical and chemical characteristics shows the absence of fermentable sugars in its molecular structure. This condition requires the use of pretreatment that promotes the formation of fermentable sugars. The best pretreatment involves the implementation of hydrolysis when corn starch is converted to glucose.
The decomposition of corn starch is complete when conducted under high temperature and pressure conditions, in the presence of a catalyst, whatever the reaction mechanism. The most important catalysts are alkalis, acids, and enzymes. In this case, enzymatic catalysis has greater selectivity, promotes the formation of products with a higher degree of purity, and requires less energy compared to acid catalysis, which presents more significant difficulties in the production of fermentable sugars (Carvalho et al., 2016; Astolfi, 2019; Luz et al., 2020).
Rocha (2007) evaluated the hydrolysis of corn starch using α-amylase bactericidal and fungal amyloglucosidase. The results suggested that smaller granules are more susceptible to enzymatic action, mainly due to the smaller surface

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area. According to this author, enzymes attack the amorphous and crystalline regions of the starch granules. Piva, Bender and Mibielli (2015) also evaluated the influence of agitation and particle size on the hydrolysis of barley bagasse. Their conclusions were similar to those obtained by Rocha (2007).

Massango (millet, *Pennisetum glaucum L)* is a small, dark-coloured cereal used for human consumption. When processed, it produces flour and animal feed and is used as grain to feed small birds, such as parakeets and canaries. Even with the above description, there are no substantial studies of corn starch hydrolysis using massango as a source of myelitis enzymes. However, Santana (2007) evaluated the hydrolysis process using other sources of myelitis enzymes when producing alcohol using two types of yeasts, *Saccharomyces cerevisiae*, and *Saccharomyces diastaticus*, using cassava starch as raw material. Cereal malt was used as a source of myelitis enzymes in this case. The author evaluated barley, wheat, corn, and rye malt, and the resulting products were analyzed based on the concentration of sugars produced. After hydrolysis, the glucose obtained was subjected to fermentation. The result was the conversion of these sugars into ethyl ethanol by microbial action.

For Santos K. G. et al. (2013), the biological process of fermentation involves reactions of partial oxidation of glucose that result in the growth of yeasts and the partial anaerobic oxidation of hexose to form alcohol and carbon dioxide.

For Folch et al. (2021), the glycolysis is followed by reactions that convert phospho-enol-pyruvate (PEP), pyruvate and/or acetyl-phosphate into the final fermentation products (Figure 1). Product formation has to regenerate the redox cofactors used in glycolysis. The redox reactions are either the reduction of oxo-groups to hydroxy groups (acetaldehyde to ethanol, pyruvate to lactate, acetoacetyl-CoA to 3-hydroxybutyryl-CoA, oxaloacetate to malate), the reduction of 2-oxoacids into amino acids (e.g. pyruvate into alanine) or the reduction of carbon-carbon double bonds (fumarate to succinate, crotonyl-CoA to butyryl-CoA).

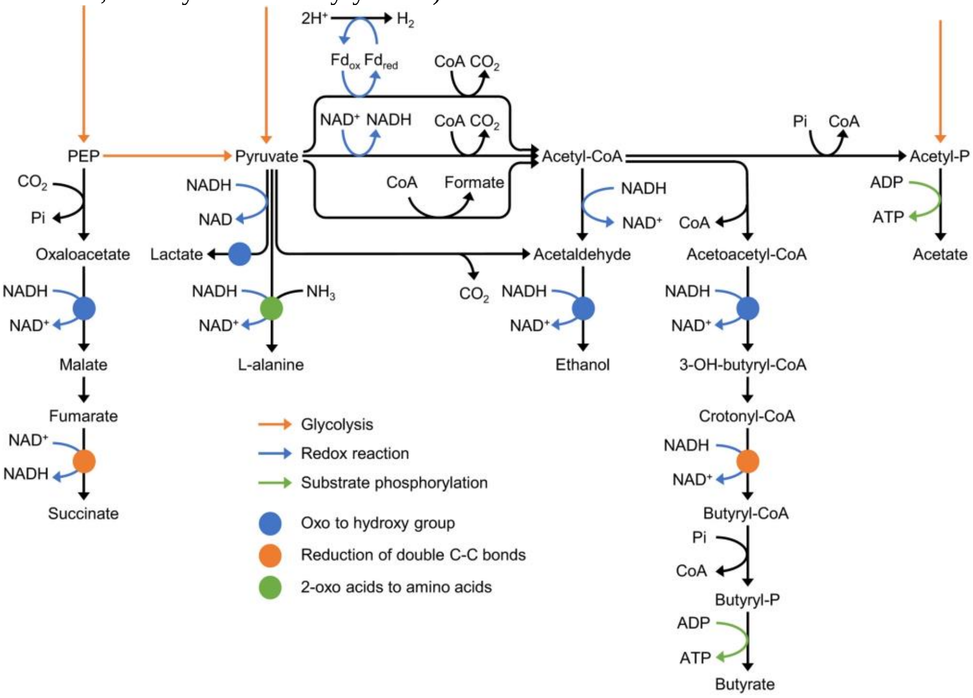

Figure 1. Conversion of PEP, pyruvate and acetyl-phosphate into final products of fermentation processes (Folch et al., 2021)

Fermentation processes are influenced by several factors, mainly the degree Brix, temperature, oxygenation, mineral and organic nutrients, yeast concentration inhibitors, and bacterial contamination. On the other hand, to increase the efficiency of alcoholic fermentation, rigorous monitoring of the referenced parameters is required throughout the process. Generally, fermentation temperatures are between 26 and 35 °C. However, the increase in temperature triggers bacterial contamination rates, increasing the toxic sensitivity of ethanol. Still, from this perspective, fermentation is initially favoured with a low pH, which grows to a range between 3.5 and 4.0.

