

CHANGES IN AIR POLLUTION FROM ROAD TRAFFIC IN CASE OF A HUNGARIAN SUBURBAN AREA

ORSOLYA FARKAS¹, TAMÁS HARDI²

ABSTRACT – The study examines the extent to which suburbanization and the accompanying increase in traffic are harmful to the quality of the environment. We have shown that in the urban areas of Hungarian cities, the increase in the number of cars greatly exceeds the increase in the population. We examined the level of air pollution on a section of road in the vicinity of Győr (a medium-sized city in northwestern Hungary). Changes between 2001 and 2022 were calculated in four suburban settlements located in a part of the Győr agglomeration, along road number 1401. The number of passenger vehicles has increased and commuting habits have also changed significantly. We calculated the emissions from road traffic (only passenger car traffic) using the COPERT program, thus quantifying a small part of the environmental impact of suburbanization. The number of vehicles in agglomeration areas increases even if the population does not increase further.

Keywords: suburbanization, commuting, pollution, population, passenger car

INTRODUCTION

The Győr agglomeration has been one of the most dynamically developing suburban areas in recent decades, not only in terms of population but also in terms of traffic growth. However, this has harmful environmental effects, including a reduction in green spaces and an increase in emissions from transportation.

The process of suburbanization is addressed by several disciplines (Bajmóczy, 2000), and the impact of suburban areas developing around large cities is significant from the perspectives of geography, sociology, urban architecture, regional economics, and transportation planning (Kocsis (2000)). The legislative framework for the creation of metropolitan areas began only early 2000s, and there are still many juridical difficulties (Rusu et al. (2012)). As a result of suburbanization, which brings about both quantitative and qualitative changes, the population of agglomeration settlements is growing, and the rural character is being replaced by an urban lifestyle (Hardi et al., 2024). In addition to the Budapest agglomeration, rural agglomeration areas have also clearly emerged. The aim of the study is to present one of the rural agglomerations and to quantify changes in transport and environmental problems over time.

METHODS

The period examined spans two decades, covering the changes between 2001 and 2022. On the one hand, existing statistical data were analysed, and on the other hand, air pollutant emissions from road traffic were quantified using COPERT software (version 5.8). During the data analysis, we

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utilized annual statistical data from the Hungarian Central Statistical Office at the settlement level, including population, the number of passenger cars, and commuting.

The Hungarian Public Roads Authority's annual cross-sectional traffic count includes the average daily passenger car traffic for four measuring stations located along Road 1401.

The following statistical data from the Hungarian Central Statistical Office were used for the emission calculation (we always used the lowest available data at the regional level):

- Average age of vehicles in Győr-Moson-Sopron County
- Distribution of vehicles in Győr by age group and cylinder capacity
- Distribution of passenger cars in Győrújfalú, Győrzámoly, Győrladamér, and Dunaszeg by fuel type
- The start date of the Euro classifications

The source of the meteorological characteristics (monthly minimum and maximum temperatures and relative humidity) was the HungaroMet Hungarian Meteorological Service, while the emission factors were obtained from the COPERT software.

RESULTS AND DISCUSSION

The domestic population has been declining for years, with the permanent population of large cities showing a negative trend alongside that of smaller rural settlements. Between 2001 and 2022, the permanent population typically increased in settlements located near Budapest, on the shores of Lake Balaton, in some border areas, and in the vicinity of large cities. Figure 1 shows the boundaries of urban areas in thick lines and the administrative boundaries of individual settlements in thin lines, with grey-black indicating growth and white indicating decline.

