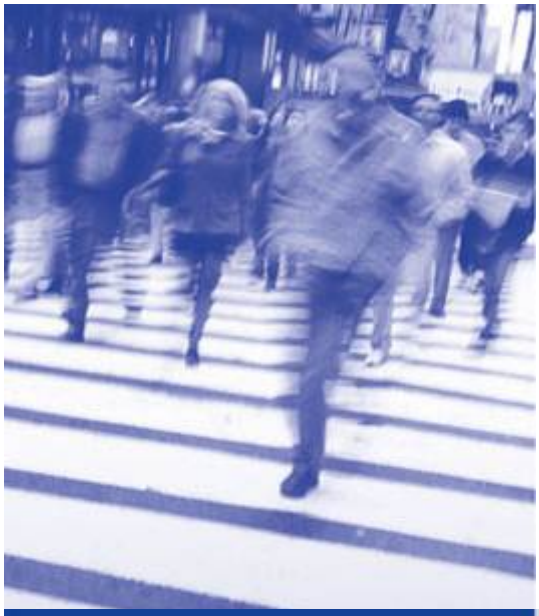

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Implementation status report on Sustainable Freight Logistics

(Consolidation of deliveries - computer simulation model for emission savings and internet portal for promotion of sustainable freight logistics)

Project acronym: ELAN
Project full title: Mobilising citizens for vital cities

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	WP1 Alternative fuels & clean vehicles
	WP2 Collective transport & intermodal integration
	WP3 Demand management
	WP4 Influencing travel behaviour
	WP5 Safety, security & health
	WP6 Innovative mobility services

x	WP7 Energy-efficient freight logistics
	WP8 Transport telematics
	WP9 Project coordination
	WP10 Project management
	WP11 Research and Technological Development
	WP12 Impact and process evaluation
	WP13 Dissemination, citizens' engagement, training and knowledge transfer

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Summary

This Deliverable includes a description and the detailed structure of the web portal for supporting and promoting sustainable city logistics and the transport model for freight delivery in the city centre of Ljubljana.

The target groups of the web portal are: freight transport service providers, distribution and logistics centres, the local business sector (manufacturers, retailers, shop owners), the Chamber of Commerce, local authorities – cities/ municipalities, universities, research institutions, and all other stakeholders and individuals that are interested in sustainable city logistics. The website encourages also participation from outside sources, e.g. social networking (Facebook, Twitter) and other, which further improves the accessibility and promotion of sustainable city logistics practices. It is foreseen that the web portal spreads awareness on the importance of sustainable city logistics not only in Ljubljana but in the whole country, being at the same time a novelty in Slovenia.

The portal includes the following: general information on sustainable freight logistics, examples of good practices from various cities, online surveys and questionnaires (important information are collected from stakeholders as well as opinions and suggestions about delivery policies), an interactive map which calculates delivery routes to the city centre (online routing tool), online forum where important issues can be discussed, members' area for submission of ideas and new projects which promote sustainable city logistics. The online routing tool includes online calculation of optimal routes to the city centre, calculation of optimal routes in the pedestrian zones and helps delivery companies to optimise their deliveries.

This document includes a presentation of the transport model which simulates the implementation of measures for city logistics including consolidated deliveries and other measures for supporting the consolidation of freight delivery in the municipality of Ljubljana. The model shows the potential reduction of delivery trips, energy savings and saved emissions of air pollutants and noise, that could have been achieved if the model of consolidated delivery would have been implemented in reality.

The document also includes an explanation of the methodology, an analysis of available data, inputs, main results and impacts of consolidated freight delivery, simulated by a developed computer transport model. Input data for the model have been collected via terrain surveys (interviews with performers of freight delivery) and via freight traffic counting in the city centre of Ljubljana.

Traffic counting has been performed at all access points into the pedestrian zone in the city centre of Ljubljana and the survey has been made on pedestrian zones. The document describes also the methodology of data collection and analyses and the methodology for the traffic model and simulation. Prior to the traffic modelling also an analysis of freight deliveries in narrow city centre of Ljubljana has been made (as summarized in 7.2-WD2) where different pilot areas have been determined and tested for suitability of consolidated freight delivery. In order to prepare a suitable freight transport delivery concept the city centre's business structure and locations of individual business entities, types of delivered goods, weight of unloaded cargo, types and fuel of vehicles have also been analysed. These analyses are also the inputs for the computer simulation model.

As an output of the consolidated delivery transport model the document presents results of the model, including fuel consumption, vehicle kilometre and emission savings in case of implementation of consolidation of delivery.

1. Introduction

The main implementation results are the establishment of an internet web portal (including online rooting tool) and a freight logistics model for Ljubljana, showing environmental benefits.

The document thus includes two main chapters: Internet portal for promotion of sustainable freight and Computer simulation model for emission savings.

The first main chapter presents the web portal which includes the following: general information on sustainable freight logistics, examples of good practices from various cities, online surveys and questionnaires (important information are collected from stakeholders as well as opinions and suggestions about delivery policies), an interactive map which calculates delivery routes to the city centre (online routing tool), online forum where important issues can be discussed, members' area for submission of ideas and new projects which promote sustainable city logistics. The online routing tool includes online calculation of optimal routes to the city centre, calculation of optimal routes in the pedestrian zones and helps delivery companies to optimise their deliveries.

The second main chapter includes the presentation of transport model which simulates the implementation of consolidated deliveries in Ljubljana. The model shows the potential reduction of delivery trips, energy savings and saved emissions of air pollutants and noise, that could have been achieved if the model of consolidated delivery would have been implemented in reality.

2. Internet portal for the promotion of sustainable freight deliveries

2.1. Introduction

The internet portal freight for the promotion of sustainable freight deliveries spreads awareness on the importance of sustainable city logistics not only in Ljubljana but in the whole country, being at the same time a novelty in Slovenia. A national web portal is prepared to support and promote sustainable city logistics including research activities for its development and for the contents of the portal (information about sustainable freight logistics, good practices cases, etc.). The website encourages participation from outside sources, e.g. social networking (Facebook, Twitter) and other, which improves the accessibility and promotion of sustainable city logistics practices in the future. Part of the web portal is also an online routing tool for deliveries in Ljubljana which includes an online calculation of optimal routes to the city centre of Ljubljana and calculation of optimal routes in the pedestrian zones. The online routing tool helps delivery companies to optimise their deliveries in the city centre of Ljubljana. The web portal can be found at www.dostave.si, and for all the other contacts with portal administrators a special e-mail address is available: info@dostave.si.

The target groups of this web portal are: freight transport service providers, distribution and logistics centres, the local business sector (manufacturers, retailers, shop owners), the Chamber of Commerce, local authorities – cities/ municipalities, universities, research institutions, and other stakeholders and individuals that are interested in sustainable city logistics.

Activities for developing the internet web portal started August 2011, when works on 7.2 – WD4 started. WD4 includes the determination of the web portal structure and a plan for its development and establishment. The test launch of web portal was in December 2011. In January and February 2012 additional features were under construction, such as programming activities for an online routing tool and other. The portal was programmed by IT-engineers from PI and is based on an external web content management system.

Figure 1: Home page of the freight delivery portal

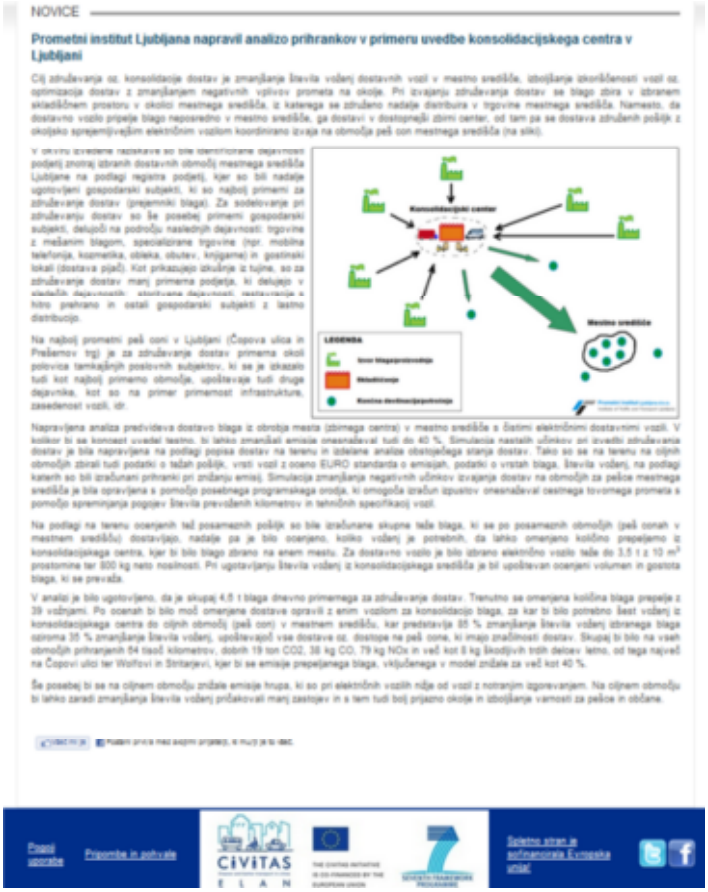
The interactive “home page” of the portal includes short information from portal users and links to other contents on the portal. The front page includes links to news concerning freight transport, “events” where most of the events concerning freight transport are included ant to other actual contents that cannot be put into other location. On the front page there is also a link to pictures with the current situation of freight deliveries in the city centre of Ljubljana. Questionnaires for operators of freight deliveries in Ljubljana or other interested people concerning the improvements of freight transport in Slovenian cities are also available.

