Smart Transportation CO₂ Emission Reduction Strategies

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Abstract. Transport represents the sector with the fastest growing greenhouse gas emissions around the world. The main global objective is to reduce energy usage and associated greenhouse gas emissions from the transportation sector. For this study it was analyzed the road transportation system from Brasov Metropolitan area. The study was made for the transportation route that connects Ghimbav city to the main surrounding objectives. In this study ware considered four optimization measures: vehicle fleet renewal; building the detourn belt for the city; road increasing the average travel speed; making bicycle lanes; and implementing an urban public transport system for Ghimbav. For each measure it was used a mathematical model to calculate the energy consumption and carbon emissions from the road transportation sector. After all four measures was analyzed is calculated the general energy consumption and CO₂ reduction if this are applied from year 2017 to 2020.

1. Introduction
The cities from Europe are centres of many activities: economic, social and innovation. Many of them face many challenges to their mobility systems: traffic jams, poor air quality, noise pollution, greenhouse gases emissions and road accidents. All of these have significant negative impacts over the environment, human health and economic performance of cities. These problems will increase in intensity in the future, because, the cities continue to grow [1].

Urban transport systems are important elements of the European transport system and are a concern for the European Common Transport Policy. The 2011 Transport White Paper sets very ambitious targets to address these challenges, especially for Central European Countries. In this case, there is a wide range of instruments available to implement the policy efforts: efficient land usage, urban planning, pricing policy, infrastructure for non-motorised vehicles, charging/refuelling of clean vehicles to reduce emissions, 100% green transportation systems and infrastructure upgrades. These instruments should be part of a meaningful strategy in order to develop cost-effective interventions. The target is the year 2030, in order to meet the Transport White Paper objectives for urban transportation [1].

The development of the roadmaps helps to recognise that different types of policy measures are appropriate for different types of cities. The analysis of scenarios and roadmaps help to assess the impact of the European urban mobility policies in the long term [1].

In Romania transport policy aims to align the national transport system continues to Community Transport Policy principles defined in the Transport White Paper (with corresponding updates) and the requirements of sustainable development of Romania [2].

For this study it was analyzed the road transportation system from Brasov Metropolitan area. The study was made for the transportation route that connects Ghimbav city to the main surrounding objectives. This region faces many mobility problems, because is situated in the centre of Romania, at the junction of several main transportation routes. This mobility problems affect Brasov city and all
communities from the metropolitan zone. The city of Ghimbav is an important industrial, economic and residential city, despite its size (5200 inhabitants).

2. The analyzed area
For this study it was analyzed the transportation modes from Brasov Metropolitan Area, especially in the surroundings of Ghimbav city. The city of Ghimbav is located in the west of Brasov County, with the following geographic coordinates: 45 degrees 39 minutes wide. N; 25 degrees 36 minutes long. E. The road connections with these areas are insured by the national road network (DN1 and DN73B) and county road (DJ 103C).

This area is an important industrial zone, but also an expanding residential zone. In the future in this area will be developed some important objectives, such as: International Airport Ghimbav-Brasov, Brasov-Comarnic highway, an agreement zone and more residential districts. The connections between the Ghimbav city centre and all this objectives will be made by road transportation (passengers and freights). In the figure 1 is presented the Ghimbav zone and its connections with actual and future objectives.

Figure 1. Analyzed area - Ghimbav city and its connections with actual and future objectives (Google Maps)

3. Energy consumption and CO$_2$ mitigation model for

3.1. Mathematical model for Ghimbav transportation system
For the city of Ghimbav it was made a prediction model in order to estimate the energy consumption diminish and the CO$_2$ amount resulted from road transportation. Three optimization measures were considered: vehicle fleet renewal; making bicycle lanes; and green public transportation system implementation.

There were calculated the proportions of decrease for the following:

- Final energy consumption [MWh].
- Total CO$_2$ Emissions / CO$_2$ equivalent [6].

The study was start from initial data: Ghimbav vehicle fleet composition during 2008 - 2012; values expressed in tones of CO$_2$ produced in the 2008 -2012 period.

The prediction model uses traffic volumes data from 2010 - 2015 period in order to predict the traffic flows for the 2016 - 2020 period. Using existing data on vehicle fleet, the total energy consumption and CO$_2$ emissions for Ghimbav we can calculate the total energy and CO$_2$ emissions for 2016 - 2020
period. Following the mathematical modelling results the dependence of total energy consumption and amount of emitted CO2 over the vehicle fleet evolution [6].