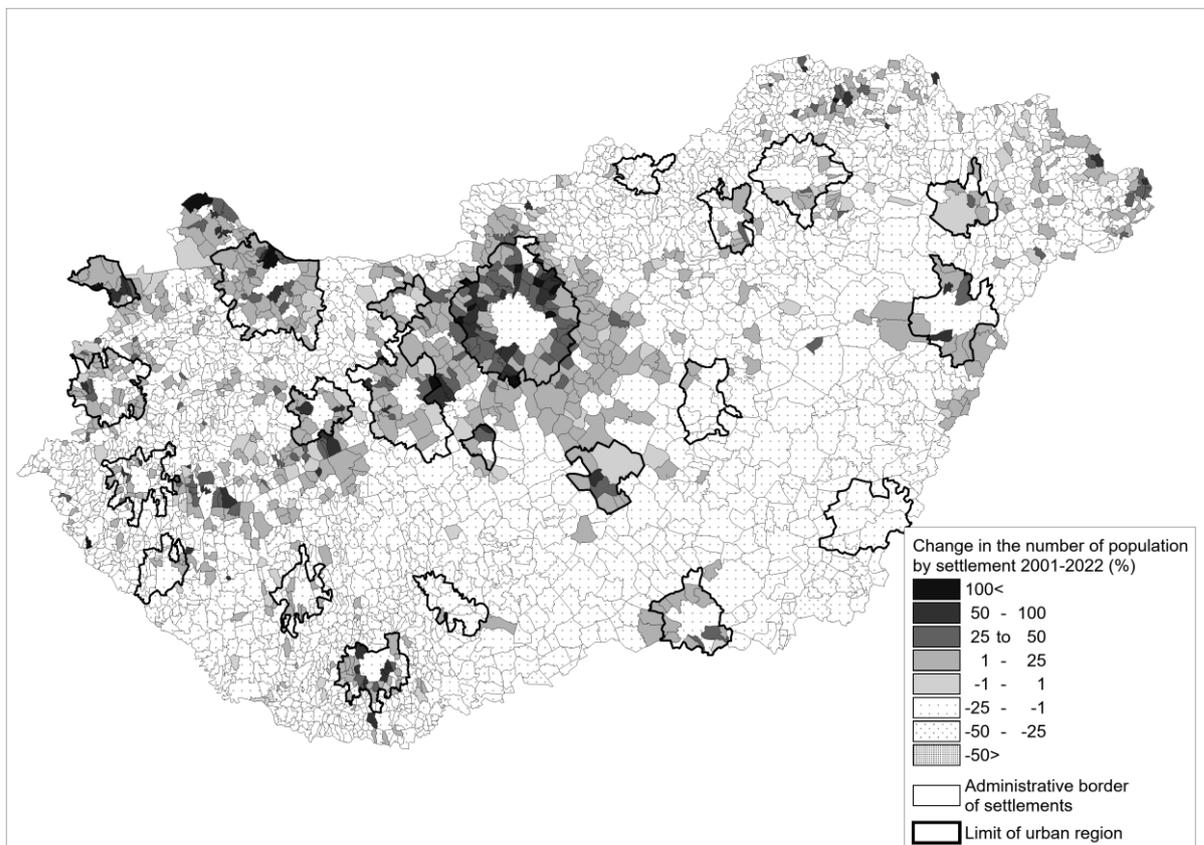


Figure 1. Change in the number of population by settlement between 2001 and 2022 [%]

Source: own editing

As a result of suburbanization, built-up areas are increasing, and instead of rural-style development, new residents are opting for suburban, urban forms, such as semi-detached houses on

smaller plots and apartment buildings with a few flats. In many places, paved yards, parking spaces, and higher building density are common, further reducing green space. This increases the heat island effect, reduces carbon dioxide sequestration capacity, and increases the amount of surface runoff from precipitation.

Along with changes in building styles, customs also changed, with farming and self-sufficient rural lifestyles declining. A significant proportion of residents commute from home to work and also spend time in the city on numerous other activities. Households in rural agglomeration settlements typically own several cars, which they use for daily commuting (kindergarten, school, work, extracurricular activities, training, shopping, and all kinds of other services and leisure activities), resulting in noticeable traffic congestion in agglomerated areas. Congestion has developed on the outskirts of large rural cities and on major transport routes, while parking difficulties have arisen within cities. These factors, among others, may be behind angry and irritable driver behaviour (Hógye-Nagy et al., 2025).