After alcoholic fermentation, the products are fractionated by conventional and extractive distillation to produce anhydrous ethyl alcohol. In this context, distillation is based on the difference in boiling points of the constituent components of the mixture, especially water (100 °C) and ethyl alcohol (78.4 °C). For Wolf et al. (2001) and Bertoli et al. (2017), the distillation processes are based on the principles of balance between the phases that leave a given stage and make it possible to recover the constituent components of the mixture with a high degree of purity. To evaluate the performance of distillation processes in fractional distillation columns, Noriler et al. (2009) and Siqueira,

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G. A. (2011) evaluated the microscopic behaviour of the flow of liquid and vapour phases in the plates, mainly in terms of interaction between the phases, and related them to the separation transfer efficiency. Soares et al. (2013) related the flow behaviour in liquid stream flow ducts to understand the phenomenological behaviour of mass transfer in distillation columns with a tray. For Zöldy et al. (2007) and Zöldy (2011), ethanol is a renewable resource that could partially contribute to global warming concerns. Ethanol does not contain sulphur, which means it does not emit any sulphur dioxide. The NO_x emission is lower because of the ethanol's higher vapour heat, which cools the combustion temperature.
Based on the literature review, ethanol and ethanol-based chemicals will substantially make mobility more sustainable. The key factor will be the efficiency increase in production. The aim of our research is to develop alcohol production methods for larger yields and better distillate volume. The hypothesis is that a temperature range can be defined for optimal fermentation.

2. Experiment

The study of alcohol production by hydrolysis and fermentation involves 4 phases. The first and second steps of the experiment are preparing the material to be processed, and the definition of the methods must be used to determine the best parameters associated with the hydrolysis and fermentation processes. The third and fourth phases involve conventional and extractive distillation processes to purify and evaluate the alcohol produced.

2.1. Hydrolysis and fermentation procedures

To prepare the material for the experiment, the corn bran mass was weighed and transferred to a beaker, and distilled water was added. The mixture was heated under controlled stirring to 70 °C. After this process, the sugar mass was weighed and dissolved in the water previously weighed. The mixture was then cooled to room temperature, and then hydrolysis was carried out. Data from the operation are described in Table 1:

Table 1. Characteristics of worth samples

Parameters/Sample	A	B	C	D	E
Mass of biomass (g)	65.86	65.568	65.108	65.420	800.00
Mass of water (g)	500.00	501.455	500.90	500.16	6,100.00
Sugar mass (g)	150.05	150.09	50.00	50.314	1,820.00
Temperature (ºC)	40.00	25.00	40.00	40.00	35.00

Source: made by the author, 2021

For samples A and B, the same masses of raw material were used, and the effect of process temperatures was evaluated. The effect of enzymes was investigated for samples C and D with the same temperature. In the case of E, the influence of mass was investigated to see the effect of α-amylase on the yield. The hydrolysis of corn bran was carried out using two different procedures, as follows:

a) The first procedure consisted of using the massango seeds as an enzyme with the raw material and;

b) The second procedure involved using α-amylase enzyme with the raw material.

Sample C was selected for hydrolysis using the massango as an enzyme. For this, 87.178 g of massango was first ground. A solution of this powder was prepared, diluting it in 28.591 g of water, and this solution was added to the prepared must. In the case of enzymatic hydrolysis, 5.4 and 27 g of the enzyme α-amylase were dosed in samples D and E, respectively. After 3 hours of hydrolysis, fermentation was carried out using *Saccharomyces cerevisiae*, i.e. yeast, a material commonly used in the bakery industry.
Yeast preparation involved dissolving this material in distilled water at a ratio of 1:20 (m/m), i.e., 5 g of yeast for every 100.0 g of distilled water, then added to the hydrolyzed mixture. In sample E, as part of the expansion of the amount of biomass, 60.0 g was prepared in 1,200.0 g of distilled water. Fermentation time was measured when yeast was added to the hydrolyzed mixture. Fermentation was carried out with the progressive measurement of the degree Brix for three days.

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2.2. Distillation procedures

For this study, fractional distillation was performed using a distillation flask with a capacity of 500 mL and a heating mantle. 250 mL of the fermented must be poured into the flask, and, with heating, the ethanol was progressively recovered at the top of this apparatus, with concentrations higher than those of the fermented must.

During the distillation process, the temperature of the top steam was controlled up to approximately 100 ºC, characteristic of the minimum concentration of ethanol in the mixture. To minimize the thermal dissipation rates by radiation, the flask was insulated with aluminium foil, thus enabling the use of maximum energy for the distillation operation. After the conventional distillation was concluded and considering that the ethanol/water mixture forms an azeotropy point that prevents the production of ethanol with a high degree of purity by conventional distillation, the structure for extractive distillation was implemented. In the extractive distillation processes, Figure 2 was structured, containing a 250.0 mL distillation flask, a heating mantle, and a fractionation column with fillings.

The experimental procedure included inserting 100.0 mL of ethanol from conventional distillation into the volumetric flask. At the top of the distillation column, a funnel with 60.0 ml of glycerol was inserted as solvent.

The fractionation operation started with the activation of the blanket and consequent heating of the mixture contained in the flask. With the beginning of the formation of the ascending ethanol vapour streams, the solvent supply valve was opened, which descends by gravity and interacts with the ascending ethanol vapour.