Without applying any measures, the energy consumption will increase in the following years. Equation (1) described by polynomial second degree regression curve, represents Energy consumption evolution up to 2020, for transportation sector (also in Figure 2):

\[ X_{\text{Energy}} = 25,432 \cdot V_E^2 - 10217 \cdot V_E + 10^8 \]  

(1)

Where: \( X_{\text{Energy}} \) is the approximate amount of the total energy consumed, and \( V_E \) is the number of etalon vehicles. For this function, the standard deviation \((R^2)\) is 0.9963.

**Figure 2.** Energy consumption prevision for 2020 without any transportation applied measures

The CO2 emission values will increase directly proportional with energy consumption. In order to decrease energy consumption and CO2 emission values it is necessary to implement the measures mentioned above [8].

The standard emissions factors applied in this study are:
- 0.249 [tones CO2 / MWh] - for spark ignition engines;
- 0.267 [tones CO2 / MWh] - for compression ignition engines;
- 0.000 [tones CO2 / MWh] - for biofuels [6].

For the transportation sector, data for each fuel and vehicle were calculated using the formula:

\[ X_{\text{UsedFuel}} = D \cdot C_{\text{average}} \cdot Y \]  

(2)

Where: \( X_{\text{UsedFuel}} \) - Energy consumption for road transportation [kWh]; \( D \) - route distance [km]; \( C_{\text{average}} \) - average fuel consumption [liters/km]; \( Y \) - conversion factor for each fuel [kWh/liters]. \( Y = 9.2 \) for gasoline and \( Y = 10 \) for Diesel [8].

3.2. Vehicle fleet renewal

This measure can only be applied to the municipal and local transport fleet. Using the data on the number of municipal vehicles fleet of Ghimbav city and from related fuel consumptions, result the following [6].

Fleet renewal for municipal fleet will lead to a consumption decrease for: from 10 liters/100 km to 8 liters/100 km for light vehicles and from 30 liters/ 00 km to 25 liters/100 km for heavy vehicles. After applying these measures will have a reduction: 448.97 [MWh] and 117,84 [tones CO2].
3.3. Bicycle lanes implementation

Cycling has a major role for mobility quality in metropolitan areas. By using non-motored vehicles, congestions will be lighter and local air pollution and emissions of greenhouse gases will decrease. About 20% of car trips are less than 3 kilometres, a distance that can be easily made by the bike in less than 15 minutes [5]. The study is based on approximate traffic volumes decrease by creating bicycle lanes in Ghimbav city and on the main roads that connects Ghimbav with the stranding cities (Brasov, Codlea and Cristian).

![Bicycle lanes implantation strategy](image)

**Figure 3.** Bicycle lanes implantation strategy: bicycle lane example (left); bicycle lanes strategy in Ghimbav city for 2020

According to the analyzed data in this study for bicycle lanes, resulted a decrease of 8% road traffic volumes after the construction of a bicycle lane in Ghimbav. After applying this percentage reduction for total vehicle we have a reduction of: 1015.28 [MWh] and 260,82 [tones CO2] [6].

3.4. Implementing a green urban public transport system for Ghimbav

Public transportation systems, including electric buses, contributes to cleaner air and quality of life in cities and reduces green house gas emissions, as it uses up fewer resources and emits less CO₂ than other transportation modes. Compared to private motorised mobility, public transportation makes the most efficient and equitable use of scarce resources, such as fuel and public space. By occupying less space and generating fewer emissions per passenger, public transport enhances the quality of life in cities. The full potential can be exploited in the right conditions, when buses operate on reserved priority lanes and with prioritization measures [3].

Also, implementing a public transportation with electric buses will lead to a noise level diminish in city area. Road traffic noise may depend by several parameters: the traffic volume, the traffic flow typology, the vehicles typology, the road and pavement features, the speed. The influence of the speed on the noise is determined by two main factors: the interaction between tires and road and the power train noise, influenced by the engine speed. The power train noise will be significant decrease if electric buses are used [7].

For Ghimbav city was proposed two public buses routes. First route will cover the Ghimbav city centre, connections to schools, City Hall, commercial objectives and residential areas. The second route will cover residential areas, City Hall, industrial areas, Ghimbav Industrial Park, Aerotec an Airbus (in the perimeter of future International Airport) and commercial objectives.

For this paper it will be presented Route 1. The public transportation system parameters are presented in the following paragraphs:

- The total length of the route: 5,50 km.
- Total journey time: 30 minutes.
- Number of bus stations (stops) on the route: 11.
- The average bus stop time in stations: 1.2 minutes.
- Number of intersections (without priority) on the route: 7.
- The average stop time at intersections is 30 seconds.
- Buses speed limit on the route: 50 km/h.
- Cruising speed (average) of the route: 25 km/h.
- Peaks of passenger demand: Monday - Friday (working days): between 6:00 h – 10:00 h and 14:00 h – 18:00 h; Saturday: between 18:00 h – 22:00 h; Sunday: between 18:00 h – 22:00 h.
- Necessary buses: 3 pieces.