When choosing a place to live, transport needs are only one factor among quality and floor space requirements, property prices, and available financial resources (Lengyel-Rechnitzer, 2004), with property prices typically having the greatest influence on the decision (Hardi, 2002). Access to public transport is less of a consideration in suburban areas.

The Budapest agglomeration and rural urban areas account for 54% of the population and more than 65% of jobs. Thus, commuting within urban areas and from rural areas to urban areas is significant and growing rapidly. Based on census data, the number of commuters within the Budapest agglomeration was approximately 350,000 in 2022, which is more than double the value of 2001. The increase in internal commuting in rural-urban areas is more modest, with an increase of around 52 percent during this period. The growth in the number of commuters from outside urban areas has been more dynamic, nearly tripling in the Budapest agglomeration (272,000 people in 2022) and increasing by about 130 percent in rural urban areas to 324,000 people. According to our calculations, this means that the average distance between residential and work locations (weighted by the number of commuters) for commuters from rural urban areas has increased from 16.1 to 26.7 kilometres. In terms of transport, this means that the commuting area has grown and become more dispersed, reducing population density and reinforcing car dependency in rural areas.

On the one hand, in terms of population, only Debrecen, Kecskemét, Budapest, Győr, and the Sopron suburban area increased. On the other hand, in terms of the number of passenger cars, all urban regions, the countryside, and the national average also showed growth between 2001 and 2022. The Győr agglomeration is surpassed in both indicators only by the Sopron metropolitan settlement cluster located along the Austrian border, where the proportion of foreign workers is very high due to its geographical location. In the case of Budapest city and the Budapest agglomeration, the percentage increase in the number of passenger cars between 2001 and 2022 is well below the national average, which may indicate a kind of saturation and more favourable suburban public transport compared to individual transport. Comparing changes in population with changes in the number of passenger cars reveals a linear correlation ($y=0.9621x+65.637$), which is clearly illustrated in Figure 2. This indicates that even if the population remains unchanged, the number of passenger cars in agglomeration areas will increase by more than 65%.

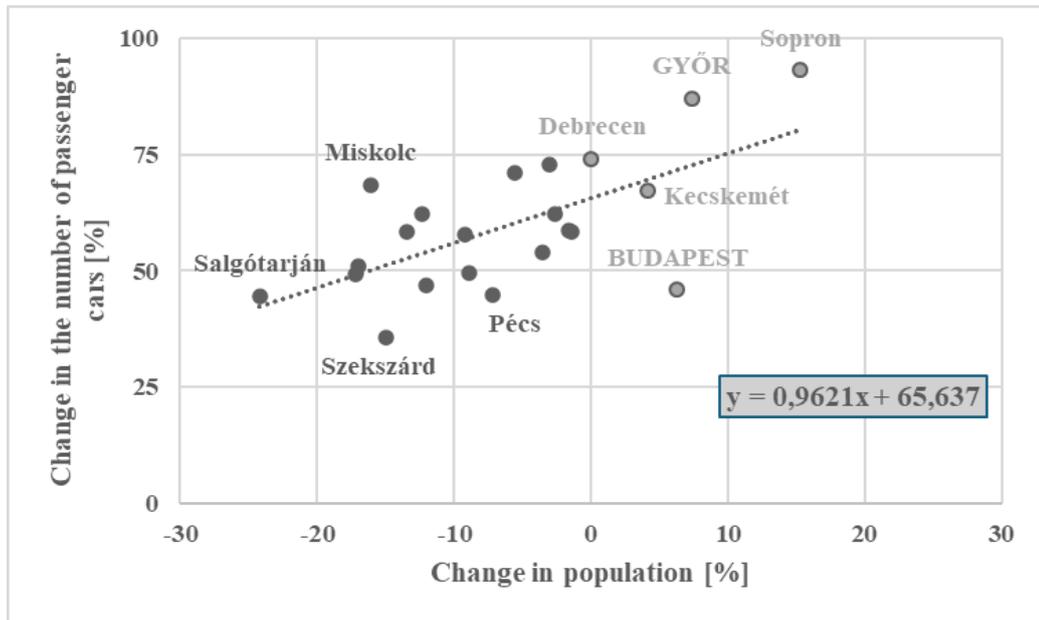


Figure 2. Correlation between change in population and in the number of passenger cars by urban regions between 2001 and 2022