The web portal for freight deliveries is divided into further contents: “home page”, news, route planner, links to other web pages with similar contents, description of CIVITAS-ELAN measures and its partners in Ljubljana, information and contracts about the Institute of Traffic and Transport Ljubljana as an administrator of the web portal. Portal users can write their proposals and put them on a forum page where issues related to urban freight deliveries can be discussed.

2.2. Contents and features of the freight delivery portal

In the CIVITAS-ELAN project sustainable ways of passenger and freight transport are being promoted to citizens and stakeholders. With the aim to promote sustainable transport logistics in urban areas the portal presents general information concerning sustainable urban deliveries. Special focus is on the presentation of the system of consolidated deliveries and positive environmental, social and other effects of consolidated deliveries in urban areas.

Figure 2: Printscreen of general description on consolidated deliveries in urban areas

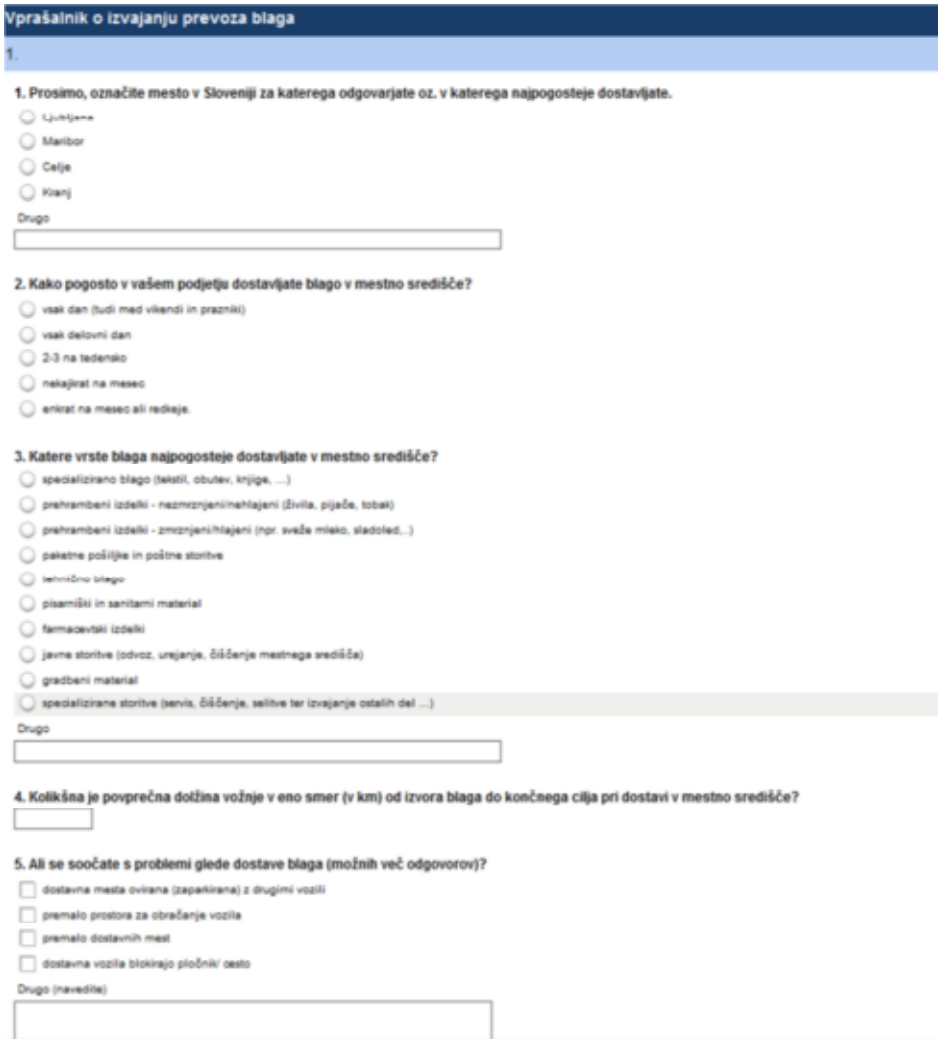


Benchmarking is also an important concept to transfer good practices of urban delivery to other urban areas in EU. The CIVITAS-ELAN delivery portal is contributing to promote sustainable urban freight delivery also by transferring and promoting good practices from EU cities. Within the portal there are some good practices of sustainable urban freight deliveries implementations described. In the sustainable delivery portal there are good practices from Copenhagen (Denmark), Bristol (Great Britain), Reggio Emilia and Ravenna (Italy). For each of the good practice studies there is a description of the status before and after the implementation of sustainable delivery measures and other impacts of the implementation.

Figure 3: Print screen from portal of good practice from Reggio Emilia and Ravenna

The aim of the portal is also to receive opinions and suggestions concerning further implementations in the field of sustainable urban freight logistic in Ljubljana or other major cities in Slovenia. For that purpose an online survey and questionnaires were prepared and included in the portal. The questionnaire is divided for two stakeholders. The first group are inhabitants of major urban areas where urban deliveries take place and influence their lives. In the questionnaire the inhabitants of the urban areas propose their view how to organize urban freight deliveries in order to lower the negative influence of urban deliveries. The second group to whom the questionnaire is concerned are the performers of city deliveries, which can specify some of the elements (delivery times, locations of delivering, type of goods, willingness to participate in consolidated delivery scheme, etc.) of urban deliveries. By filling in the questionnaires important information is being collected from stakeholders as well as opinions and suggestions about delivery policies.

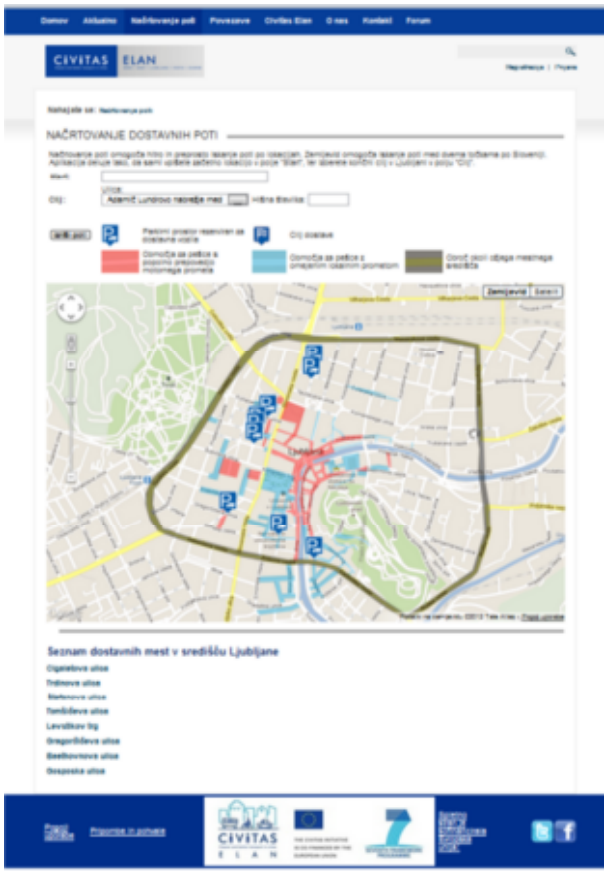
Figure 4: Print screen of questionnaire for performers of urban city deliveries