Figure 4. Electric public transportation system for Ghimbav - Route 1 presentation

Figure 5. Electric bus Route 1 length (Google Maps)

The arrival frequency of bus stops in weekly hours is shown in the Table 1.
Table 1. Frequency buses arrival in station (hourly intervals)

| Weekdays       | Hour interval                                      | Time frame between consecutive arrivals |
|----------------|----------------------------------------------------|-----------------------------------------|
| Monday - Friday| 22:00 h – 6:00 h                                   | 60 minutes                              |
|                | 10:00 h – 14:00 h și 18:00 h – 22:00 h             | 20 minutes                              |
|                | 6:00 h – 10:00 h și 14:00 h – 18:00 h              | 10 minutes                              |
| Saturday       | 22:00 h – 6:00 h                                   | 60 minutes                              |
|                | 6:00 h - 22:00 h                                   | 20 minutes                              |
| Sunday         | 22:00 h – 6:00 h                                   | 60 minutes                              |
|                | 6:00 h - 22:00 h                                   | 20 minutes                              |

The transportation system will have an integrated management system in order to control very efficient the network. It can be used as an example the public transportation management system from Brasov. Necessary infrastructure for electric buses will be needed. Also, two terminal stations and 15 bus stations will be made.

Figure 6. The public transportation management system from RAT Brasov

The implementation of an urban public transport system serving the Ghimbav population will reduce the number of daily journeys made with personal cars in the following years as follows:

Table 2. The decrease percentage of local road traffic

| Year | 2016 | 2017 | 2018 | 2019 | 2020 |
|------|------|------|------|------|------|
| The decrease percentage of local road traffic after public transportation implementation: | 5 %  | 15 % | 30 % | 40 % | 50 % |

After applying this measure, we will have a reduction of: 1785.35 [MWh] and 458.64 [tones CO2].

3.5. Estimated impact of analyzed measures in the future

In order to estimate the impact of implementing the proposed long-term measures, a calculation resource used in the European Union was used. This resource is Urban Transport Roadmaps framework (it is one of the tools used by the metropolitan development agencies). Using this framework, we can estimate the benefits of implementing the three measures for reducing energy consumption for Ghimbav, up to year 2030 (Figure 7, 8, 9 and 10) [4].
In Figure 7 is presented the evolution of carbon dioxide emissions after the implementation of the measures (reference year - 2017). On the left is anticipated the quantitative reduction of CO$_2$ from 2015 to 2030, after the implementation of the measures in 2017. On the right is the evolution of the CO$_2$ level produced by the studied region from 2015 to 2030, after applying the measures in 2017 (cumulated CO$_2$ level).

![Figure 7. CO$_2$ emissions reduction after smart measures implementation [4]](image1)

In Figure 8 is presented the evolution of carbon monoxide pollution level after the implementation of the measures. On the left is anticipated the quantitative reduction of CO from 2015 to 2030, and on the right is the evolution of the CO level produced by the studied region, after applying the measures in 2017 (cumulated CO level).

![Figure 8. CO emissions reduction after smart measures implementation [4]](image2)

In Figure 9 is presented the evolution of particulate matter (PM) pollution level after the implementation of the measures. On the left is anticipated the quantitative reduction of PM from 2015 to 2030, and on the right is the evolution of the PM level produced by the studied region, after applying the measures in 2017 (cumulated PM level).

![Figure 9. PM emissions reduction after smart measures implementation [4]](image3)
The economy output after vehicle fleet renewal, making bicycle lanes and green public transportation system implementation is expressed in the Figure 10.

4. Conclusions
For this study were analyzed three measures that can be adopted in order reduce energy consumption and CO₂ emissions: vehicle fleet renewal; making bicycle lanes; and green public transportation system implementation. The most effective measure, implementing a green urban public transport system for Ghimbav, will result in a decrease in energy consumption and CO₂ emissions by 19.71%. Making bicycle lanes will lead to lower energy consumption and CO₂ emissions by 11.21%. Vehicle fleet renewal strategy will lead to lower energy consumption and CO₂ emissions by 5%.

Using Urban Transport Roadmaps framework, we can estimate the benefits of implementing the three measures for reducing energy consumption for Ghimbav, up to year 2030. It can by noticed a substantial reduction of the CO₂, CO and PM emissions after implementation of the smart measures at
Ghimbav City. Also, the pollution level of the analyzed area will increase less after the implementation of these measures.

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