Source: own editing based on KSH dataset

In the early 2000s, there were 200-300 passenger cars per 1,000 inhabitants; only Budapest city and its agglomeration exceeded 300. By 2022, the figure ranged between 400 and 500. In Figure 3, this significant increase is further illustrated by the growth of motorization and the change in order between 2001 and 2022 in some key regions (countryside, Budapest city, Hungarian national average, and the suburban area of Budapest, Győr, and Sopron). The average motorization rate in the European Union (EU27) in 2022 was 560 (EUROSTAT, 2024).

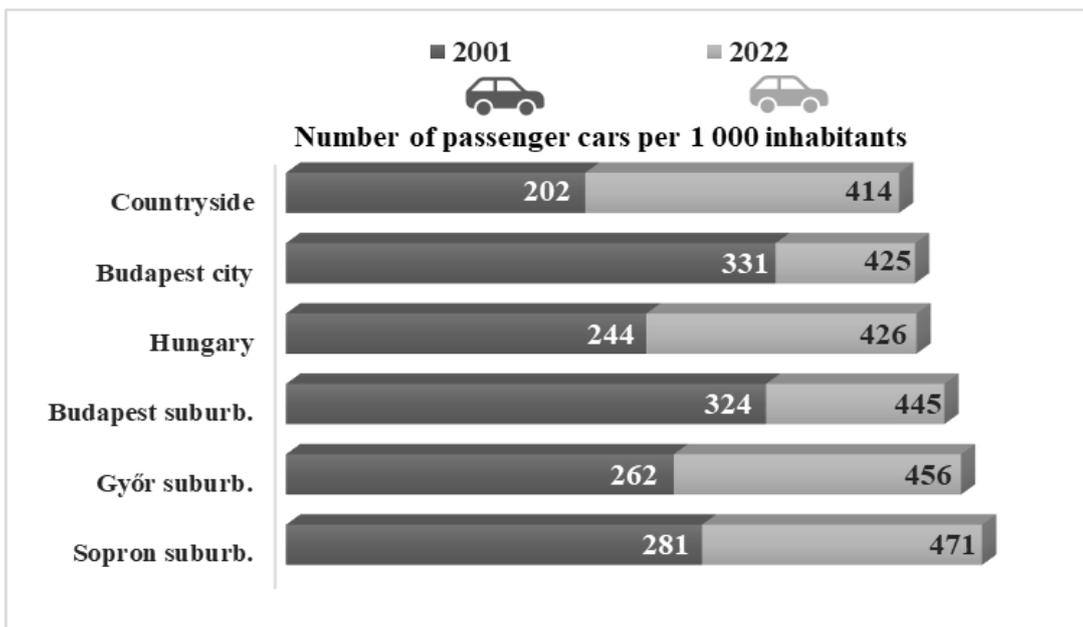


Figure 3. Change in motorization between 2001 and 2022 in some key regions

Source: own editing based on KSH dataset

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Győr is a significant transportation hub in Western Transdanubia, located near the M1 motorway, on the main road 1, and secondary main roads 81, 82, 83, and 85. Traffic on the 1401 connecting road between Mosonmagyaróvár and Győr, which runs along the settlements of Szigetköz, has also changed significantly (more than doubled) since 2001. This is why we chose Road 1401 as the basis for our pollutant emission calculations, as it has undergone significant changes in recent years.