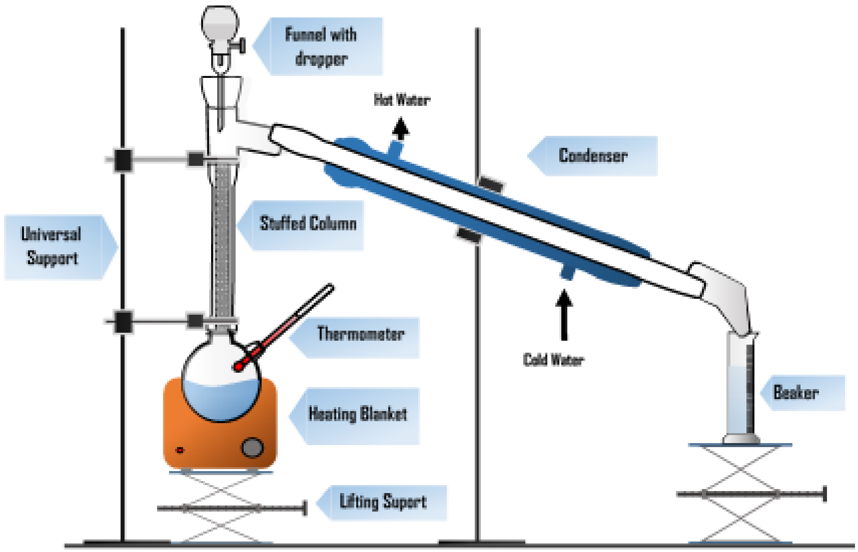

Figure 2. Experimental apparatus used for extractive distillation

The interaction between the phase results in the modification of the thermodynamic properties of the ethanol/water mixture, resulting in the production of anhydrous ethyl alcohol, recovered at the top of the extractive distillation column. This procedure was concluded by maximizing the temperature in the distillation flask, characterizing the minimization of the alcohol content present in the initial mixture.

2.3. Characterization of Alcohol

After the distillation processes were concluded, the ethyl alcohol obtained was characterized by determining the alcohol content (GL and INPM), in compliance with the Brazilian Technical Standards of ABNT 5992:2008. The refractive index, density, and viscosity were also determined by the flow time of the liquid alcohol in an Oswald capillary viscometer.

3. Results and Discussions

3.1. Hydrolysis and Alcoholic Fermentation

Samples C, D, and E were hydrolyzed for 3 hours, and the process was monitored with the evaluation of the ºBrix at the beginning and end of each experiment. In this case, the enzyme used in the process did not significantly influence

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the hydrolysis. It was evaluated during the fermentation of the ºBrix, for all experiments carried out in this study, according to the data in Table 2.

Table 2. Fermentation evolution as a function of ºBrix.

Time (days)	*A*	*B*	*C*	*D*	*E*
0	25.90	26.00	12.20	12.00	25.90
1	13.20	14.10	5.10	5.50	12.20
2	9.30	8.50	5.00	4.80	9.90
3	9.00	8.00	5.00	4.70	9.60

Source: Made by the author, 2021

Qualitatively, for all cases, this parameter decreases with fermentation time, characterized by converting the sugars present in each sample into ethanol, with greater intensity on the first and second days and strong stabilization on the third day. However, the results described in Table 2 demonstrate the need to implement hydrolysis as a strategy for converting non-fermentable sugars into fermentable sugars to increase the conversion rates of sugars into ethanol, thus ensuring a sharp reduction of the ºBrix (%). The data from the experimental tests carried out in this study are shown in Figures 3 and 4. They reveal the influence of the fermentation temperature and enzyme used in the hydrolysis on the evolution of ºBrix measured during the fermentation process.

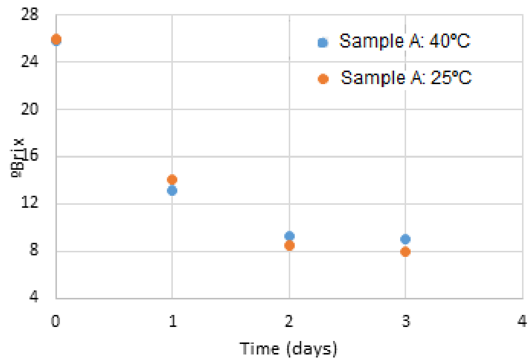

Figure 3. Influence of fermentation temperature.

The temperature evaluated confirms the initial hypothesis that fermentation in the temperature range between 26 and 35 ºC is the most appropriate, with a conversion of 65.25% and 69.23%, for temperatures of 40 ºC and 25 ºC, respectively.

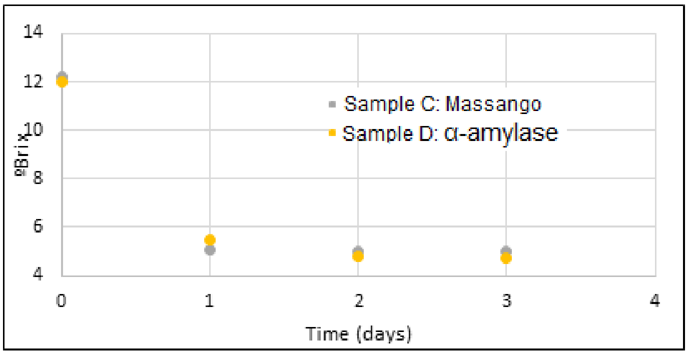

Figure 4. Enzymatic hydrolysis using massango vs α-amylase, both as an enzyme.

Despite the small difference between the two sources of amylolytic enzymes, the use of α-amylase presented a conversion of 60.8%.

