Opportunities for Sustainable Mobility Promotion among Students of the University of Maribor, Faculty of Organizational Sciences

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Abstract The aim of sustainable mobility is to choose means of transport that have the least possible impact on the environment. Since all motor vehicles cause a direct or indirect form of pollution, walking and cycling are an ideal form of mobility from an environmental point of view. If the use of vehicles is taken into account, public transport generates much less pollution per passenger than the car. In addition to logistical problems such as congestion and lack of parking space, the massive use of cars is a major contributory factor to a sharp deterioration in air quality in urban areas and causes emissions of greenhouse gasses. In addition to promoting sustainable forms of mobility, rational route planning is also important. It is, therefore, reasonable to prepare the timetable of activities, stressing the importance of limiting unnecessary routes. In this paper, we will see how sustainable mobility can be addressed in a higher academic environment. Several proposals are presented to optimize mobility by rationalizing the organization of students' obligations within the faculty.

1 Introduction

Environmental concerns are one of the reasons for the increasing emphasis on sustainable mobility. Car transport is one of the most important pollutants and greenhouse gas emissions in the atmosphere. Due to the increased car traffic, we witness poor air quality in urban areas and the emergence of the greenhouse effect. On the one hand, the way to reduce such a burden is to introduce increasingly stringent emission standards and to introduce alternative drive modes such as electric cars. On the other hand, the concern for sustainable mobility is an important step, which includes efforts to use cars less frequently and instead use public transport, cycling or walking for shorter routes. In addition, modern communication technology offers many opportunities to optimize the need for mobility, since to a certain extent it allows the realization of work or study obligations from home, therefore reducing the number of routes. In addition, it is possible to contribute to the rationalization of mobility by appropriate timing of activities that require the physical presence of the participant.

In this paper, we aim to investigate the possibility to impact on sustainable mobility using an optimized schedule at the faculty. The University of Maribor, Faculty of Organizational Sciences (UM FOV) from Slovenia was considered in this case study. At UM FOV, study activities are divided into auditorial, where students have to be present at the faculty, and e-study when students can work from home. Using an optimized timetable, with the aim to minimize the necessary travel routes, emissions caused by students can be reduced significantly.

2 Car traffic influence on air pollution

To meet daily mobility needs, we often use private passenger cars. Given that the vast majority of cars use an internal combustion engine to drive, this causes significant atmospheric loads. From 2015 there is a significant tendency for the introduction of electric cars, nevertheless, in 2018 there was only around 0.1% of electric cars in Slovenia (SURS, 2019). In 2018 the electric cars represented 0.7% of the Ukrainian market of new cars (Hens et al., 2019). Thus, regardless of the upward trend in electric car sales, the dominant share of electric cars cannot be expected in the next couple of years. In addition, the use of electric cars does not completely eliminate the problem of atmospheric pollution. When dealing with atmospheric

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pollution, it is reasonable to distinguish between pollutant emissions on the one hand and greenhouse gas emissions on the other.

2.1 Pollutants

Pollutants are substances that are present in the air and are toxic or otherwise harmful to human health or other living organisms. The most important pollutants in the atmosphere include hydrocarbons, carbon monoxide, nitrogen oxides, sulfur dioxide, particulate matter, and tropospheric (or terrestrial) ozone. With the exception of sulfur dioxide, road transport is an important source of emissions for all pollutants. Among these pollutants, tropospheric ozone (in the summer) and particulate matter (in the cold season) have been a major problem for many years. It is worth noting that modern cars are equipped with efficient catalytic systems that can greatly reduce emissions of harmful substances. However, in cities a large part of the traveled route is represented by short trips where the exhaust system is not yet fully heated and thus the catalyst is not functioning optimally and therefore the pollutant emissions are much higher than at the full catalyst efficiency (Mondt, 2000).

Ozone (O_3) is naturally rare in the ground air layer. However, ground-level ozone concentrations increase significantly in a congested atmosphere. Ozone is especially harmful to the respiratory system and often causes complications especially in people with asthma problems, so its presence in the ground air layer is not desirable. Ozone is not a constituent of exhaust gases but is produced as one of the reaction products between hydrocarbons and nitrogen oxides present in car exhaust gases. Such reactions take place under the influence of sunlight and therefore elevated ozone concentrations are measured primarily in clear and hot weather. Hydrocarbons and nitrogen oxides are also harmful to health, but normally the limit of their concentrations in air quality control is not exceeded, while ozone limits are often exceeded in Slovenia in summer (ARSO, 2018; ARSO, 2019).