The first 11 km of the 38.6 km long Road 1401 passes through Győrújfalú, Győrzámoly, Győrladamér, and Dunaszeg. In this study, we highlight the main data of the four settlements closest to Győr, as these are the most affected in terms of suburbanization. It is clear that there has been a significant increase in the population of all these settlements, with the population of Győrújfalú and Győrzámoly increasing at a higher rate, growing by almost two and a half times. In comparison, the number of passenger cars in Győrújfalú, Győrladamér, and Dunaszeg has increased even more significantly, more than tripling, and in the case of Győrzámoly, the number has increased almost four and a half times. Figure 4 clearly shows that the number of passenger cars has changed much more than the population.

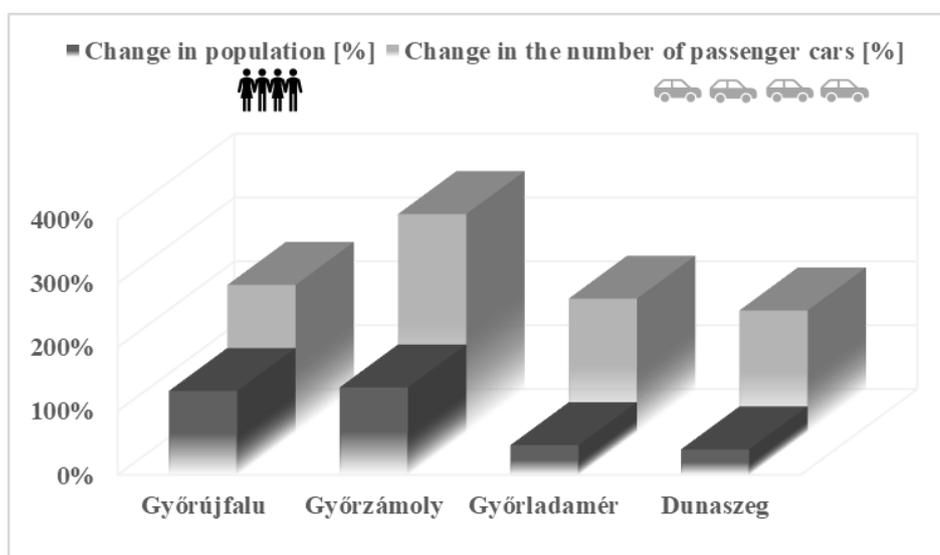


Figure 4. Change in population and number of passenger cars between 2001 and 2022 in the four settlements of Szigetköz (Győrújfalú, Győrzámoly, Győrladamér, Dunaszeg)

Source: own editing based on KSH dataset

Commuting data in Table 1. shows the number of active job seekers who commute to other settlements for work. Although Győrladamér attracted nearly 500 employees to the settlement in 2022, it can still be said that the number of outbounds is significantly higher than the number of inbounds.

Table 1. The number of inbound and outbound, as well as the changes between 2001 and 2022, in the examined settlements.

Settlement	Inbound			Outbound		
	Number [capita]		Change [%]	Number [capita]		Change [%]
	2001	2022		2001	2022	
Győrújfalú	108	130	20%	356	1121	215%
Győrzámoly	67	185	176%	473	1638	246%
Győrladamér	106	478	351%	378	785	108%
Dunaszeg	57	97	70%	522	1034	98%

Data source: National Institute of Statistics, Census of Population and Housing

Due to its proximity to Győr, most commuters travel to Győr for work. However, a change has been evident over the past two decades, as more and more people are working in Budapest or even abroad (Figure 5). There are different elements of cross-border social cohesion (Bufon, 2016). With the spread of remote working and home office, this may mean that they do not have to travel hundreds of kilometres every day to get to work, but their employer may be located further and further away from their place of residence. Besides this, commuting to other settlements in the Győr agglomeration has also increased (from 154 to 482 outbounds). Commuting is constantly sapping rural resources (Nagy et al., 2024).

