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IMPROVING CITY TRANSPORT WITH THE OBJECTIVE TO REDUCE CO_2 EMISSIONS

Summary. In the past few years traffic volume is increasing. As a consequence, negative external traffic effects are increasing too, in particular CO_2 emissions, which result in global warming and climate changes. CO_2 emissions, a by-product of vehicles are much higher in cities due to traffic density. According to European standards, Celje is not a large city; however its traffic poses a great problem that the city authorities will soon be confronted with. This paper focuses on the city centre of Celje, where traffic flow was measured and CO_2 emissions calculated. Using alternative solutions the aim was to present impacts on the environment in the municipality of Celje in an event of changed traffic regimes. In order to reach the guidelines of sustainable transport development in the municipality of Celje, in the future, different measures for reducing negative external effects of city transport will have to be put into force, for only this way the quality of city life can be improved and compatibility of environmental, economic and social objectives provided.

УСОВЕРШЕНСТВОВАНИЕ ГОРОДСКОГО ТРАНСПОРТА С ЦЕЛЬЮ СНИЖЕНИЯ ВЫБРОСОВ CO_2

Аннотация. В последние несколько лет объем перевозок увеличивается. Следствие этого является возрастание негативных внешних эффектов обусловленных трафиком, и в частности, выбросы CO_2, которые приводят к глобальному потеплению и изменению климата. Выбросы CO2, как побочный продукт использования транспортных средств гораздо выше в городах вследствие интенсивности движения. В соответствии с европейскими стандартами, Целье не является большим городом, однако его транспорт создает большую проблему, с чем городские власти в скором времени будут сталкиваться. Данная статья посвящена городскому центру Целье, где транспортные потоки были измерены и рассчитаны выбросы CO_2. Целью работы было использование альтернативных решений с тем, чтобы представить воздействие на окружающую среду в городе Целье в случае изменения режимов движения. С тем чтобы обеспечить устойчивое развитие транспорта в городе Целье в будущем, различные меры по снижению негативных внешних эффектов городского транспорта должны быть введены в действие, ибо только таким образом качество городской жизни может быть улучшено и обеспечена совместимость экологических, экономических и социальных целей.

1. INTRODUCTION

Due to contemporary way of life and the ubiquitous economic growth the environment is more and more polluted. We are confronted with negative, hardly manageable or even not manageable climate changes caused by mankind through contemporary way of life. According to British economist Stern [12] global climate changes call for an immediate global action, international cooperation of all countries. According to Wilson from Harvard University approximately 27.000 species are extinct every year (three species per hour), therefore, an immediate global action is necessary [11].

To this end, first and foremost, the often unnecessary habits that prevail need to be changed. Dr. Lučka Kajfež Bogataj [6] said that the world has three options: (1) first being the mitigation of climate changes, which means taking measures to reduce their speed and scope; (2) adjusting to them, which means measure for reducing negative impacts of climate changes on welfare; (3) suffering: dealing with negative effects which we will not be able to fight against, nor mitigate nor adjust to them.

According to the European environment agency the transport sector is the fastest growing user of energy and hence the fastest growing producer of greenhouse gases in all EU states. Current EU transport policy is not as efficient as to prevent further growth of energy use in transport although specific greenhouse gas emissions produced by new personal vehicles are already in the scope of required limits [5].

Today, city authorities in Slovenia and abroad are confronted with problems of city transportation in order to introduce the concept of green cities. These problems include too many cars in city centers, pollution, smog, accidents etc. It is therefore necessary to monitor air pollution and peoples' exposure to pollution. This falls under Air Quality Management, which has already been introduced in some places, however, should be an indispensible part of environmental management of city authorities [7].

In order to reduce the damage, inflicted on city environments, transport change and change in people and companies is needed, or they are to be forced to choose other transport means. City authorities can influence the implementation of transport in three ways [8, 10]:

- regulations and taxes,
- co-funded infrastructure development and environmentally-friendly vehicles and
- change of transport regime.

Michaelis [9] asserts that the level of CO_2 emissions in city transport can be reduced in three different ways: (1) by using more efficient, environmentally friendly transport technologies, (2) by altering peoples' travel habits and (3) to change transport policy of city authorities regarding city centre transport management.