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3.2. Distillation and characterization of Products

The fermentation products were subjected to conventional and extractive distillation operations to recover and purify the alcohol produced as a recovery strategy, ensuring compliance with international quality standards for use in internal combustion engines, as a reagent, and as an additive to systems, among other utilities. The operating conditions for each experimental test and the results are described in Table 3:

Table 3. Results of different samples obtained from the fractional distillation

Parameters	*A*	*B*	*C*	*D*	*E*
Volume fed (mL)	500.0	500.0	500.0	500.0	8000.0
Volume Distillate (mL)	30.0	78.0	27.0	34.0	1200.0
Process Performance (%)	6.0	15.6	5.4	6.8	15.0
Specific mass (g/cm^3) at 20ºC	0.831	0.832	0.833	0.860	0.865
Refractive index	1.365	1.364	1.3645	1.3645	1.364
Alcohol content (ºGL) (v/v)	90.0	89.0	87.0	82.0	80.0
Alcohol content (ºINPM) (m/m)	85.5	84.4	82.4	75.3	73.0
Viscosity ($kg \cdot m^{-1} \cdot s^{-1}$)	1.819	1.820	1.688	2.183	1.819

(ºGL: Degree Gay-Lussac) **Source:** Made by the author, 2021

From the data contained in Table 3, it is observed that sample C has a lower performance, 5.4%, supported by the reduced rates of alcoholic fermentation observed in Table 3. The highest performance tests are experiments B and E, carried out at temperatures lower than 40 ºC and with similar water and sugar contents. In this case, the tests performed at 40 ºC presented a performance between 5.4% and 6.8%. The limitation is related to the temperature at which the experiments were performed and the smaller masses of sugar added to the system.

The analyses in Table 3 show that the operations carried out involved the production of hydrated alcohol, with concentrations between 80% and 90%, which requires the implementation of extractive or azeotropic distillation to guarantee the production of anhydrous alcohol, a product with higher added value.

This way, experimental tests of extractive distillation were implemented to increase the alcohol content of conventional distillation products based on the thermodynamic modification of the ethanol–water mixture. For these tests, a packed column was used with rings. Rashing and distillation of the distillate from sample E were carried out, with glycerol (G) and ethylene glycol (EG) as solvents. The extractive distillation products were measured, and the results are presented in Table 4.

Table 4. Results obtained from extractive distillation

Number of distillations	*1st*		*2nd*	
Solvents	***EG***	***G***	***EG***	***G***
Volume fed (mL)	100.0	100.0	60.0	52.0
Volume Distillate(mL)	85.0	80.0	35.0	36.0
Specific mass (g/cm^3) at 20ºC	0.801	0.800	0.795	0.797
Refractive index	1.3635	1.3616	1.3615	1.3616
Alcohol content (ºGL) (v/v)	97.5	98.0	100.0	100.0
Alcohol content (ºINPM) (m/m)	96.1	96.7	99.5	100.0
Viscosity ($kg \cdot m^{-1} \cdot s^{-1}$)	1.415	1.310	1.187	1.257

Source: Created by the author, 2021

To increase the contact time between phases (liquid and vapour) and the interaction with the solvent used, the height of the extractive distillation column was increased, and the fillings were introduced. The physicochemical characteristics of the products are shown in Table 4 and show that the solvents used ensured the production of anhydrous alcohol with a high alcohol content that meets international specifications. The alcohol content measurements were based on the determination of the refractive index and specific mass, physical parameters related to the correlations used to determine alcohol concentrations in samples.

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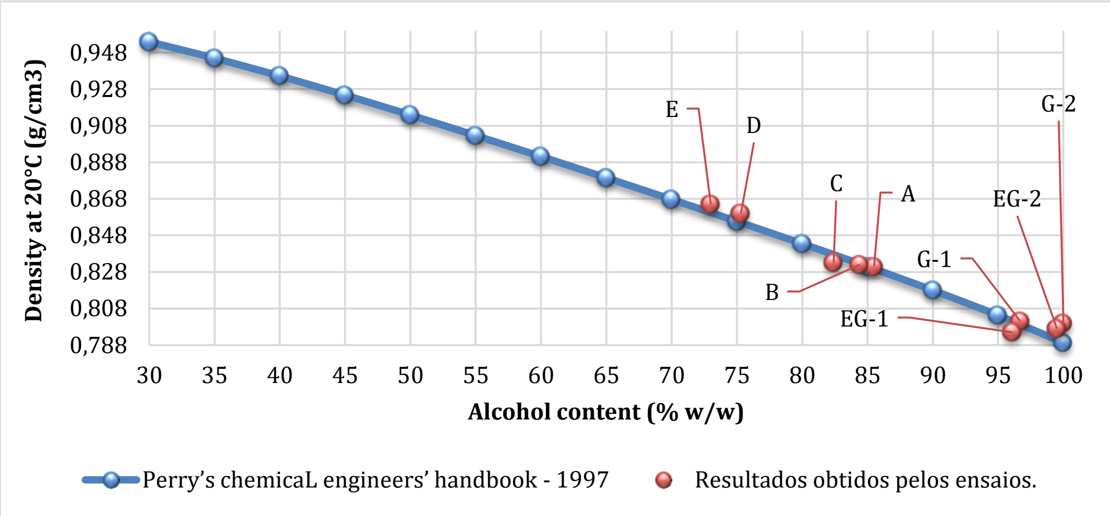

Figure 5. Comparison of density with the literature.

The two solvents used in this study showed efficiency in breaking the azeotropic boiling point, producing anhydrous alcohol with the characteristics of the international standards required for this product. Studies carried out by Barros (1997, 2022) showed that the best procedure to produce anhydrous ethyl alcohol should be associated with extractive distillation, with the use of solvents capable of causing rupture of the azeotropic boiling point, characterized by the deviation of the equilibrium curve from the diagonal. However, studies carried out by Pitt et al. (2019) showed that glycerol, when used as a solvent in extractive distillation processes, has better operational performance compared to ethylene glycol. The use of glycerol in this study is associated with the potential for reusing the by-products of biodiesel production as raw material for extractive distillation processes, guaranteeing an increase in the revenues of industrial units for the production of biofuels.