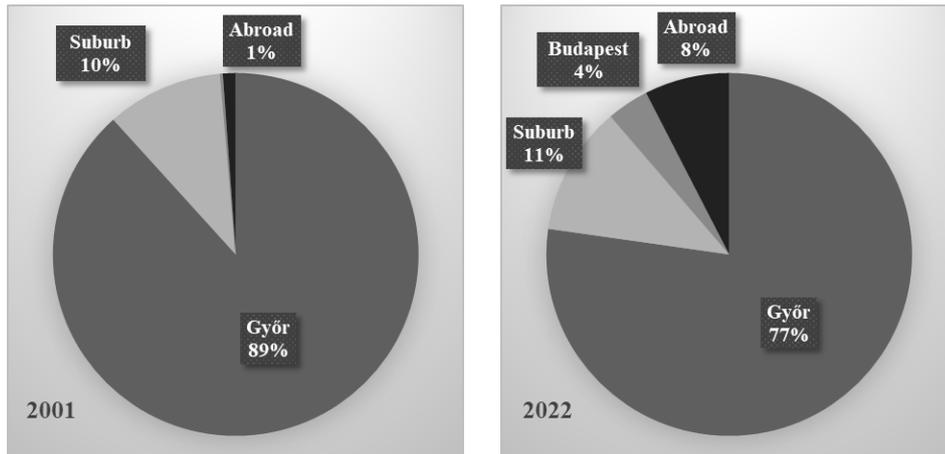


Figure 5. *Distribution of the number of outbounders in 2001 and 2022 by destination*
Source: own editing based on Census dataset

Figure 6 illustrates the change in passenger car traffic. The significant increase in traffic is clearly visible at traffic counting station 4396, where the average daily traffic on the road section between Győr and Győrújfalú changed from 4,861 to 11,053. The highest traffic volume on road 1401 occurs on the first 11 km section, thanks to the four settlements presented so far. From 2012, the number of traffic counting stations was expanded, and station No. 13550 was installed on the outskirts of Dunaszeg, which doubled the average daily passenger car traffic measured in the last 10 years (from 1,912 to 3,980). In contrast, traffic at stations further away from Győr showed only a slight increase, with rural lifestyles and lower commuting rates remaining in the Ásványráró and Darnózseli areas.

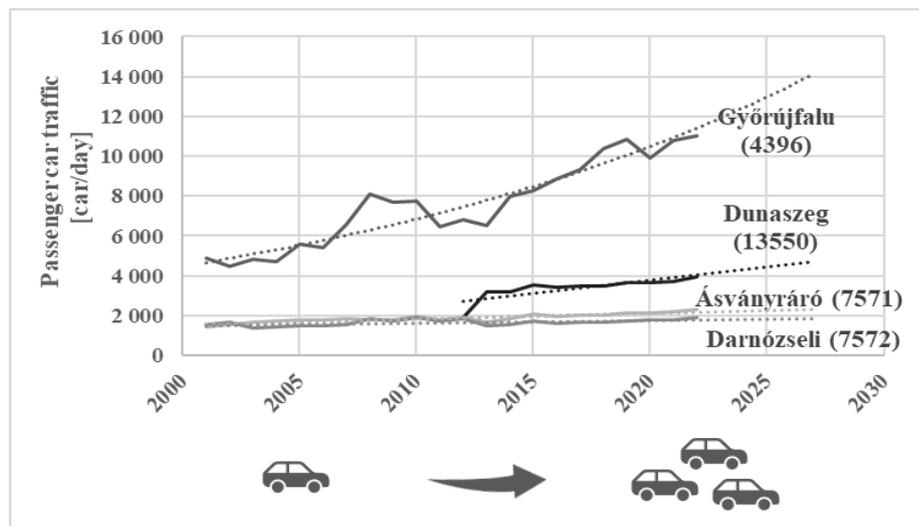


Figure 6. *Passenger car traffic in Road 1401 since 2001*
Source: own editing based on traffic count of Hungarian Public Roads

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In the past, residential areas were typically developed along main roads, resulting in long, sprawling zones. Today, however, residential development projects are taking place further away from roads, on former agricultural land. The development of residential areas requires major infrastructure development on the part of local governments and public utility providers. However, connecting new residential areas to public transport takes a long time, and the routes and frequency of services do not keep pace with the increase in population, so those who move there clearly prefer private transport, typically using cars, despite the well-developed network of cycle paths in this region. Travel time savings are an important factor in the choice of transport mode (Strommer et al., 2021).