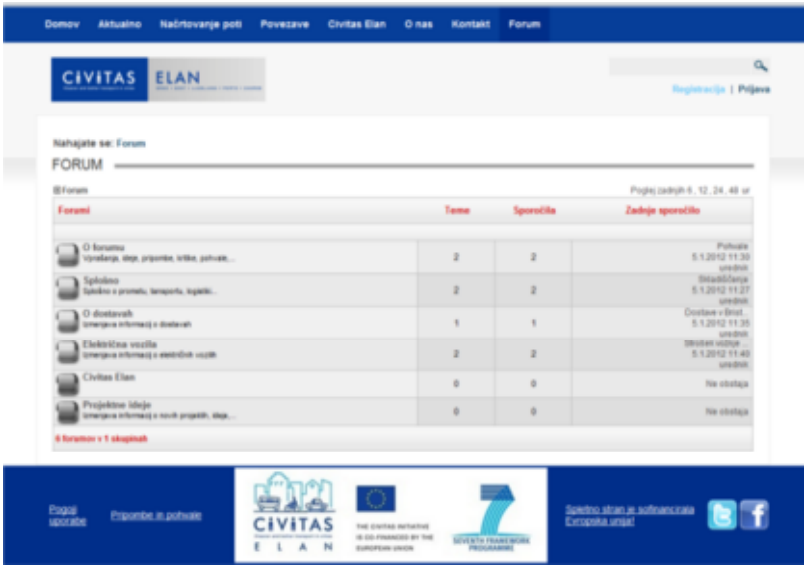
An interactive map calculating delivery routes to the city centre (online routing tool)

Within the portal an online routing tool for deliveries in Ljubljana was developed as a part of the national web portal. The routing tool includes an online calculation of optimal routes to the city centre, a calculation of optimal routes in the pedestrian zones and helps delivery companies to optimise their deliveries. Besides other relevant information for delivery operation the online routing tool shows data and explanations which are important for delivery companies such as:

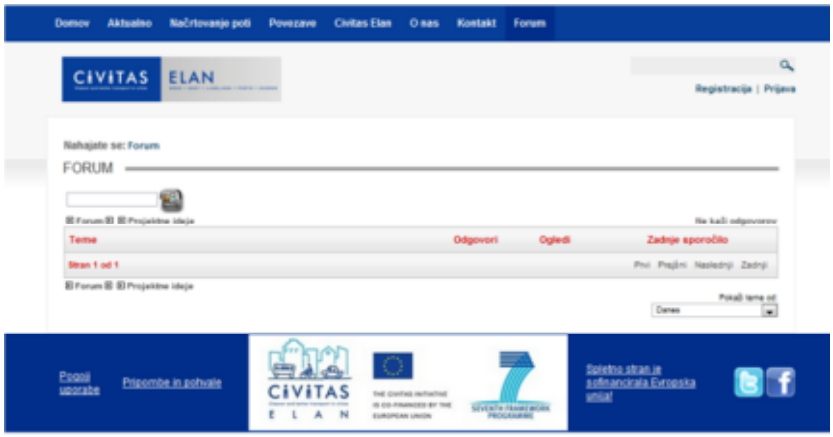
- delivery places,
- delivery time,
- traffic restrictions, etc.



Online forum where important issues can be discussed



Members' area for submission of ideas and new projects which promote sustainable city logistics



To further promote the sustainable transport portal also Facebook and Twitter accounts were prepared. With the help of Facebook and Twitter general information concerning the web portal and other relevant information is being sent to the followers and to the interested public by messaging and tweets.

Figure 5: Facebook profile account of sustainable urban delivery portal

Figure 6: Profile of Twitter account to promote sustainable freight delivery

3. Computer simulation model for emission savings

3.1. Methodology and model description

A model will simulate the implementation of city logistics measures including consolidated deliveries and other measures for supporting the consolidation. The model will show how a reduction of delivery trips, reduction of emissions, and reduction of energy consumption could have been achieved if the model would be implemented in reality.
For modelling a special computer "PTV Visum" software for traffic simulations will be used. The results will be presented in tables and graphically.

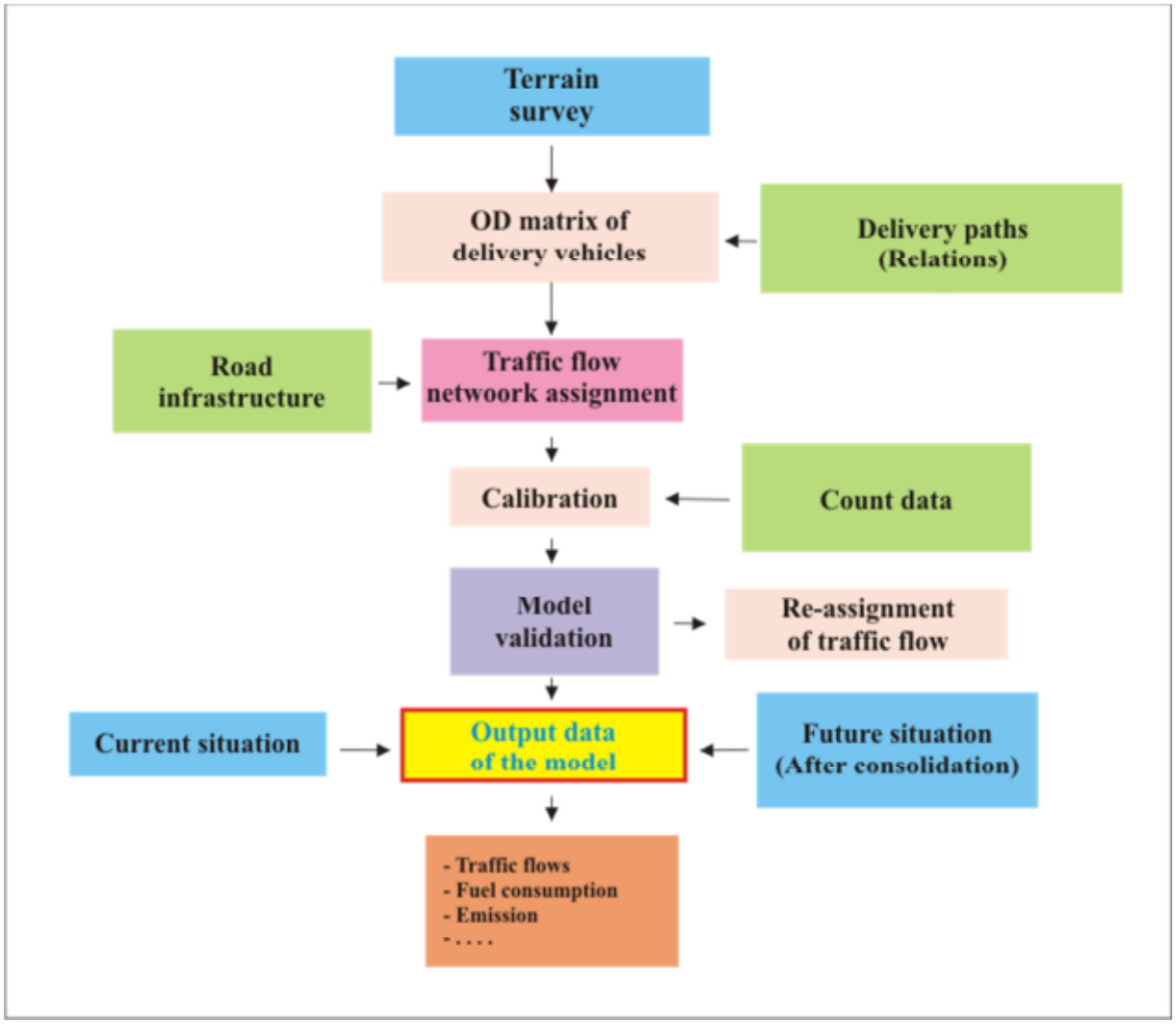
a) Input data for modelling
Data based on current transport and delivery

- information on relations of delivery vehicles collected through terrain survey and relevant databases (e.g. delivery permits database);
- information on vehicle types (light, medium, heavy);
- type of goods delivered (clothes, food and drink, groceries, ...)
- data from traffic counting (static street counters),
- delivery mass, vehicle occupancy;
- air pollution by certain types of vehicles and vehicle operating costs,
- etc.

b) Outputs of the model

- air pollution – CO_2, NO_x and PM_{10},
- number of delivery vehicles and trips, delivery kilometres, fuel consumption,
- cost per tonne-kilometre,
- simulation of benefits (energy and emission savings,...)

Figure 7: Structure of the traffic model for delivery consolidation



Source: Prometni institut Ljubljana d.o.o.