4. Conclusions

Based on the results contained in this article, it can be concluded that:

a) The methodology used allowed the study of hydrolysis, fermentation, and conventional and extractive distillation procedures capable of producing anhydrous alcohol with international specifications;

b) The implementation of experimental hydrolysis assays, with amylase as an enzyme, presented a better performance in terms of distillate volume;

c) The increase in hydrolysis time should be explored to assess the increase in alcoholic fermentation yield;

d) The structured apparatus to carry out the extractive distillation tests proved viable, as it guaranteed the purification of anhydrous ethanol with physical parameters similar to those in the literature.

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How to use cognitive tools to increase sustainability of elderly people mobility?

Hang Cao
Dept. of Vehicle Technology
Budapest University of Technology and Economics
Budapest, Hungary
hang.cao@edu.bme.hu

Abstract
Aging is a major international trend. The effective and long-term development of activities for the elderly is an important issue. Vehicles must improve the range of activities of older people and increase their life trajectory beyond their age limits. With human participation, autonomous vehicles need to improve driving capabilities to drive safely in traffic scenarios and implement sustainable solutions. We will explore the mobility of aging people when riding in traffic and as pedestrians, with the hope of having sustainable development in terms of convenience and safety for aging people in transportation. The discussion is illustrated in terms of the impact on driving behavior, the functionality of vehicle sensors, and the interaction with traffic road users. This paper helps to illustrate that autonomous driving tasks can benefit aging drivers in terms of driver users, vehicle sensors and systems, and road users when dealing with new or unexpected traffic situations. Identifying cognitive changes and relationships is important better to understand the road environment's cognitive processes and behaviors.

Keywords
Autonomous vehicle, elderly people, cognitive, mobility

1. Introduction

Age problem also has been a worldwide trending issue in the past 30 years, reflects communities' mental health and physical health, and as a popular topic to discuss on mobility. The mobility scheme is exchanging their mobility allowance. Some research results showed that the attention-related risk for elderly drivers increases in complex driving situations. Beyond a certain age, keeping appropriate car driving decisions is hard. Today, congestion is a primary problem in traffic environments worldwide; several accidents occur because of driver inattention and distraction, negatively affecting vehicle fuel consumption (Zoldy and Zsombók, 2018). Some approaches to traffic congestion problems have been proposed, such as analyzing and improving road traffic engineering (Lekić et al., 2019) and managing the road system through Intelligent Transport System (ITS) (Zear et al., 2016). Many researchers address the problem of traffic congestion by using a routing technique (Cao and Zöldy, 2020; Cao and Zöldy, 2021) since vehicles can adopt a new route to avoid congestion. However, traffic congestion at a different location may occur if a high number of vehicles adopt the optimal route. This situation can be considered a scientific, social dilemma in game theory and social psychology (Dawes and Messick, 1980). It is important to realize that the individual rational choice does not coincide with the rational choice for a society (Hiraishi and Mizoguchi 2017）.

The French researchers designed a questionnaire to evaluate aged-driving behavior with comparison. However, findings found that cognitive abilities test via self-evaluation is more effective than driving behavior questionnaire. The self-evaluation measurement includes process velocity and attention. Bergen et al. (2017) classified self-regulation aged drivers into three groups: high self-regulation group, medium self-regulation group, and low self-regulation group, and found that to reduce transportation risk, training avoidance of orientate driving situations and driving weekly frequency is necessary.

Vehicles and their embedded technologies provide people with significant changes in easy and comfortable living. People of different ages need to benefit from such assistance without generating new attention-related risks (JC Marquié, 2010). The US Department of Transportation (USDOT) established five levels of vehicle automation (Alyamani et al., 2017)

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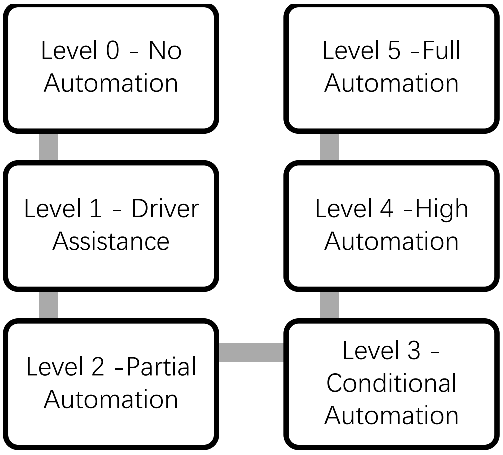

Figure 1. The structure of five levels of vehicle automation (based on Alyamani et al., 2017)

The competency to drive effectively and sustainably involves several cognitive abilities. Anderson and his colleagues (2017) use a neuropsychological composite score to evaluate cognitive and overall driving ability. They proposed a cognitive test including four aspects, i.e., attention, memory, visuospatial and visuomotor skills (Kim and Bishu, 2004). The work explores driving responses and improving unsafe driving sustainability, considering older drivers' risk (Anderson et al., 2005). Sustainability-minded driving refers to vehicle drivers who are environmentally concerned. Rapoport's team categorized the sustainability of driving capability in cognitive performance, driver perceptions, and self-monitoring driving restrictions (Kim and Bishu, 2004; Rapoport, 2013). Changes in cognition lead to actual driving results over time, resulting in typical driving situations and hazardous driving conditions, i.e., crashes and violations (Anstey, 2005; Rapoport, 2013). Cognitive ability, executive function, and memory values can lead to poorer driving performance and increase the risk of collisions (Anderson et al., 2005). Motoyuki summarized the effects of cognitive and physical changes on satisfaction using alternative modes of transportation from the perspective of older adults' mobility (Motoyuki et al., 2006). The speed and quality of specific movements can be measured by considering cognitive factors to improve sustainability (O'Connor, 2020)