Pollutant emissions from road transport are influenced by a number of factors, such as fuel quality, consumption, mileage, vehicle fleet quality, different traffic situations, travel speeds, meteorological characteristics, and thermodynamic properties. A software program called COPERT (Computer Programme to calculate Emissions from Road Transport) was developed on behalf of the European Environment Agency (EEA) to calculate road transport emissions, and has been continuously improved for decades (Ntziachristos et al., 2009). EMISIA SA, in collaboration with several research institutes, determines emission factor values based on laboratory measurements and pollutant emission values measured under real traffic conditions using portable emission measurement systems (PEMS), separating each vehicle category in detail.

When calculating pollutant emissions, the program used emission factors based on a reliable database, taking into account the vehicle fleet in the Győr area. The COPERT 5.8 software used distinguishes between 205 COPERT categories of passenger cars based on fuel type (petrol, diesel, hybrid, electric, CNG, LPG dual fuel), cylinder capacity (mini, small, medium, large), and Euro classification. In order to calculate the data specific to the road section under investigation, the first step was to determine which COPERT categories were relevant for the given years (2001 and 2022).

Although the COPERT program is capable of calculating 28 pollutant emissions, this study only considers 7 air pollutants (methane (CH₄), carbon monoxide (CO), carbon dioxide (CO₂), ammonia (NH₃), non-methane volatile organic compounds (NMVOC), nitrogen oxides (NO_x), and particulate matter (PM₁₀). These were chosen because they are also included in the annual emission inventory reports, aggregated by different emission sectors (Farkas, 2018).

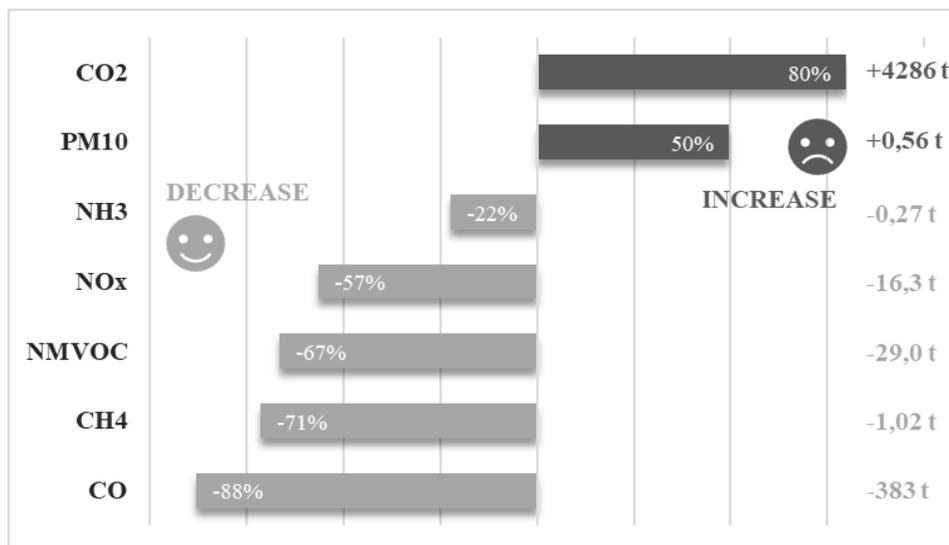


Figure 7. Change in air pollution from passenger cars in Road 1401 between 2001 and 2022
Source: own editing

Figure 7 illustrates the changes between 2001 and 2022: a decrease in air pollutant emissions from passenger car traffic on the left side, and an increasing trend on the right side. For the sake of comparability, the extent of the change is shown in percentage terms; nevertheless, there are

differences in magnitude in absolute terms for each pollutant. Among greenhouse gases, methane, for example, is around half a ton, and later lower, while carbon dioxide is several thousand tons. For comparability, the global warming potential (GWP) value shows the relative warming effect of a unit mass of a greenhouse gas compared to carbon dioxide over a 100-year time scale. If CO₂ 1, then CH₄ 27.9 (IPCC, 2021).