Another problematic type of pollutant is particulate matter, often referred to as PM. There are two categories: PM 10 (particulate matter less than 10 µm or 0.01 mm in diameter) and PM 2.5 (particulate matter less than 2.5 µm or 0.0025 mm in diameter). Particulates may vary depending on the origin and chemical composition, but in a stressed atmosphere, carbon particulate matter, caused by incomplete combustion,

is a problem. For a long time, diesel engines have been considered a problematic source of particulate matter. Many cities in Europe have thus restricted or prohibited the entry of older cars with diesel engines not equipped with a particulate filter. Intermediate-fueled gasoline engines produced inappropriately smaller, practically negligible emissions of these particles. However, a problem has arisen with modern, energy-efficient direct injection (DI) gasoline engines. These engines have lower fuel consumption, which is also welcome from an environmental point of view, emit similar or even greater quantities of particulate matter than diesel engines. Therefore, the control of PM particulate matter is also required in such engines (Dieselnet, 2019).

In Slovenia, particulate matter limits are often exceeded, especially in the cold part of the year, when combustion plants join other sources of emissions (ARSO, 2018; ARSO, 2019). The results of the PM2.5/PM10 measurements in Kyiv, Kharkiv and Lviv cities showed that PM values during the cold period of a year are often higher than maximum permissible level according to EEA standards (Shelestov et al., 2019).

According to Curry Brown (2013), PM 2.5 solids are the cause of over 3 million premature deaths each year. Adverse effects, in addition to the respiratory tract damage and the potential for causing cancer, also affect the nervous system and, above all, the cardiovascular system (Curry Brown, 2013; Suglia, 2007). According to some findings, elevated PM 2.5 concentrations present an even greater risk of cardiovascular disease mortality than lung disease mortality (Brook, 2010; Pope, 2004). Research results show the adverse effects of both long-term and short-term exposure to elevated particulate matter concentrations. Thus, the results of a large-scale US survey of 8,000 participants in 6 US cities over a 14- to 16-year period indicate that the cardiovascular mortality rate was 1.26: 1 in the city with the highest and least congested air. (Dockery et al., 1993; Brook et al., 2004). Also, Pope et al. (2004) find a link between prolonged exposure to high particulate matter concentration and mortality from cardiovascular disease. In addition, studies conducted in Europe and North America confirm the link between short-term exposure to increased particulate matter concentration and the incidence of cardiovascular complications. In days when the concentration of particulate matter is increased in the air, mortality from cardiovascular diseases increases (Katsouyani et al. 2001; Zanobetti et al. 2003; Brook et al. 2004; Dominici et al. 2005). On days

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with PM 2.5 particulate matter elevation, there was also a significant increase in defibrillator usage (Peters et al., 2000).

2.2 Greenhouse gases

Greenhouse gases (GHG) include all gases whose presence in the air enhances the ability of the atmosphere to retain heat. Carbon dioxide is the major contributor to the anthropogenic greenhouse phenomenon. Carbon dioxide, however, does not pose a risk to human health in the atmosphere, so it is not considered a pollutant. Carbon dioxide is the end product of the combustion of any carbon-containing fuel. Unlike pollutants, carbon dioxide emissions from engines cannot be reduced by any catalytic converters or filters, but only by lower fuel consumption or alternative sources of propulsion. However, even in electric vehicles, significant carbon dioxide emissions can be generated indirectly, as long as electricity to charge the batteries is generated from thermal power plants.

In Slovenia, transport represents the largest source of GHG emissions (in accordance with Decision 406/2009/EC (European Commision, 2009). The share of emissions from transport was 50.9% in 2017, with the majority of emissions from road transport. Transport is also the only sector in Slovenia where GHG emissions increased by 1.125 kT of carbon dioxide equivalent in the period 2005-2017, while emissions from other sectors decreased by 2.009 kT of carbon dioxide equivalent in that period. Thus, the transport sector contributed only 38% of GHG emissions (Đorić et al., 2019). In Ukraine, GHG emissions from fossil fuel combustion in 2017 amounted to 223.2 million tonnes of carbon dioxide equivalent (Yang, Cela and Yang, 2019).

