Analysis of CO$_2$ emissions in municipality Most pri Bratislave

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Abstract. The most discussed topics in the 21st century at the global level are climate change, carbon neutrality, digitization and globalization. They have impact on the lives of all people, the quality of the environment in which we live, the health of the whole population, the development of cities and urban areas, the development and direction of industry and its new technologies, and last but not least, they shape humanity to which they are giving direction. To meet our 2030 goals, we need to know where we are now from carbon footprint point of view and where CO$_2$ production comes from around us.

1. Introduction
In the last two decades, we have experienced the 18 warmest years since the beginning of measurements, and extremes of weather such as forest fires, heat and floods are increasingly occurring in Europe and around the world [1]. Europe's forests are ageing and more and more trees are unable to absorb carbon dioxide emissions [2]. All these indicators represent a global challenge, to which we must also respond globally, but in response we can also work individually. In December 2019, EU leaders endorsed the objective of achieving a climate-neutral EU by 2050 [3]. Slovakia must also adapt and honour its commitment to implementing the agreement and setting out a long-term strategy in a socially just and cost-effective way. This background document is a commitment for all of us, and for me personally it is key to further explicitly defining indicators by sector, and by volume of CO$_2$ production. In terms of the urban zone, seven sectoral producers and their subsectors predominate (Figure 1), with which we work further.

Figure 1. Sectoral breakdown of CO$_2$ producers taken into account.

2. Study area and data.

2.1. Study area
The benchmark village is called Most pri Bratislave, located in Western Slovakia, only 3 kilometers from Bratislava. The village with an area of 19.01 km$^2$, is located in the Danubian Lowlands in the north-west part of the Žitný ostrov on the river Little Danube and consists of two catastral areas: Most
pri Bratislave and Studené. The village Most is currently experiencing a large construction progress and thanks to the relatively short distance and excellent accessibility to the Capital City, the small provincial village is becoming a satellite town with a current population of 3,716.

The economic structure of the inhabitants of the village and low unemployment rate result in a significant migration of inhabitants to the nearby Capital City, respectively neighbouring towns Senec, Šamorín and Dunajská Streda. Also, the strategic position of the mentioned village on the secondary road number 572, provides conditions for the migration of the population for employment purposes and so the daily frequency of cars is at the level of 6 to 7 thousand cars per day, which is why the transport sector was evaluated as one of the main producers of CO$_2$.

2.2. Input data

An important key aspect for the processing and correct calculation of the volume of CO$_2$ production for the benchmark village is to obtain data from publicly available sources, or from the municipality itself, based on which we can take into account several aspects in the recalculation itself. The most important input data to be taken into account is the combination of geographical, demographic and geo-spatial dataset of information. By combining and taking into account these three factors, and by their subsequent analysis, we can move to and reach the most accurate measurable result of production (Figure 2).

3. Methods and methodology

3.1. Geometric research

Geometric research of spatial urban structure must always take into account geographical and geospatial predispositions, demographic methods of data collection such as UPI (UPI – ground plan) statistics of socio-economic indicators, community development strategy, transport accessibility etc. From the geographical point of view, especially the natural landscape predisposition, morphology, climate, geological, climatic information, and other data provided by the municipality or self-government. In the absence of specific information for further analysis, we have requested these data from other sources or they have been added by us.

Geospatial-mathematical mapping is a method that is based on the quantification of objects using vectors expressed in a coordinate system (x-, y-, and z-axes). Often, the use of simplified geospatial information will help to better classify data information and its subsequent use in the accurate conversion of unit values. This process is the most important for the calculation and integration of the solution as it provides us with absolutely accurate data, which serves as a relevant basis for further processing. Digitization of geospatial information in real scale into digital can also be understood as a “digital twin” – a carrier of data and a large amount of information, which means that it is essentially a virtual model of the real factual situation. Currently, the term Digital Twin means a virtual representation of physical and non-physical objects and entities [4], such as buildings, networks, manufacturing and transportation facilities, but also processes, systems, workers, data, or the entire environment.
3.2. Level of detail (LOD)
Level of detail is the geometric relationship of the x, y, z coordinate system and its complexity of representation in the form of a 3D model polygon mesh. In general, there is a positive correlation, i.e., the lower level of detail of the displayed 3D object is, the faster the display in the software interface is (Figure 3).

**LOD 1**
Level of detail 1 which is characterized by a lower quality display of a 3D object formed by a small polygon network, without text and materials with basic “x, y, z” information.

**LOD 2**
Level of detail 2 is a representation of the model in a significantly higher quality, where the tectonics of the facade, division and building openings are visible. LOD 2 is a model formed by a medium polygonal network, the type of material used, a higher accuracy of “x, y, z” information.

**LOD 3**
It consists of a real depiction of the facade, building openings, technological equipment, building carpentry and all items that correspond to it in real scale so, as from the position of an observer we can perceive the detail of the facade and the architecture itself. Each object carries a texture in real UVW scale, which is standardized by the surface mapping technique using a raster matrix. Level 3 provides high accuracy that is characteristic of the category of BIM models. The model contains GPS coordinates of our territory in the coordinate system S-JTSK (Figure 4).