3.2. Computer software for the freight transport model

With the aim to prepare a quality transport model the integrated software tool PTV Visum (Germany) was used. The system is well-established in the EU and is capable of transport models production and operational analysis in real time. It is also used as a planning tool for modelling traffic flows, since the software is used in producing and generation of travel distribution and assistance in preparation of origin/ destination matrices.

The PTV software tool Visum consists of several modules that allow transport planning at the microscopic, mesoscopic or macroscopic level. The size of the transport network is not limited to the area of analysis and is compatible with public or private means of freight and passenger transport. The programme provides the complete design and the preparation for various types of pollution networks (road,

rail, pedestrian, etc.) and with it a detailed analysis of the results can be obtained. Within meaure 7.2-LJU a traffic model of consolidation of freight deliveries in the narrow city centre of Ljubljana was prepared with the latest version of Visum 12.0.

As mentioned above, it is very complex to prepare and analyse a traffic model of consolidation of freight deliveries in the area of pedestrian zones of the city centre of Ljubljana. The model covers a wide range of information needed to complete the model, and for its transfer from field theory. As in other transport models the basis for the freight transport mode is reliable input of data. The starting point of the presented model is represented in the form of traffic counts and surveys of performance suppliers. In addition, the model includs road infrastructure with all the traffic (one-way streets, the statutory direction) and spatial limitations and represents the actual situation on the ground.

With the aim to allocate the differences between the traffic model and real practice there has been a calibration of traffic flows in the transport model. When the model resembles to the real satiation it is possible to obtain various data on emissions, fuel consumption, congestion of highways that target stem travel, driving times, distance category, etc.

3.3. Definition of area and transport zones

To prepare a model for the consolidation of freight deliveries in the area of the pedestrian zones in the city centre of Ljubljana much further preparation is needed and data has to be collected. The model includs road infrastructure with all the traffic (one-way streets, the statutory direction) and spatial limitations and represents the actual situation on the ground.
The figure below shows selected micro and macro transport zones that were used in the freight transport model. Inside the selected area there are micro zones of the Ljubljana city centre, BTC City (business centre) and the logistics centre Ljubljana Moste, which are the potential origin and destination points for consolidated delivery.

Figure 8: Division of transport zones in Ljubljana included in the transport model

Source: google.maps in Prometni institut Ljubljana d.o.o.

With the purpose to allocate the traffic patterns of freight deliveries, the narrow city centre of Ljubljana was further divided into 14 zones where delivery of goods to the city centre is taking place.

The area in the city centre of Ljubljana is in the north limited by Dalmatinova street, and in the south by Zoisova and Levstikova street. To the east the city centre is divided by Resljeva, Kopitarjeva street and also the area of Ljubljana Castle. Slovenjska cesta is bordering the city centre on the west side of the analysed area.

To obtain input data for the traffic model, counting is carried out at nine locations shown in the figure below which also indicates the locations where city delivery is entering or exiting the city centre (location of sinking bollards or other obstacles to enter the city centre).

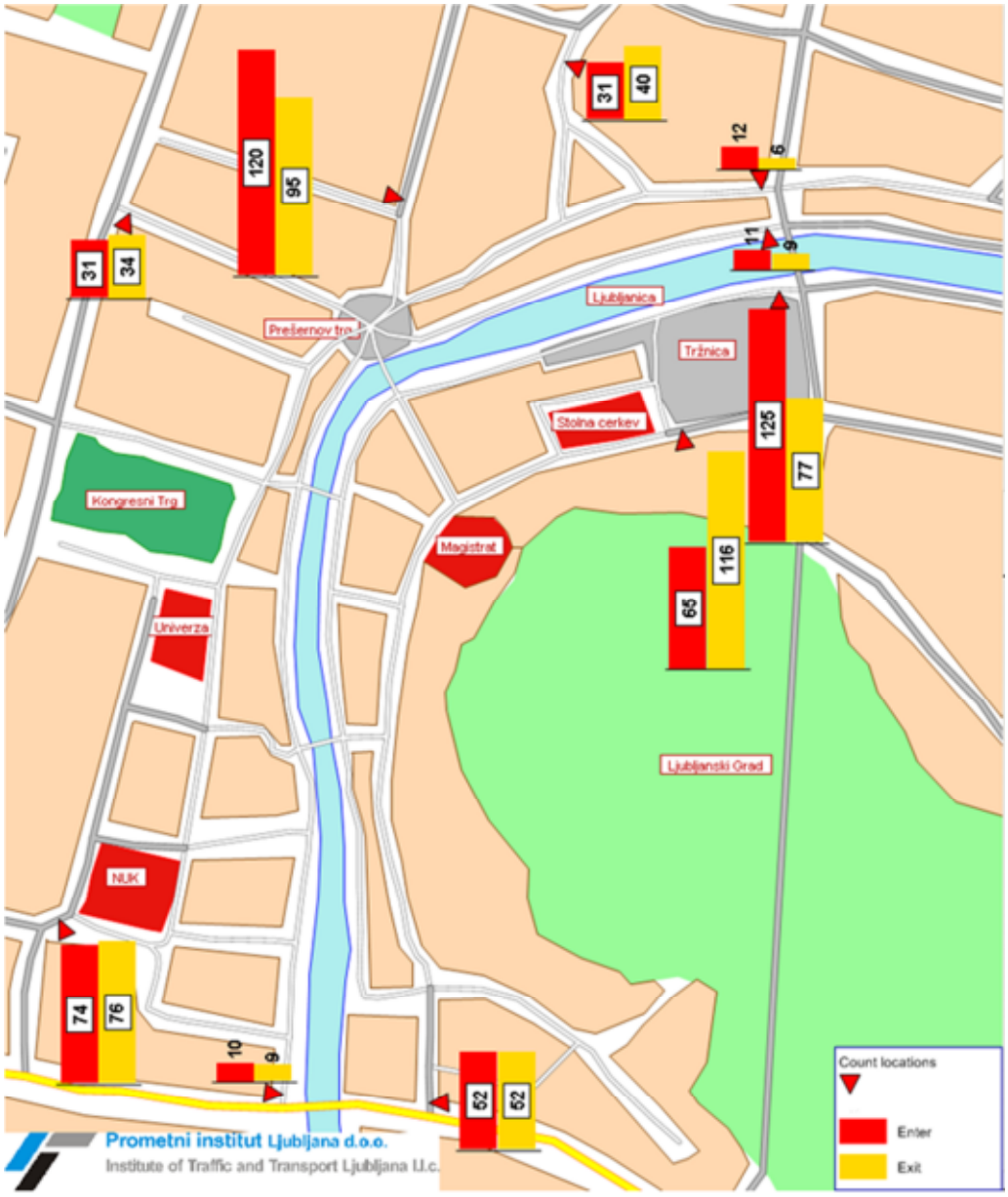
Figure 9: Micro zones and entering locations to the city centre of Ljubljana

Source: google.maps in Prometni institut Ljubljana d.o.o.

3.4. Results of freight transport model

The picture below shows the number of delivery vehicles, entering or exiting in an area of the old city centre of Ljubljana.