Traffic jam in city centers is continuously increasing despite various measures due to rapidly increasing transport demands. The evolution and development of urban logistics in the past decade has only decreased the situation, partly also due to increased use of motor vehicles. Due to the said problems, the experts around the world are striving to optimize transport frequency within city centers and if necessary restrain it. Solutions are also sought after in areas other than technology, in new laws and regulations. Taking care of the environment and to improving the environmental situation should be incorporated into the spatial planning and any kind of planning concerning the environment. In order to reduce negative impacts on the environment, different economic instruments have been implemented such as environmental taxes whereby the polluter pays. An important instrument is also the implementation of reducing payments or taxes or exemption from such taxes due to investments in environmental protection. Environmental technology or green technology is the power of environmental science, to protect the nature and to reduce the impacts caused by mankind. The nature and environment can also be protected using transport policy and based on the laws that are defined by such policies.

Let us have a look at some of the European best practices: Early in 2002 Copenhagen started with the implementation of the so called City Goods Ordinance scheme in the medieval city centre regarding the use and the capacity of motor vehicles [2]. The aim of this endeavor was reduce the impact of transport of goods has on the environment and to improve the accessibility of narrow medieval streets, by reducing the number of vans and all vehicles, which are driving into towns. The first half of the year concentrated on restricting the tours of vans and lorries to those with acquired certificates. The fine for those without such a certificate amounted to 68 Euros. According to the survey, the residents mostly approved of the scheme. Four larger Swedish cities introduced the so called environmental zones within city centers with the objective to improve air quality and reduce noise pollution [3]. This program refers to busses and lorries whose weight exceeds 3.5 tones. The key requirement for entering the environmental zone was that no diesel vehicle be older than eight years. Older vehicles may enter the zone provided they have undergone emission tests or they can be entirely banned from entering the city centre. Following the Swedish example, Great Britain [14] showed huge improvements regarding emission reduction by introducing the so called Low Emission Zone. It is a precisely defined area which may only be accessed with specific vehicles that meet the set requirements or standards. The main aim of this measure is to reduce traffic impact on the environment and hence increase quality of air and encourage the use of cleaner or greener vehicles in city centres or areas with high level of pollution. Although it is not necessary that the number of vehicles in these areas will decrease as a result, and the number of cleaner vehicles with fewer emissions will increase. As an alternative to classic batteries, more and more systems with fossil cells are developed. This is said to be one of the most forward-looking alternative energy resources. Three German cities [4] have implemented a law which forbids those vehicles which pollute the environment, to enter certain parts of city centres. These areas are labeled environmental zone. In Berlin, Hannover and Cologne drivers must equip their vehicles with special stickers as proof that the vehicles comply with the new environmental standards.

2. MEASUREMENTS AND METHODS

The issue over CO_2 emissions is also increasing in the municipality of Celje. The city centre is congested with vehicles, delivery vans and lorries. To achieve the guidelines for sustainable development of transport systems the problem of congested city centres needs to be solved. This problematic situation of city transport is a result of bad traffic regimes in cities and lack of encouragement of using environmentally friendly vehicles and public transportation. To this end, this research aims to present the actual situation in city centre of Celje and propose possible solutions of new traffic regulations and their impact on the environment. Here, emphasis was placed on CO_2 emissions which are based on the number of vehicles in the studied period of time and a specific area.

Vehicles were counted during 7 am and 5 pm in the city centre of Celje in 15-minute time interval, the number and brand of personal vehicles were registered.

The first measure point (MP1) was situated at the crossing of Prešernova Street (S1) and the square Trg celjskih knezov (S_2). On Prešernova Street the incoming traffic flows c_{10} and c_{12} and the outgoing traffic flows c_{01} and c_{21} were taken into account. Prešernova Street may be entered and left at one side only, as the other side is closed with bollards and is thus a dead end road. The length of the street open to vehicles is only 155m. The majority of drivers drive along the streets to the bollards, where they turn and drive back, as parking spaces are up to 90 % taken. On the square Trg celjskih knezov the incoming traffic flows c_{20}, c_{21} and c_{23} as well as traffic flows c_{02}, c_{12} and c_{32} were taken into account. The length of the street is 105 m.

The second measuring point (MP_2) was situated at the crossing of the square Trg celjskih knezov (S_2) and Gosposka Street (S_3). In Gosposka Street the incoming traffic flows c_{32} and c_{34} and outgoing traffic flow c_{23} were measured.