3   Methodology

We aim to assess the extent to which the optimization of the faculty timetable could reduce the environmental burdens caused by the students by driving to the faculty with cars. For the first insight, we focused on the first year of academic higher education study at the Faculty of Organizational Sciences of the University of Maribor (UM FOV). The calculation is based on the visits to the faculty for the fulfillment of study obligations in lectures and exercises, which are scheduled each semester. Three study programs were included in this research: Organization and Management of Information Systems (OM IS), Organization and Management of Human Resources and Educational Systems (OM KIS) and Enterprise Engineering (IPS). A block study concept is applied to generate the timetable at the UM FOV. This was students can attend a maximum of 4 study blocks per day, where each study block consists of 3 hours of activity in a certain course. One block of a particular course is scheduled daily, whereas usually two or three blocks can be scheduled in one day.

For the general calculations, several assumptions were necessary. We assumed that all students take their own cars to drive to the Faculty. Due to the known fact, that only the minority of students uses public transport or car-sharing system to get to the Faculty, we assumed this least sustainable form of mobility. Distances of routes were calculated with the help of the Google Maps application. For the students with residence in the same city as the faculty, we assumed that they walk to lectures and exercises, which might not always be true. Nevertheless, the error gained this way can compensate for the error due to several other assumptions. For the students, with residence over 100 km away from the faculty, we assumed that they live in a dormitory or somewhere else near the faculty, therefore they walk to their activities at the faculty.

The study programs were considered separately since they have certain differences in the distribution of study obligations. The length of the route (s) that students take on a particular study program per day is expressed by Equation 1:

$$s = \sum_{i=1}^{m} 2 \cdot n_i s_i$$

(1)

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Where s_i is the distance from a particular place to the faculty, n_i is the number of students living in a certain location, and m the number of locations.

To calculate the carbon footprint, the average emissions for new vehicles in Slovenia in 2015 was 119.2 g CO_2/km (Šulin Košar, 2017). Emissions are expressed in kg/day for each study program (2):

$$C_d = \frac{s \cdot e}{1000}$$

(2)

Where C_d daily emissions of carbon dioxide in kg, s daily route (in km) and e average carbon dioxide emissions (in g/km).

4   Results

The daily distances traveled and the resulting carbon dioxide emissions for each study program are shown in Table 1.

Table 1: Distances and carbon dioxide emissions.

Study programme	Number fo students	Distance [km]	CO₂ emissions [kg]
OM IS	29	712	84.9
OM KIS	25	759	90,4
IPS	14	526	62,7

The emissions can, of course, be reduced by the number of routes completed, which can be achieved by rationalizing the distribution of study obligations. In practice, students in different fields are divided into groups and the timetable is quite complex. Therefore, for model treatment, the system was slightly simplified and took into account the average number of rides that students have to take in the current timetable and the number of required rides if two or three blocks were consistently implemented daily. Table 2 shows the required number of drives for each of the listed study programs.

Table 2: Required number of arrivals to the faculty for study programs.

Study program	OM IS	OM KIS	IPS
Number of arrivals (actual state)	96,75	96,75	96,75
Number of arrivals (2 blocks / day)	72,50	77,00	75,00
Number of arrivals (3 blocks / day)	48,33	51,33	50,00

By optimizing the timetable and reducing the required number of arrivals, carbon dioxide emissions would be reduced, since the emissions are directly proportional to the routes taken or the number of faculty visits (3).

$$C_y = p \cdot C_d$$

(3)

where C_y cumulative emissions caused by students in a particular direction during the academic year, C_d emissions caused by routes in one day, and p number of required arrivals.

Table 3 shows the cumulative carbon dioxide emissions for each study program for three different timetable alternatives (current timetable and timetable with 2 or 3 blocks per day). It also shows the reduction of emissions that would be achieved if two or three blocks per day were introduced.

Table 3: Cumulative annual carbon dioxide emissions [kg] and possible reduction of emissions aligned with timetable optimization.