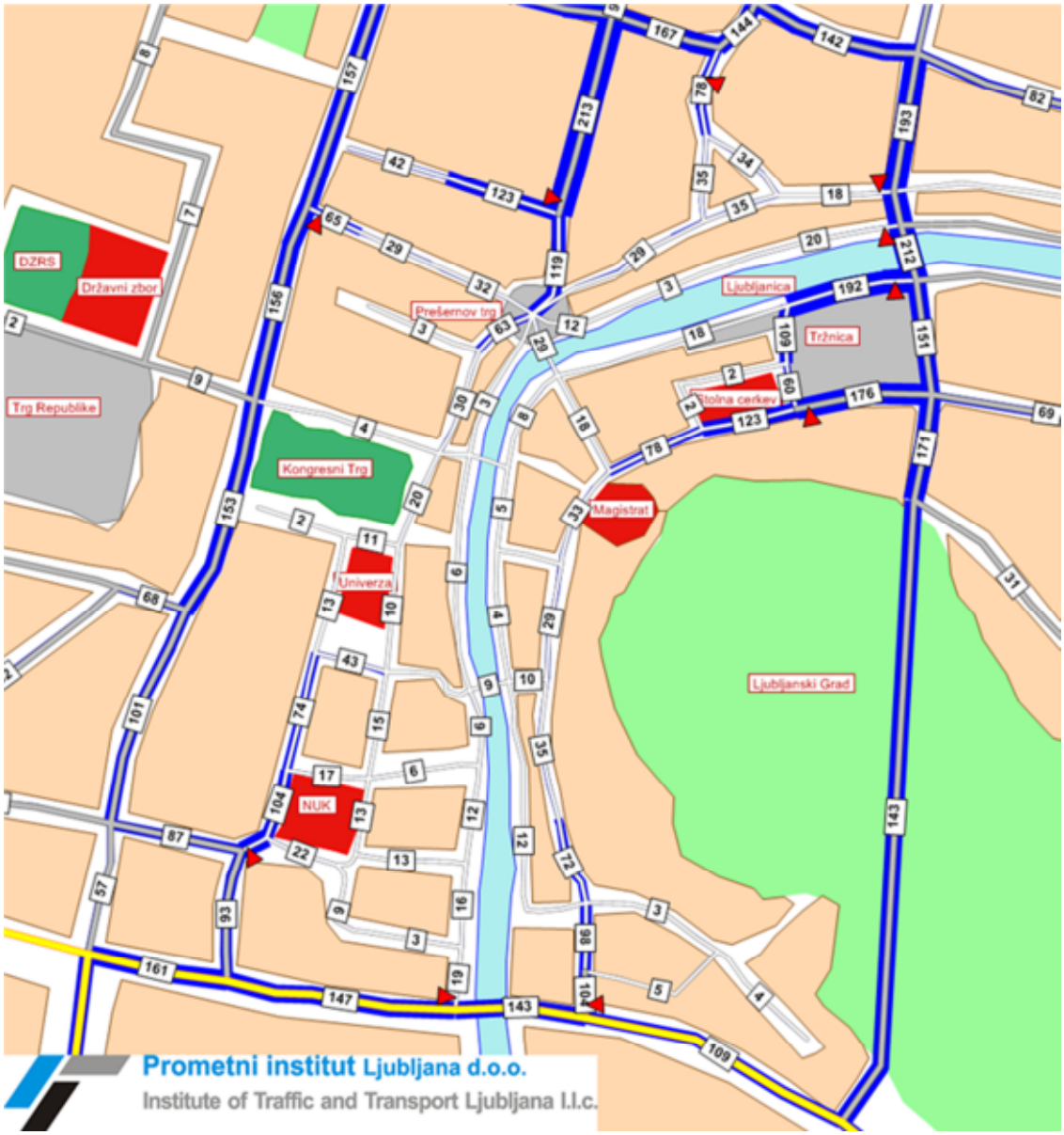
Figure 10: Number of delivery vehicles crossing the counting locations



Source: Prometni institut Ljubljana d.o.o.

On the day the terrain survey was conducted, the heaviest volume was counted at a counting location near the crossroad between Miklošičeva and Nazorjeva Street, with 210 delivery vehicles. By the volume the second counting location is Tržnica with access from Resljeva Street, with more than 200 deliveries. In the 3rd place is Krekov trg, with access to Tržnica and Ciril-Metodov trg with 181 deliveries.

Figure 11: Traffic volume of delivery vehicles



Source: Prometni institut Ljubljana d.o.o.

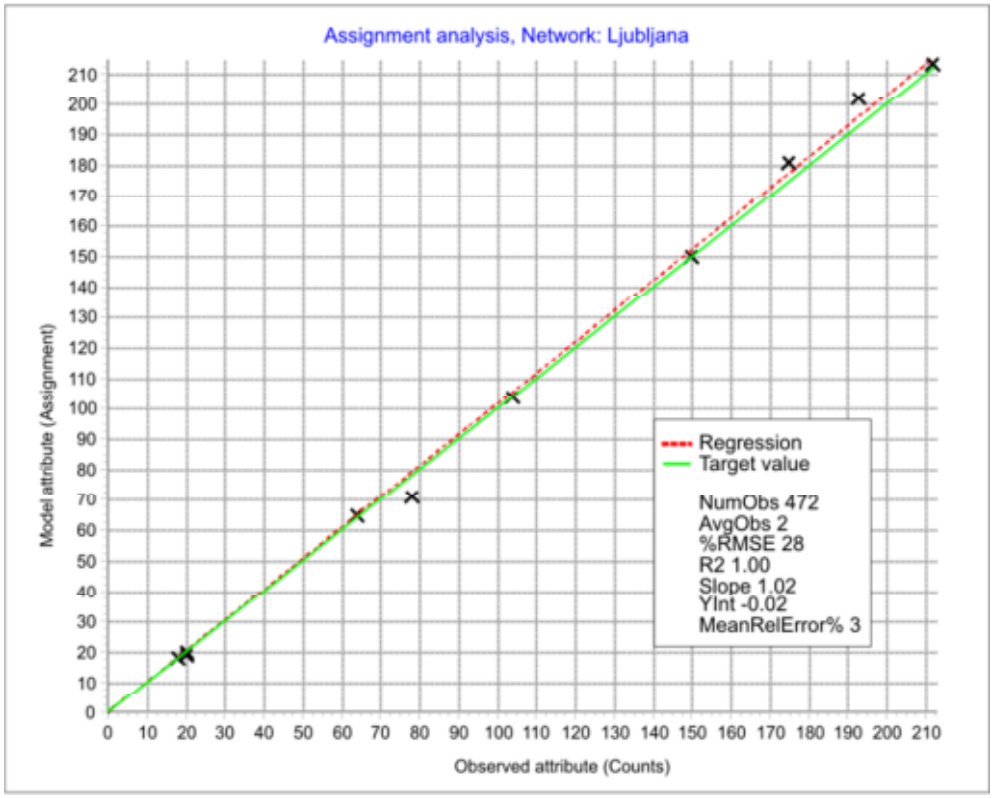
The picture above shows the traffic volume of delivery vehicles in the city centre of Ljubljana on a daily basis. The heaviest traffic is presented by the blue colour of the streets. The streets with the high occupancy level are the following streets: Slovenska, Miklošičeva, Resljeva and Zoisova. Some short streets in the pedestrian area are closed for motorized delivery traffic with physical barriers (stairs, small column, etc.).

Traffic assignment

During the traffic assignment on the network there are some differences between simulated traffic flows and the counting data. Therefore, the data in the validation process are compared with each other. Data at the 9th counting location were obtained through the counting of delivery vehicles. For the validation all nine road section with access to the pedestrian area were selected.

For the validation of the traffic volume on the road network with delivery vehicles primarily indicator factor correlations and the relative standard deviation were used. The correlation factor was calculated on the basis of traffic counts and modelled data, gathered by terrain survey. The relative standard deviation is a deviation between the data in the model and the counted data. The result is shown by the dispersion diagramme.

Figure 12: Dispersion diagramme of delivery vehicles



Source: Prometni institut Ljubljana d.o.o.

The correlation factor for vans (expressed in number of vehicles per day) is 1.0, while the standard deviation is 3%. The mean relative error is 3%. On a basis of the input data, the traffic model is an excellent approximation of the current situation.

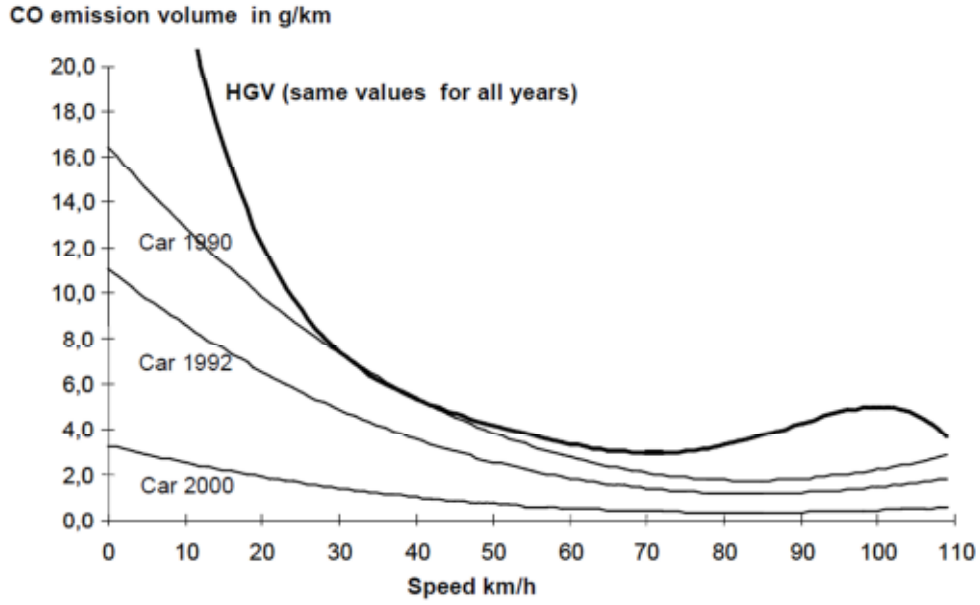
Pollution-Emis procedure is based on emission factors issued by the Swiss Federal Office for the Environment (BAFU) for pollutants NO_x, CO, HC and SO_2, for both cars and HGVs. For each pollutant, a regression curve with polynomes to the 5th degree is used:[3]

$EMISS = a + b*v + c*v^2 + d*v^3 + e*v^4 + f*v^5$

The parameters a, b, c, d, e and f of the polynome were determined separately for different pollutants for cars and HGVs for the difference reference years. Recent measurements have shown that actual emission values are generally overestimated by 1990 calculation factors, because the change in vehicle fleets (more vehicles have now been equipped with catalytic converters) has contributed to decreasing volumes per vehicle. The latest Swiss emission factors take this change into account with modifications for the years 1992 and 2000.