Human driver familiarity with the environment and situation will result in different driving styles and performances. Drivers specify helpful information and identify whether the road is driveable from the surrounding environment. Due to adequate awareness of the energy distribution of the obstacle, such as light reflected by surfaces and objects (Sánchez and Araújo, 2021), drivers take action. The scenario for the self-driving car to travel mainly consists of structured and unstructured roads (Chen et al., 2019). Clear boundaries and traffic signs are defined as the features of structured scenario roads. Meanwhile, unstructured roads can be seen as rural areas with no clear boundaries (Chen et al., 2019). Getting self-driving cars to follow established lanes and traffic signs reasonably and legally on structured roads, or to drive safely and smoothly on unstructured roads, is another challenge for self-driving cars (Zöldy et al., 2021).

This paper discusses elderly drivers facing problems and the autonomous vehicle . The rest of the article is structured as follows. Section 2 introduces the elderly driver's cognitive aspects related to the detection of and adaptation to the environment. Section 3 illustrates the autonomous vehicle system cognitive changes considering older people's characteristics. Section 4 presents the difficulty of cognitive changes of autonomous vehicles. Section 5 is the conclusion and discusses expectations concerning the cognitive problem of self-driving cars for elderly people.

2. Driver's cognitive ability to adapt to the environment

Mobility is critical to the quality of life of older adults, and all trends suggest that in the next century, most of their transportation needs will be met by private cars. (Schaie and Pietrucha, 2000). **Cognitive flexibility** is the ability to appropriately and efficiently adjust one's behavior according to a changing environment. Some researchers summarized comparisons of what drivers currently do and what they intend to do as behavior surveys in several categories. Li et al. (2021) studied standard driving modes into six categories, i.e., deceleration, stable, acceleration, left turn, right turn, and roundabout scenario case (Li et al., 2020), and collected driving modes with acceleration and angular speed. A roundabout has specific traffic rules to obey. Alyamani concluded that left/mixed-handed drivers show better driving performance when entering roundabouts and approaching intersections (Alyamani et al., 2017). The differences in driving flexibility influence the

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driving errors when exiting roundabouts. Driving errors include driving in the wrong lane, failing to use the indicator light, or using an incorrect directional indicator. Left/mixed-handed people show superior cognitive flexibility in tasks that require such ability as right-handed people.

Hiraishi and his team expand the Time-constrained heuristics search (TCS) process from two cognitive psychological views: prospective theory and present-oriented bias (Hiraishi and Mizoguchi, 2017). Considering that the driver prefers immediate profit and sufficient spare time to ensure a comfortable and relaxed environment, in this case, the driver reaches the goal of finding the optimal route. Strayer et al. (2019) found that 65% of the vehicles supported texting and 25% supported destination entry using a navigation system when the vehicle was in motion.

Cognitive map

The study found that older adults have less accurate verbal memory for urban landmarks and less accurate memory for the location of landmarks than younger adults. In addition, the discriminant analysis revealed that older adults relied more than younger adults on certain architectural attributes upon to remember urban landmarks. For example, the naturalness of the surroundings, direct access to the street and unique architectural style, high public use, and high symbolic significance. However, older adults have become much less inexpensive with age and other cognitive impairments for this memory method for their transportation. The car's mapping system will significantly help the elderly to get around. **Cognitive map** is the description of future scenarios and potential situations. Zhang and his colleagues created Fuzzy Cognitive Maps (FCM) to illustrate high-level scenario planning, providing an accessibility method that could give an integrated description of the mental models (Zhang and Jetter, 2018).

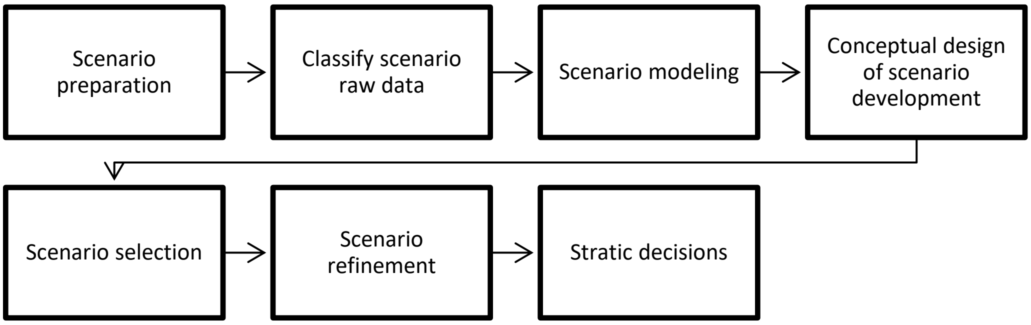

Figure 2. Cognitive scenario planning framework (Felix et al, 2019)

As Figure 2 shows, in the main cognitive maps framework, the key idea is to build and transform the useful scenario data, classifying the scenario raw data and identifying model components, integrating and constructing the cognitive maps scenario, inference complex causal modeling and probabilistic scenario cases. Cognitive mapping will give the elderly a clearer picture of their current and future travel status and routes than possible. For cognitively impaired older people, vehicle systems with cognitive mapping will greatly compensate for the cognitive deficits of the elderly during driving.