The third measuring point (MP_3) was situated at the crossing of Gosposka Street (S_3) and the square Muzejski trg (S_4). In Gosposka Street the outgoing traffic flow Gosposka Street c_{43} as measured. The length of the square Muzejski trg is 200 m.

The fourth measuring point (MP_4) was situated at the exit of Gosposka Street (S_3), where the outgoing traffic flow c_{03} was measured. The length of Gosposka Street is 310 m.

The city centre of Celje may be defined as a system of incoming and outgoing traffic flows. The studied system is defined as $S = (S_i, R)$, whereby $S_i = (S_1, S_2, S_3, S_4)$ a number of system elements and present the streets in the city centre and as $R = (c_{10}, c_{01}, c_{20}, c_{02}, c_{21}, c_{12}, c_{32}, c_{23}, c_{34}, c_{43}$ in $c_{03})$ the number of links between the elements of the system and the environment.

Fig. 1. City centre of Celje
Рис. 1. Городской центр Целье

Note: S_1 = Prešernova ulica - street, S_2 = Trg celjskih knezov - sqaure, S_3 = Gosposka ulica - street,
- S_4 = Muzejski trg - sqaure, MP_i = measure point.

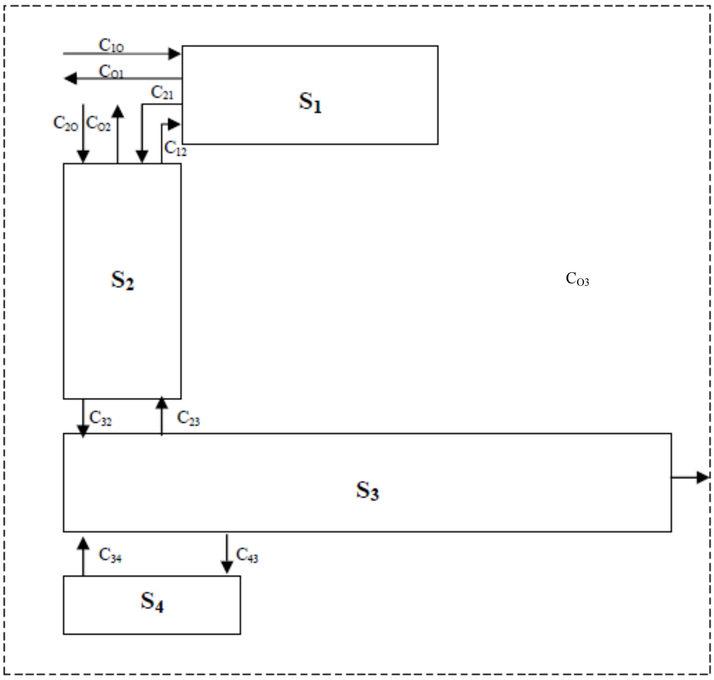

Fig. 2. Systemic image of streets
Рис. 2. Системный образ улиц

Structure of the system and the environment can be shown using matrix C, as seen below:

$$C = \begin{array}{c|ccccc} & O & S_1 & S_2 & S_3 & S_4 \\ O & x & c_{01} & c_{02} & c_{03} & 0 \\ S_1 & c_{10} & 0 & c_{12} & 0 & 0 \\ S_2 & c_{20} & c_{21} & 0 & c_{23} & 0 \\ S_3 & 0 & 0 & c_{32} & 0 & c_{34} \\ S_4 & 0 & 0 & 0 & c_{43} & 0 \end{array},$$

whereby

O = system environment.

Matrix C can be classified into four submatrices, in that: Co = (x), matrix linking elements of environment which are not part of the research, Cv = $\{c_{10,} c_{20}\}$, incoming matrix of the system, $C_i = \{c_{01,} c_{02,} c_{03}\}$, outgoing matrix of the system and C_n = matrix of internal links as seen below:

$$C_n = \begin{array}{c|cccc} & S_1 & S_2 & S_3 & S_4 \\ S_1 & 0 & c_{12} & 0 & 0 \\ S_2 & c_{21} & 0 & c_{23} & 0 \\ S_3 & 0 & c_{32} & 0 & c_{34} \\ S_4 & 0 & 0 & c_{43} & 0 \end{array}$$

Based on the number and type of vehicle and data on emissions produced by individual brands of vehicles CO_2 emissions were calculated using the following equations:

$$s = N \times d \tag{1}$$

$$C_F = s \times \phi_F \tag{2}$$

$$E_{CO_2} = C_f \times 2{,}48 \frac{kg}{l} \; ^{1} \tag{3}$$

whereby: s – total driven distance, N – number of personal cars, d – length of street, C_F – used fuel, ϕ_F – average use of fuel, E_{CO2} – CO_2 emission (in kg).