The polynome approximation of emissions relative to speed shows the following developments for CO for the different reference years:

Figure 23: Emissions relative to speed



Source: PTV Vision, VISUM 12 – Fundamentals, Karlsruhe, November 2011

To calculate noise volumes based on traffic volumes, VISUM offers the Noise-Emis-Rls90 procedures. The Noise-Emis-Rls90 procedure is based on the RLS-90 of the noise reduction for roads by the German Federal Minister for Traffic, the Noise-Emis- Nordic procedure on the Nordic Council of Ministers (1996) model.

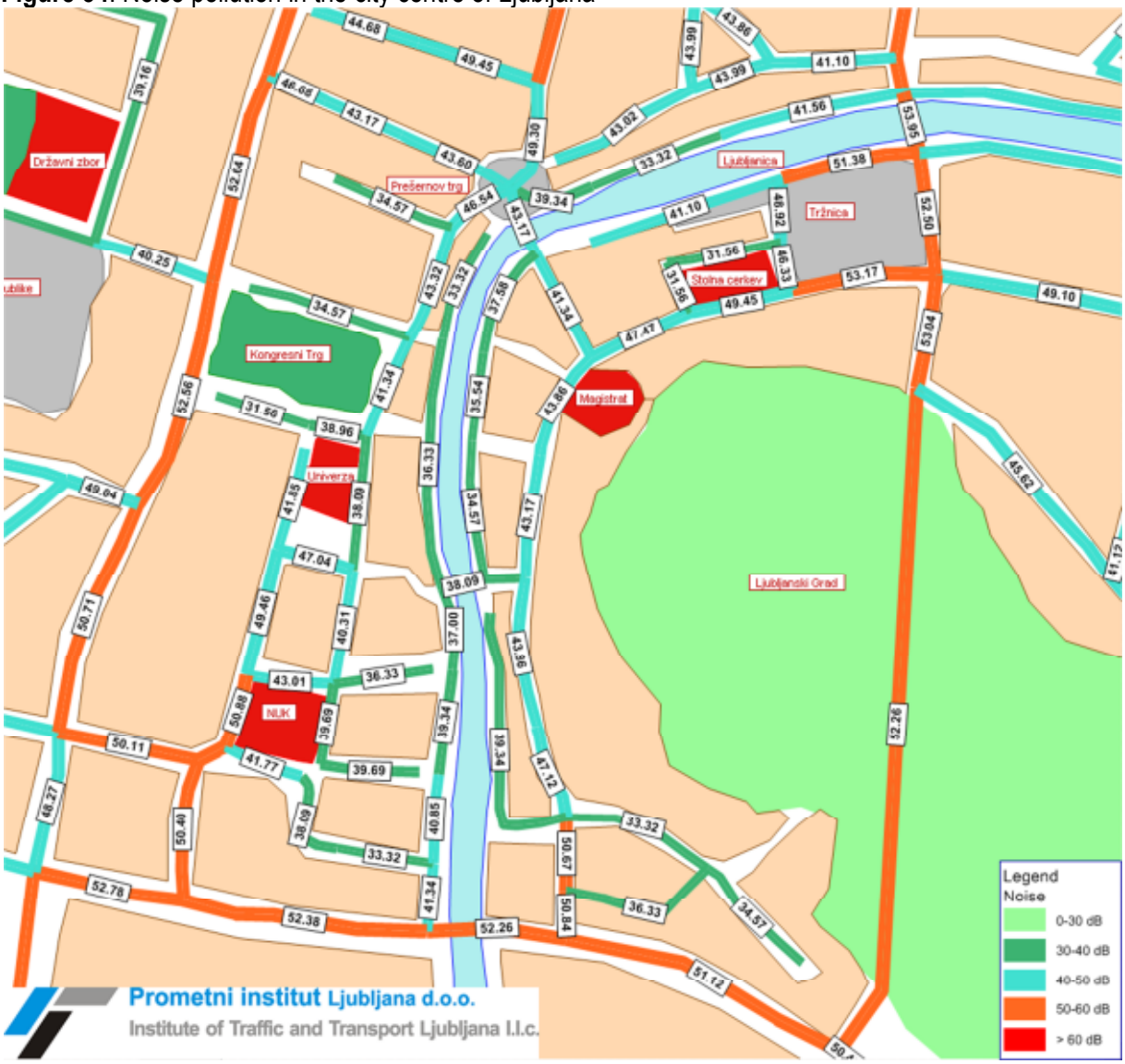
[3] Source: PTV Vision, VISUM 12 – Fundamentals, Karlsruhe, November 2011

The model is fairly simple but sufficient to identify relative variations, that is, how, where, and to what extent traffic-routing and road construction measures affect traffic volumes and, as a consequence, the noise situation of particular roads.

The estimated noise level Ld is calculated for each road for the time of day during the delivery period from 6 to 10 hours, expressed in dB and calculated as follows:[4]

Ld = Ld(25) + Dspeed + Dslope+ Droad + Ddistance +Dhigh + Dground + K

Figure 34: Noise pollution in the city centre of Ljubljana



Source: Prometni institut Ljubljana d.o.o.

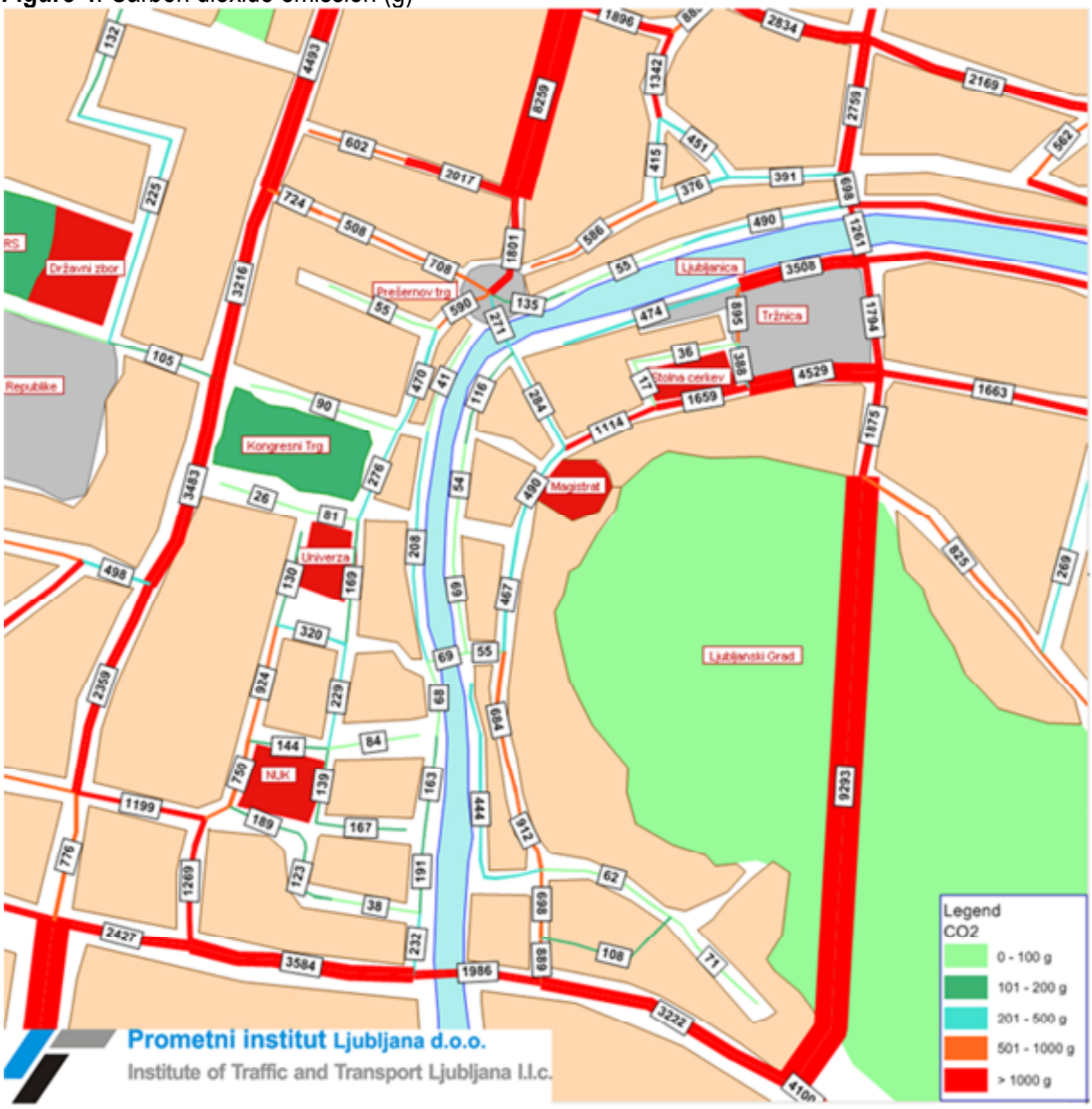
The figure above shows the noise pollution in the city centre of Ljubljana for each street. Most streets of the pedestrian zones belong to the class of intensity of noise between 30 and 50 dB. The intensity of noise is increased at Tržnica and inner city ring formed by the Slovenska, Zoisova in Resljeva street.