Study program	OM IS	OM KIS	IPS
Annual CO_2 emissions [kg]			
Current timetable	8214	8749	6068
2 blocks timetable	6154	6963	4704
Reduction	*2059*	*1786*	*1364*
3 blocks timetable	4103	4642	3136
Reduction	*4111*	*4107*	*2932*

Figure 1 shows the average emissions caused by student arrival to the faculty of a particular study program. Whereas Figure 2 shows possible annual reductions of CO_2 emissions per student considering two or three block timetable.
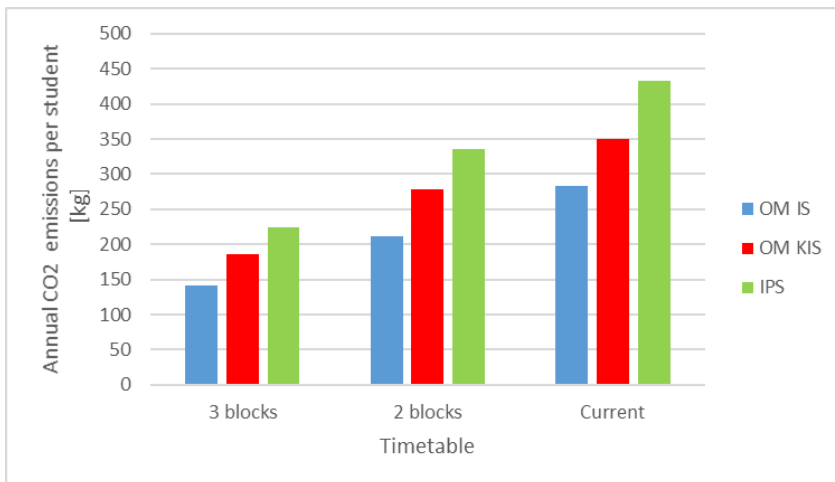
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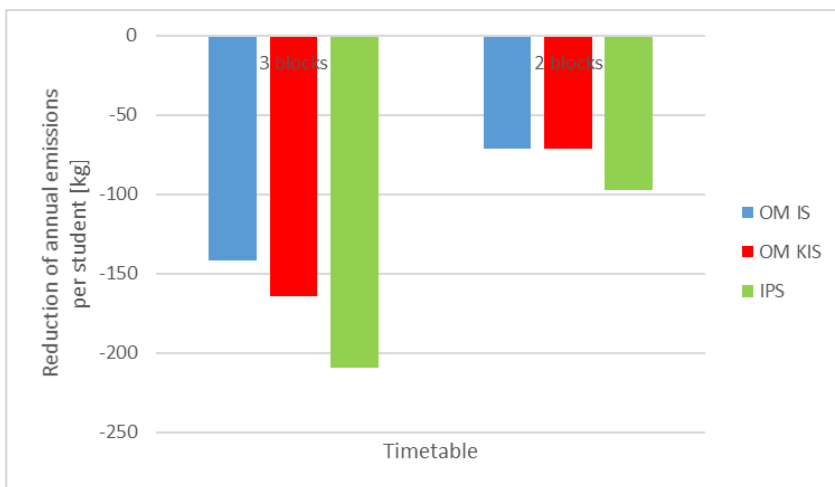**Figure 1: Average annual carbon dioxide emissions [kg].**

Figure 2: Average reduction of annual carbon dioxide emissions [kg].

5   Conclusions

The trend of sustainable mobility promotion in European cities is rising. While several cities promote public transport and bicycles, others promote car-sharing, carpooling or in general, usage of electric cars. The main reason for the promotion of sustainable mobility lies in a significant increase in polluted air in the cities.

Although many cities have improved air quality using alternative resources for heating, transport is still a significant problem.

The trend of sustainable mobility has did not get enough attention among university students. Even though they have been taught about sustainable mobility, the majority of them prefer using their own cars to drive to the faculty. One of the reasons for picking their own means of transport is also their timetable. Since they are divided into groups when attending exercises, they have issues consolidating their activities with their peers. In addition, The presented paper aims to identify the opportunities for the promotion of sustainable mobility with the optimization of faculty timetable.

We have shown, that there are possibilities to optimize the faculty's timetable and reduce the emissions of CO_2 produced by students. Therefore, we can achieve to not only lecturing about sustainable mobility but also practicing it. In this case, the only first year of academic higher education students was considered. Several assumptions about their travel habits have been made. In future research, we plan to include all the students at UM FOV with detailed information about their traveling habits and routes. In addition, an opportunity to compare the traveling habits of Slovene and Ukrainian students has been identified.

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