![LOD 1](image1)
![LOD 2](image2)
![LOD 3](image3)

**Figure 3.** Level of detail

![Digital model Most pri Bratislave](image4)
![Digital model LC (Land cover map) LOD1](image5)

**Figure 4.** 3D digital model of village.

**Transport** as a separate chapter have been analysed by entering the village via secondary road and with one output, we have been able to identify, using the differential protocol, the number of cars leaving the village and the number of cars passing through the village.

We carry out the analysis of **Green areas** on the basis of their diversification into four categories of wood species and their average value of annual wood growth for one vegetation period. Based on measuring the diameter of the trunk at a height of 1.30 meters above ground level and measuring the growth pattern of the crown part, as well as the total height of the tree, we have been able to recalculate the coefficient Y. We work with this coefficient further as with the absolute weight of the tree during the growing season. When multiplying this value by a constant of 120%, which means a multiple of its
weight +20% of the root system, - (minus) the point of fiber saturation, which means the moisture content in the wood mass -72.5%, - 50% wood dry matter we get the CO$_2$ value contained in wood. By simply recalculating the offset of the area in square meters and the total area that the greenery occupies in terms of the map of the land cover, we have been able to identify the quantity of trees for each category and the number of pieces (Figure 5).

\[
\text{year} / \text{increment}^* \times \Omega^2 \times \text{height} \times 120\% \times 72.5\% \times 50\% = \text{CO}_2 \times 3.67 \ \text{CO}_2 \ \text{in the atmosphere}
\]

* average annual increment per growing season

![Coniferous tree / average](image1)

![Volunteer trees / average](image2)

**Figure 5.** 3D tree model.

Modern technologies form a very important part of smart cities, and should contribute to more efficient transport management, greener energy, and well-thought-out waste management, which will increase the sustainability of the local economy. When recalculating the volume of CO$_2$ production, we have taken into account the demographic factor – the number of the population and multiplied it by the unit value of waste production. According to the Statistical Office of the Slovak Republic, in 2019 the average Slovak produced 435 kg of municipal waste (MW), which was 35% more than ten years ago [5]. The inventory of emissions from the waste sector includes direct greenhouse gas emissions (CH$_4$, CO$_2$, N$_2$O) and indirect emissions (NMVOC), an equally important study in terms of the percentage of CO$_2$ is [6] a waste management method that also has a significant impact on the carbon footprint.

### 4. Results

In our work, we have tried to draw attention to the environmental issues that move the world, which to a greater or lesser extent also affect our country, as well as the region that we have focused on in this work. The aim was to calculate and record the most accurate emissions data, especially carbon dioxide in the village of Most pri Bratislave, produced by households as such, transport, other contributors to the production in question, which will subsequently help prepare and implement strategies to reduce greenhouse gases in our territory.

Applying the research methodology, where we have used, among other things, the analysis and synthesis of specialised information, we have been able to recalculate specific results of CO$_2$ production per person, car, aircraft or production hall of the food industry, based on the formula:

\[
33,200,313 \ \text{kgCO}_2 \times 1,419,763 \ \text{kgCO}_2 \times 1,078,383 \ \text{kgCO}_2 - 895,451 \ \text{kgCO}_2 = 34,802,265.00 \ \text{kgCO}_2
\]

* Transport × Waste - Greenery = CO$_2$ of the municipality of Most pri Bratislave

*LC – Land cover map
Average Slovak 5.888 tCO²
Average inhabitant of Most pri Bratislave 9.364 tCO²

Figure 6. CO₂ production.

while we included in the input data various aspects and factors that contribute to the increased result of the emissions concerned in any way whatsoever. In this scientific study, the result of the annual emission production from the cadastral area of Most pri Bratislave, taking into account all aspects and factors, was 34 802 265.00 kgCO². In the process of processing the described aspects and factors, I tried to reach the result of this scientific study by pointing to the main producers of CO₂, but also to highlight the need to address emissions not only from transport as one of the main producers, but also from agriculture, waste management or as already mentioned households as such.

As part of CO₂ reduction, cities and municipalities should focus primarily on reducing emissions from the production of various components in industry and, secondly, on electricity generation, as the energy industry is one of the largest producers of greenhouse gases. The general fact is that countries today have an ecological deficit, which means that their management is environmentally unsustainable from a long-term perspective. In this work, we pointed out several indicators of environmental sustainability, which provide information on how humanity, states, cities, municipalities, households and individuals live on the verge of said sustainability. Despite our findings and efforts to reduce the impact on global warming, this process is irreversible, and we will not feel the effects of its slowdown until many years later. Nevertheless, we believe that the data from our work will help in the preparation of low-carbon to carbon-free strategies for municipalities and cities, which will then act for the benefit of nature for future generations.

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