[4] Source: PTV Vision, VISUM 12 – Fundamentals, Karlsruhe, November 2011

Carbon dioxide is the most important greenhouse gas. Because of the quantities that are released, it is the main cause of climate change. Usually, it is caused by the combustion of fossil fuels, while the content of carbon is oxidized and released into the atmosphere as a carbon dioxide.

Based on freight vehicle traffic in the city centre some estimates of carbon dioxide were made as depicted in the figure below. Emissions are given in grams, and are depending on the length of the road section, and on traffic volume. The emission values apply to the delivery time in the area of pedestrian zones for a representative working day.

Figure 4: Carbon dioxide emission (g)



Source: Prometni institut Ljubljana d.o.o.

Most carbon dioxide is emitted on roads with higher traffic volumes - at Miklošičičeva street and the tunnel under the Ljubljana Castle. CO_2 emissions in the area of the pedestrian zones, with the exception of Nazorjeva and Tržnica, do not exceed a value greater than 1,000 g on individual sections of the streets.

3.4.1. NO_x emissions

Nitrogen oxides have an important role in the occurrence of air pollution such as acidification, eutrophication and photochemical smog. The main source of nitrogen oxides is urban traffic. Moreover, the concentrations of NO_2 also depend on meteorological conditions and changes over the years. Significant impact on the amount of NO_x is ozone.

The deployment of existing EU legislation gradually leads to a reduction in NO_x emissions. The highest concentrations of NO_2 are measured at highways. With the use of catalysts, emissions have decreased substantially and in urban areas is slowly reaching the required standards.

Emissions of nitrogen oxides on individual road sections on the area of pedestrian zones do not exceed 10 g. Exceptions, where the limits are exceeded are the areas of Miklošičeva, Nazorjeva and Tržnica.

3.4.2. PM_{10} emissions

Particulate matter (PM) is expressed through the dust that is presented in the air during the given period. In winter months, a significant contribution to the emission of particulate matters is made by individual heating appliances, wood and fossil fuels. In recent years, the largest shares of total dust emissions were made by the individual heating appliances. Transport is a major source of pollution with particulate matter, especially in areas with high traffic density.

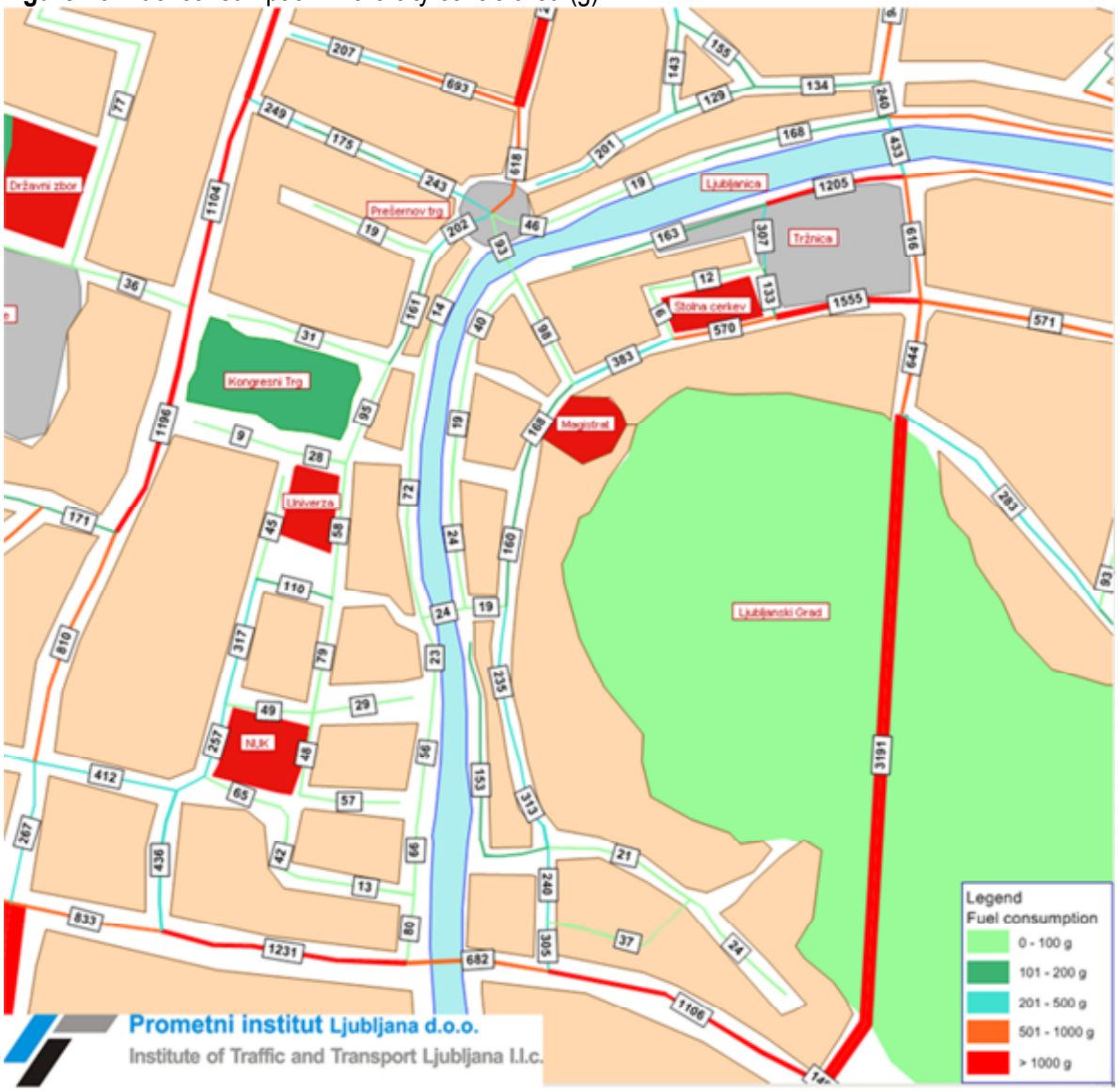
Emissions of particulate matter on individual road sections in the area of the pedestrian zones do not exceed a value of 1 g per section. The exception is Tržnica and Krekov trg and the intersection of Miklošičeva and Nazorjeva street, where particulate matter exceeds the value of 1g.

3.4.3. Fuel consumption

Fuel consumption is an important factor when driving a delivery vehicle. After the consolidation of deliveries fuel consumption should be lower in the area of the pedestrian zones. Fuel consumption is affected by several factors, including: type of vehicle, type of drive derivative, travel speed, driving style, road gradients, loading vehicles, etc.. All these parameters are included in the transport model, which means that the outgoing data traffic model is also on fuel consumption.

An estimation of fuel consumption is shown in the following figure. Fuel consumption is given in grams. Fuel consumption is calculated for delivery time in the area on the pedestrian zones for a representative working day.