3. RESULTS AND DISCUSSION

In the studied period of time 7257 vehicles drove through the analysed system of streets in the city centre of Celje. Based on the equation (1) the total distance driven was 1268,64 km. Using equations (2) and (3) we may calculate that CO_2 emissions in the analysed period of time amount to 283,16 kg. Figure 3 depicts daily emissions in individual streets.

[1] coefficient 2,48 kg is calculated 0,7 x 2,4 kg/l + 0,3 x 2,67 kg/l,
whereby: 0,7 – percentage of personal vehicles using fossil fuels and 0,3 percentage of personal vehicles using diesel fuels in Slovenia in 2008 [13], 2,4 kg CO_2 emissions, produced by one litre of fossil fuels, 2,67 kg CO_2 emissions produced by one 1 l of diesel fuels [1].

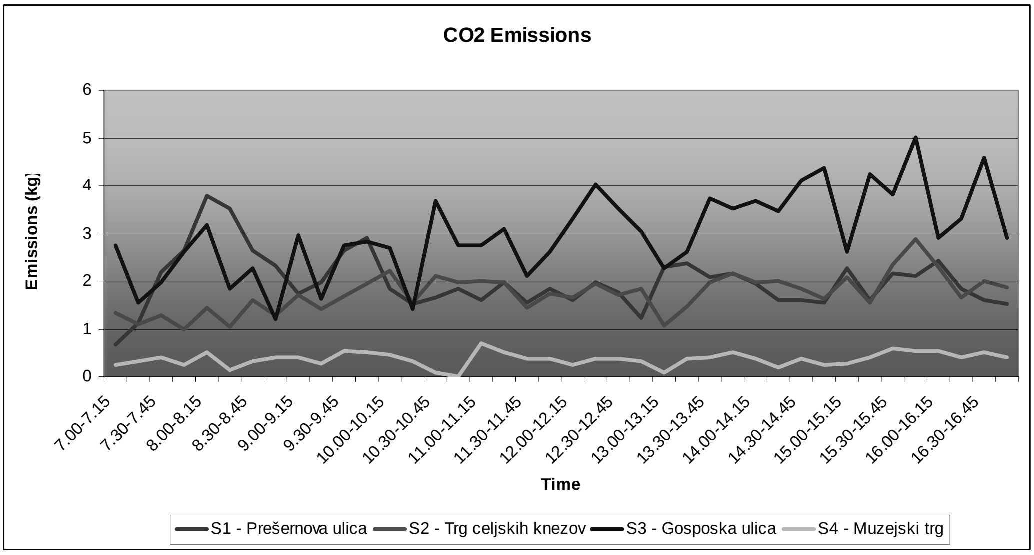

Fig. 3. CO_2- emissions in particular streets
Рис. 3. Выбросы CO_2 на выбранных улицах

The objectives of contemporary environmental and transport policy is to reduce CO_2 emission in cities and hence improve quality of life in city centers, In order to reduce traffic volume in city centers and thus CO_2 emissions, two possible solutions were analyzed linked to the change of traffic regime in particular streets. We assumed that the incoming matrix c_v will remain unchanged, but we also wanted to preserve the partially open system, which allows the vehicles to enter and leave the system.

The first possible solution presupposed the implementation of one-way regime on the square Trg celjskih knezov, which influences the incoming and outgoing traffic flows in the subsystem S_2. Figure 4 depicts the system of links between subsystems.