Of the seven pollutants, only two (CO₂ and PM₁₀) showed an increase, while emissions of five pollutants (CH₄, CO, NH₃, NMVOC, NO_x) decreased over the two decades examined. This positive shift is due to stricter environmental regulations (Vestreng et al., 2009) and the modernization of the vehicle fleet. Carbon dioxide emissions have increased significantly due to the growing number of passenger cars on the road, but the rate of increase slows down as one moves away from the city of Győr, as is the case with airborne particulate matter smaller than 10 µm in diameter.

CONCLUSIONS

Passenger car traffic in the Szigetköz region, which is part of the Győr agglomeration, increased significantly between 2001 and 2022, growing two and a half times. The number of passenger cars travelling on connecting road 1401 exceeds an average of 11,000 per day. The growth also exceeds the percentage change in the population of the suburban area in the number of passenger cars providing individual transportation. While the number of passenger cars per thousand inhabitants indicated one car for every four people in the early 2000s, by 2022, there will be almost one car for every two people. According to census data, commuting has also increased two to threefold, and a regional transformation has begun, as more and more people are willing to travel longer distances, even hundreds of kilometres, between their homes and workplaces.

Based on population and vehicle statistics, we can conclude that car ownership and use now depend more on lifestyle than income. The emergence of urban lifestyles in rural agglomeration areas has led to increased traffic, which is mainly carried out by passenger cars. The 2008 economic crisis temporarily moderated the increase in traffic, and the COVID pandemic also influenced transportation habits, but no significant change in direction occurred. The pandemic has impacted urban public transport (Ekés-Surányi, 2020).

Using the example of the island settlement complex, we have attempted to quantify the environmental impacts of transport typical of agglomerations. Our modelling using the COPERT software shows the negative environmental impact of the increase in motor vehicle traffic associated with the spatial spread of residential areas through changes in the emissions of seven selected pollutants. In addition to particulate matter (PM₁₀), which is harmful to health, the amount of greenhouse gas carbon dioxide (CO₂) increased in 2022 compared to 2001, while the other pollutants methane (CH₄), carbon monoxide (CO), ammonia (NH₃), non-volatile organic hydrocarbons (NMVOC) and nitrogen oxides (NO_x) showed a downward trend, thanks to increasingly stringent reduction requirements from year to year.

In rural areas, private road transport is predominant, and the bus transport typical of the Szigetköz region is not as efficient and is by no means a competitive alternative for the population moving out, even though there are bus services tailored to shift work. The location and nature of the newly developed residential areas do not indicate coordinated urban expansion, which will further increase mileage. That will maintain the negative impact (PM₁₀, CO₂) despite the modernisation of the vehicle fleet and stricter regulations (Szabados et al., 2022).

Regional strategies and local development directions must be closely linked; a complex development approach is necessary. Unfortunately, regional strategies have failed to address local development patterns (Cristea & Benedek, 2012). On the contrary, in case of Iași integrated urban and peri-urban strategy included the good development-related factors (Popescu, 2011).

Continuing with this topic, we consider the following directions worthy of further investigation:

- If people's habits do not seem to be changing (i.e., moving to agglomerations and commuting long distances individually to the city), what could be the air pollution benefits of electric vehicle penetration under different scenarios?

- To what extent do the calculated environmental pollution values (increases) affect the total road traffic air pollution values in Hungary?

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