3. Cognitive design on the self-driving car system view

Most autonomous vehicle (AV) system designs are based on a social-cognitivist assumption to explain navigation tasks and cooperative tasks. The ego car must understand the mission of all navigational tasks and collaborate with other road users, which greatly helps aging people. AVs are equipped with advanced sensors to obtain environmental information, including cameras, lidar, radar systems, etc. The vehicle's software recognizes the objects and the sensors detect road users, which are also responsible for the car's compliance with traffic rules (Sánchez-García and Araújo, 2021). The embedded detection system software cooperates with a digital map to identify the driving situation and make rational driving decisions (Sánchez-García and Araújo, 2021). Understanding the environment and the decisions are stored in the computational memory. The vehicle expects the same navigation style from other road users, i.e., to share the road information with the other drivers or road users in the same situation, to reach the specific goals of each driver, and to follow traffic rules to take part the interaction.

Cognitive changes include visual scanning, attention, processing speed, executive function, and memory (Donoghue et al., 2012). Visual/manual touchscreen interactions may divert the driver's eyes, while auditory/sound interactions may keep

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the eyes on the road; however, any benefits of the former may not be realized if the auditory or sound interactions take longer to execute than the visual/manual interactions. In many cases, a task can be performed using auditory commands, visual/manual interactions, or a hybrid combination of /audio and visual/manual interactions (Strayer et al., 2019).

The in-vehicle system can help aging people while driving. The audio entertainment in the car system allows the elderly to change the music to different radio stations and satellite radio sources, and also allows them to call and dial their cell phones via Bluetooth connection. The in-car system also helps the elderly to navigate, step by step, in a way that makes it easier for them to get around according to their own characteristics. A cognitive module is introduced in the system architecture to enable the transition from perception to decision-making. The hardware and software systems collaborate to select the best driving strategy through traditional context-aware scenario analysis or AI techniques.

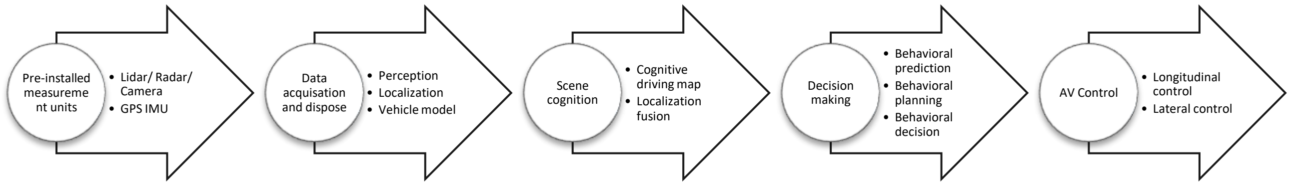

Figure 3. Relationship among AVs sensors, data disposal, and driving behavior planning (Zhang, X et al., 2020; Knoefel et al., 2019)

Figure 3 shows the relationship between vehicle sensors and the manipulation of vehicles. The vehicle body has its own sensory system, i.e., pre-installed measurement units, for example, odometer, inertial measurement unit (IMU), gyroscope, and controller area network (CAN) bus (Knoefel et al., 2019). These self-sensing features instantly detect wheel velocity, yaw angle and steering behavior. GPS and IMU as external sensors determine vehicle destination and real-time position. Environment sensors are used to obtain the surrounding information and other road users' states.

Mobility impairment in older adults appears to predict more generalized disability and susceptibility to other geriatric syndromes (Sims et al.,1999). Some research groups found that falls and vehicle crashes are related in some older drivers. Vulnerable older adults consistently exhibit multiple impairments due to the effects of medications, chronic illness, emotional disorders, and visual and cognitive dysfunction (Sims et al.,1999). These changes include the following relevant declines in ability: decreased mobility, decreased strength, more rapid onset of fatigue, visual deterioration, reduced ability to process information, slowed reaction time, and hearing loss (Smith et al., 1993; Herriotts, 2005). SHIRAI and TAKAHASHI (2018) considered the possible conditions for older people. They designed a skin potential reflex device (SPR) to reach the demand of releasing the elderly stress on mobility, e.g., the weak legs problem for older people. The researchers focused on links between cognitive function levels and crashed risk among older drivers without dementia over a 14-year study period. They also assessed the link between changes in cognitive function over time and later risks of crashes.

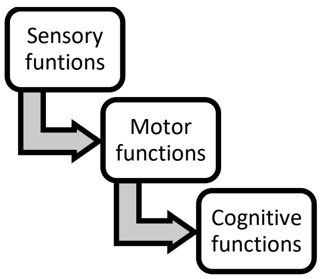

Figure 4. Age-related functional changes for autonomous vehicle

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As Figure 4 shows, age-related functional changes mainly include the interaction of sensory, motor, and cognitive functions. Normal aging and structural changes in the eye lead to a decrease in visual acuity and contrast sensitivity, and this part of the visual limitation becomes more pronounced with increasing age. The cognitive vehicle system of the elderly happens to need to account for such losses. The motor function described with age increases, and the loss of body muscle strength diminishes. Cognitive functions mainly control attention supporting, e.g., visual search, visuospatial skills, and attention switch, suppress irrelevant information and inappropriate responses, multitask, and monitor one's own performance. This pattern will help high correlation on accurate position and maneuver for ego vehicles.

BMW raised the concept of "Environment–Driver–Vehicle" cycle (Hoch, S., 2016) to illustrate the cognitive effect on the vehicle software framework. However, the routes provided by the GPS are not optimal and lack on-demand user requirements. Smith et al. (1993) explores the cognitive field within the in-vehicle framework. The GPS provides the route and coordinates with a satellite communication system to store the available route. The route data are learned, stored, and read inside the cognitive memory for an optimal route provision. The vehicle learns about the routes and matures with route experience by itself over time. Fuzzy modeling was used to examine the effect of cognitive variables on static and conventional parameters (Baranyi et al., 1996). On the body of the car, there are high-resolution cameras that can scan meters in any direction; there are also front and rear radars to detect the environment and nearby objects.