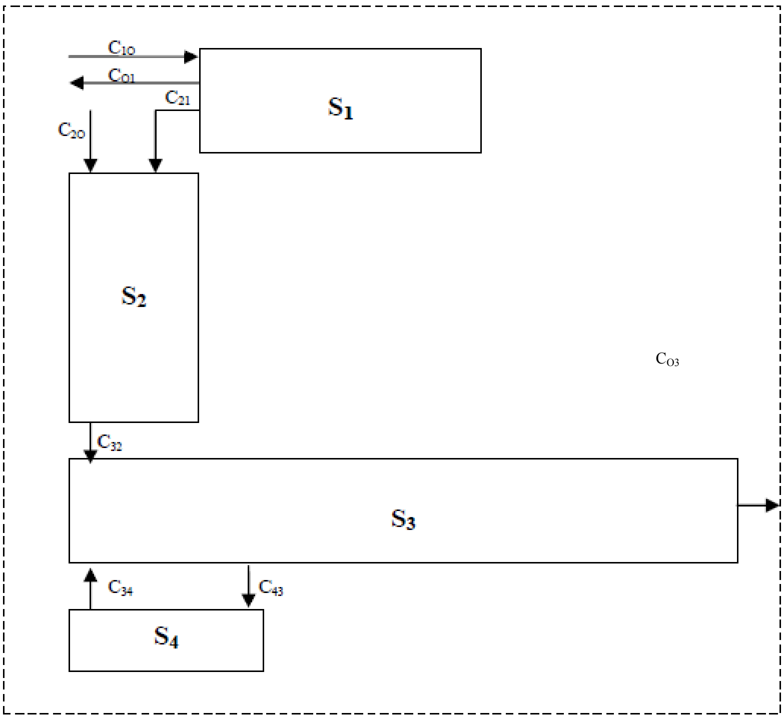

Fig. 4. Links in a system of first solution
Рис. 4. Связи в системе – первое решение

After the implementation the links between subsystems and the environment may be presented as follows:

$$C_1 = \begin{array}{cccccc} & O & S_1 & S_2 & S_3 & S_4 \\ O & x & c_{01} & 0 & c_{03} & 0 \\ S_1 & c_{10} & 0 & 0 & 0 & 0 \\ S_2 & c_{20} & c_{21} & 0 & 0 & 0 \\ S_3 & 0 & 0 & c_{32} & 0 & c_{34} \\ S_4 & 0 & 0 & 0 & c_{43} & 0 \end{array}$$

In the event of implementing a one-way regime on the square Trg celjskih knezov, the level of CO_2 emissions is to increase by 8.1% and would amount to 305,84 kg. However, the CO_2 emissions on Prešernova Street and on the square Trg celjskih knezov are expected to decrease by 4% and 23%, respectively. Yet in this case, a drastic increase of CO_2 emissions is to be expected on Gosposka Street (34%). The reason for such an increase could lie in the diversion of traffic flow c_{23} to the outgoing flow c_{03}, which would increase CO_2 emissions due to the length of Gosposka Street. The CO_2 emissions on the square Muzejski trg would remain the same, as it had already been assumed that the vehicles which were previously driving in direction c_{23}, were leaving the city centre.

The second possible solution presupposed the implementation of a one-way regime in Prešernova Street and on the square Trg celjskih knezov, whereby an exit into c_{01} into Savinova Street could be introduced due to geographical options. Figure 5 thus presents a system of links between subsystems.

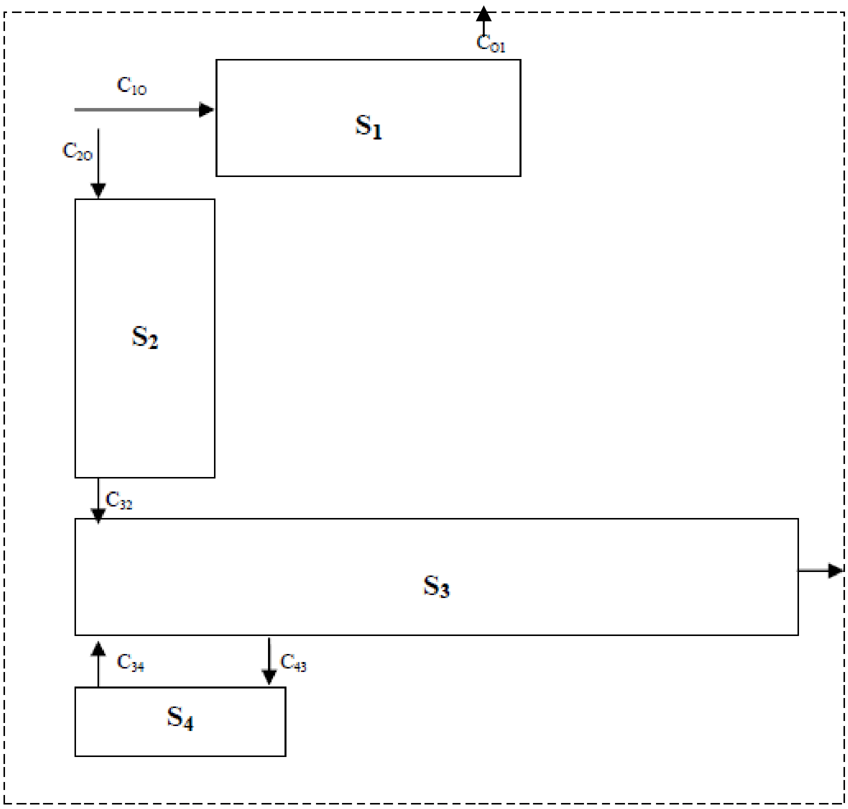

Fig. 5. Links in a system of second solution
Рис. 5. Связи в системе – второе решение

After the implementation of a one-way regime in Prešernova Street and the square Trg celjskih knezov, the links between the subsystems and the environment may be presented as follows:

$$
C_2 = \begin{array}{cccccc}
 & O & S_1 & S_2 & S_3 & S_4 \\
O & x & c_{01} & 0 & c_{03} & 0 \\
S_1 & c_{10} & 0 & 0 & 0 & 0 \\
S_2 & c_{20} & 0 & 0 & 0 & 0 \\
S_3 & 0 & 0 & c_{32} & 0 & c_{34} \\
S_4 & 0 & 0 & 0 & c_{43} & 0
\end{array}
$$

In the event of implementing the second solution, the level of CO_2 emissions would decrease by 15% in comparison to the initial state and would amount to 241,01 kg. Moreover, the CO_2 emissions on Prešernova Street and on the square Trg celjskih knezov would decrease by 60% and 29%, respectively. Despite the increase of CO_2 emissions by 21%, which would occur on Gosposka Street, overall the entire system would reduce the emissions. The CO_2 emissions on the square Muzejski trg would remain the same, as it had already been assumed that the vehicles which were previously driving in direction c_{23}, were leaving the city centre.

4. CONCLUSION

Urban areas play an important role in implementing objectives of Sustainable development strategies of the EU. Environmental, economic and social dimensions are closely linked in urban areas. In cities, a number of environmental problems occur, however, cities are also the centre of closing deals and making investments. Four out of five Europeans live in urban areas and their quality of life is directly influenced by the state of the urban environment. High quality urban environment contributes to the renewed Lisbon strategy on “creating Europe, which will attract employment and investments”. Attractiveness of European cities will increase their growth and employment opportunities; therefore cities are very important for implementing the Lisbon strategy programme.

Organization and integration of city freight transport can contribute a great deal to this, as its constant presence has an immediate influence on the quality of life of the people and economic subjects that work in cities and rely on it. As a consequence, all city policies which aim to create optimal conditions for development and attractiveness of city centres are confronted with a number of problems, contrary to the rural areas. City centres do not have unlimited areas to build expensive new infrastructures, which are also difficult to access. Outside cities, the trend is in building large distribution and retail centres, which are located near city centres or just outside city centres. That is why they do not have these problems. These are attractive attributes which city authorities are well aware of.

Our research and systemic approach to the problem of pollution in the city centre of Celje aimed to present the level of CO_2 emissions in the analysed area and in a set period of time. Moreover, possible changes of traffic regimes and the levels of CO_2 [2] emissions in various solutions were presented. Based on the objectives of the environmental policy in the future, emissions in city centres should amount between 186[3] and 198 g/km per vehicle, on average. In our research, the average CO_2 emissions amount to 223,20 g/km which exceeds the set goals by 13 to 20%. We are talking about gradual reduction, as both the age of the vehicle fleet as well as the current transport regulations must be considered. However, we are hoping in the future, these will improve.

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[2] The average CO_2 emissions for new vehicles after 2010 are said to be 120 g /km per vehicle.

[3] Considering the data from DAT (2006) and the group of observed vehicles, when driving in citiy centres, the CO_2 emissions are from 55 to 65% higher.

Further research may be conducted in the area of sustainable transport policy provision in the city centre of Celje. The main priority are the areas such as managing transport regime in the city centre, optimisation of traffic flows, temporal determination of delivery and implementation of environmentally-friendly vehicles and infrastructure.

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