Complex lighting and weather conditions all have different effects on vehicle movement. Various lighting conditions and corresponding scene changes, such as darkness and roads that do not reflect light well, cause significant interference with the images obtained by the camera. Poor weather conditions interfere with the reception of LiDAR point cloud data, resulting in LiDAR's inability to detect obstacles accurately.

4. Cognitive interaction among road users

AVs driving route is based on their understanding of the environment and road conditions. For automotive vehicle systems, help older drivers understand the scenario and driving conditions is important. Some road conditions are complex, lead drivers need to give right of way, and turning, those in difficult or unexpected situations involve other road users. Roundabout is one of these complex crossroads. Figure 5 illustrates the ego car route planning category based on the roundabout types, i.e., the traffic sign exits or a no-signal roundabout.

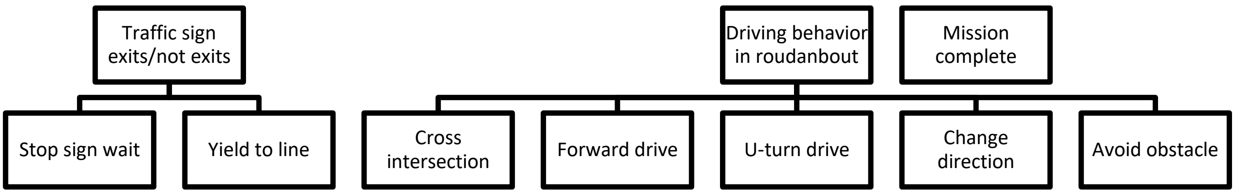

Figure 5. The case of ego car route planning in roundabouts – summary

The ideal case is when the ego vehicle drives without other road users. However, in the real world, traffic needs the vehicle to cooperate. The road users can be passenger cars, large vehicles, pedestrians, and cyclists. Determining the ego car's mission, evaluating other road users' behavior, and quickly and accurately reacting are the critical core of AV interaction. The challenges of transportation "negotiation" are widely discussed in transportation research and cognitive science. Trust in AVs was defined as the tendency to be influenced by the actions of AVs (Jayaraman et al., 2021).

Trust, preference for AV, anxiety, and mental workload are four autonomous vehicle interaction outcomes (Du et al., 2019). Jayaraman et al. find that the autonomous vehicle's aggressive driving depends on the type of crosswalks (Jayaraman et al., 2018) and the presence of traffic lights. Pedestrians' gaze at certain areas/objects, pedestrians' distance to collision, and jaywalking time substantially impact the AV trust (Jayaraman et al., 2018). The pedestrian's trust is fed back to the vehicle's movement, and the two interact to determine the vehicle's travel speed and route.

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Uncertainty reduction theory (URT) is embedded deeply in many research fields and can be applied to cognitive changes between an AV and a pedestrian. The greater the uncertainty, the more people seek information to reduce uncertainty; the more information is provided, the less uncertainty is. Helping avoid sudden automation incidents and adverse emotional reactions play essential roles in autonomous vehicle interaction. AV explanation promotes automation trust since it provides humans with clarity (Du et al., 2019). The effects of explanations, their timing, and the degree of autonomy on drivers' trust, preference, anxiety and mental workload have been tested in 6-8 minute drives ((Du et al., 2019). Driving control moves from the knowledge or rule-based levels towards the skill-based level, reducing the mental or cognitive workload required for the operations involved in the driving task.

5. Cognitive difficulties

Driving behavior varies because of the reactions from different driving experiences. Chater et al. (2017) categorized driving ecology and scale of cognitive science challenges with automated negotiating skills. Fatiha and Abdelghani (2017) summarize metacognitive difficulties in the driving context and illustrate methodology based on the combination of quantitative methods, e.g. statistical analysis and qualitative methods related to the drivers' expectations and driving experiences. One's cognition of one's limitations and strengths enables one to choose strategies to accomplish a task in the best possible manner and assess the gap between the performance and goals to manage the risks associated with task complexity properly.

For metacognitive skills for elder people planning, difficulties are in route planning and remembering the itinerary. A metacognitive difficulty in control and monitoring is the lack of sensitivity to inconsistent information about the road environment. Urban environment complexity and drivers' cognitive resources are also problematic: a driver in an urban environment faces an overflow of information from other users, neighborhoods, infrastructures design, roads signs etc. It is also difficult to deal with the information quickly and in real-time (Zöldy M et al., 2021). Furthermore, the cognitive burden of older people belongs to data privacy. How to deal with data using and maintaining data privacy is an important issue.

6. Conclusion

Driving automation may become the assistive device of the future. However, partial vehicle automation continues to evolve in the coming decades and needs to consider the needs of people of different ages. Full vehicle automation is still many years away and may completely change the requirements for driving ability. Helping drivers promote sustainability-focused driving patterns and lead the autonomous vehicle to increase cognition aid is essential for the future. Training vehicles to increase cognitive ability from driver to system view will increase the efficiency of traffic users and enable increasingly optimal mobility decisions. For older people, restricting driving is not a good solution for older people's mobility. Moreover, the industry should consider older people's characteristics, cognition state, and social interactions for automotive system design. Let us make the "shrinking world" of elderly people have a more expansive lifestyle.

In addition to developing these technologies, efforts must be made to address numerous ethical and legal challenges. A neglected problem has long been how to understand and process environmental perception data from the sensors referring to the cognitive psychology level of the human driving process. Cognitive computing ability is another challenge in vehicle driving to remedy older people's cognition driving style. Significant changes in the elderly cognitive principles and public policy are needed to regulate vehicle automation to advance the field of vehicle automation as a safety aid of the future.

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