Figure 16: Fuel consumption in the city centre area (g)



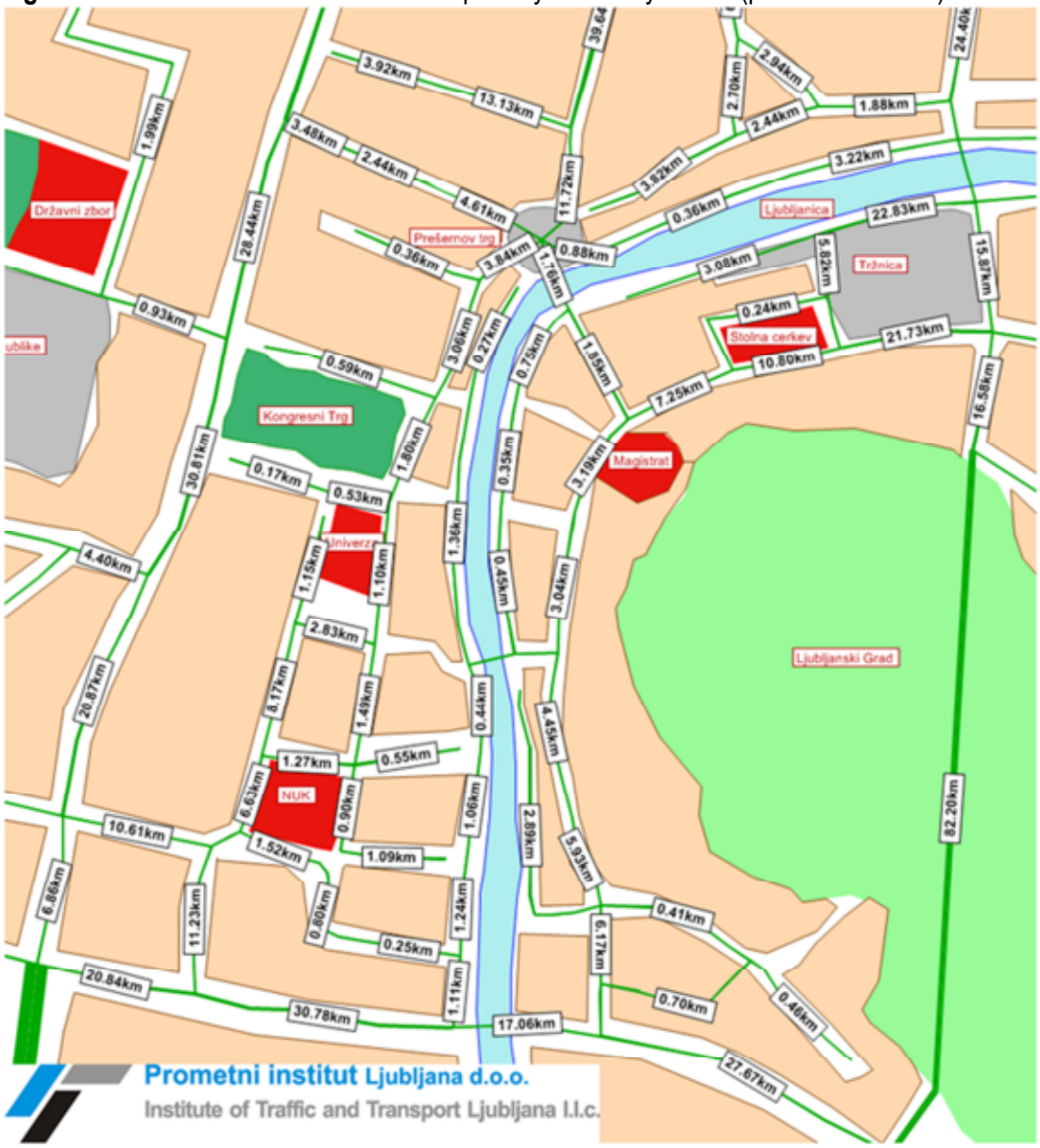
Source: Prometni institut Ljubljana d.o.o.

Fuel consumption depends on the length of the trip and the speed of the delivery vehicles. The average density factor for converting grams of fuel in litres is 820 g/dm^3.

3.4.4. Number of kilometres covered

The estimation of the number of kilometres covered is based on the volume of traffic delivery vehicles on each road segment and on the length of the road section. The number of kilometres covered per day is given in the following figure.

Figure 17: Number of kilometres covered per day in the city centre (pedestrian zones)



Source: Prometni institut Ljubljana d.o.o

3.4.5. Consolidation of goods with an electric delivery vehicle with total weight up to 3.5 tonnes

Between the consolidation centre (BTC) and the area of the city centre (pedestrian zone) it is necessary to transport 8.5 tonnes of consolidated goods per day. To transport such a large quantity of goods an electric delivery vehicle with a total weight up to 3.5 tonnes and with a load capacity up to 1,500 kg can be used. The next load limiter for the calculation the number of runs is also the volume of goods. During the calculation both factors must be taken into consideration.

The consolidation contains different types of goods. In terms of volume utilization it is impossible to achieve 100% utilization. Based on the terrain survey data about utilization, electric delivery vehicle volume utilization is going to be around 75% (restrictions on loading pallets, because of different types of goods). The net mass of goods on the vehicle is estimated at 950 kg which represents 64% of the load capacity of the vehicle.

Based on preliminary data it is necessary to calculate the number of runs that would be made by the electric delivery vehicle on the route between the BTC (consolidation centre) and the pedestrian area in Ljubljana city centre, according to the following equation:

$$\frac{\text{Consolidation goods mass (kg)}}{\text{Net mass of goods on vehicle (kg)}} = \frac{8.515\ \text{kg}}{950\ \text{kg}} = 8{,}96 \approx \textbf{9 runs}$$

If therefore 8.5 tonnes of goods should be transported from the consolidation centre (BTC) to the pedestrian area in the city centre, 9 runs are needed. Since the electric vehicle has to return to the consolidation centre empty, a further 9 return trips should be considered. The total number of electric vehicle runs between the consolidation centre BTC and the pedestrian areas in the city centre are **18 runs** (9 full + 9 empty).

Assuming that the length of the distance BTC - pedestrian zones in the city centre is 5 km, the total length of the transported kilometres made by electric delivery vehicle is 90 km. This total number of kilometres does not include kilometres which are made in the area of the pedestrian zones during the actual delivery of consolidated goods. It is estimated that the electric vehicle would have to drive additionally 55 km per day in the area of the pedestrian zones. The total number of kilometres covered per day would then be 145 km.

The range of electric vehicles currently is only ca. 100 km. For the successful implementation of the consolidation centre two electric delivery vehicles would be required.

3.4.6. Consolidation of goods with an electric delivery vehicle with total weight over 3.5 tonnes

Between the consolidation centre (BTC) and the area of the city centre (pedestrian zone) it is necessary to transport 8.5 tonnes of consolidated goods per day. To transport such a large quantity of goods an electric delivery vehicle with a total weight up to 7.5 tonnes and with load capacity of up to 3,4 tonnes can be used. The next load limiter for the calculation the number of runs is also the volume of goods. During the calculation both factors must be taken into consideration.

The consolidation contains different types of goods. In terms of volume utilization it is impossible to achieve 100% utilization. Based on the terrain survey data about utilization, electric delivery vehicle volume utilization is going to be around 75% (restrictions on loading pallets, because of different types of goods). The net mass of the goods on the vehicle is estimated at 2.200 kg which represents 65% of the load capacity of the vehicle.

Based on preliminary data it is necessary to calculate the number of runs that would be made by the electric delivery vehicle on the route between the BTC (consolidation centre) and the pedestrian area in Ljubljana city centre, according to the following equation:

$$\frac{\text{Consolidation goods mass (kg)}}{\text{Net mass of goods on vehicle (kg)}} = \frac{8.515\ \text{kg}}{2.200\ \text{kg}} = 3{,}87 \approx \textbf{4 runs}$$

If therefore 8.5 tonnes of goods should be transported from the consolidation centre (BTC) to the pedestrian area in the city centre, 4 runs are needed. Since the electric vehicle has to return to the consolidation centre empty, a further 4 return trips should be considered. The total number of electric vehicles runs between the consolidation centre BTC and the pedestrian areas in the city centre are **8 runs** (4 full + 4 empty).

Assuming that the length of the distance BTC - pedestrian zones in the city centre is 5 km, the total length of the transported kilometres made by electric delivery vehicle is 40 km. This total number of kilometres covered does not include kilometres, which are made in the area of the pedestrian zones, during the actual delivery of consolidated goods. It is estimated that the electric vehicle would have to drive additionally 25 km per day in the area of the pedestrian zones. The total number of kilometres covered per day is 65 km.

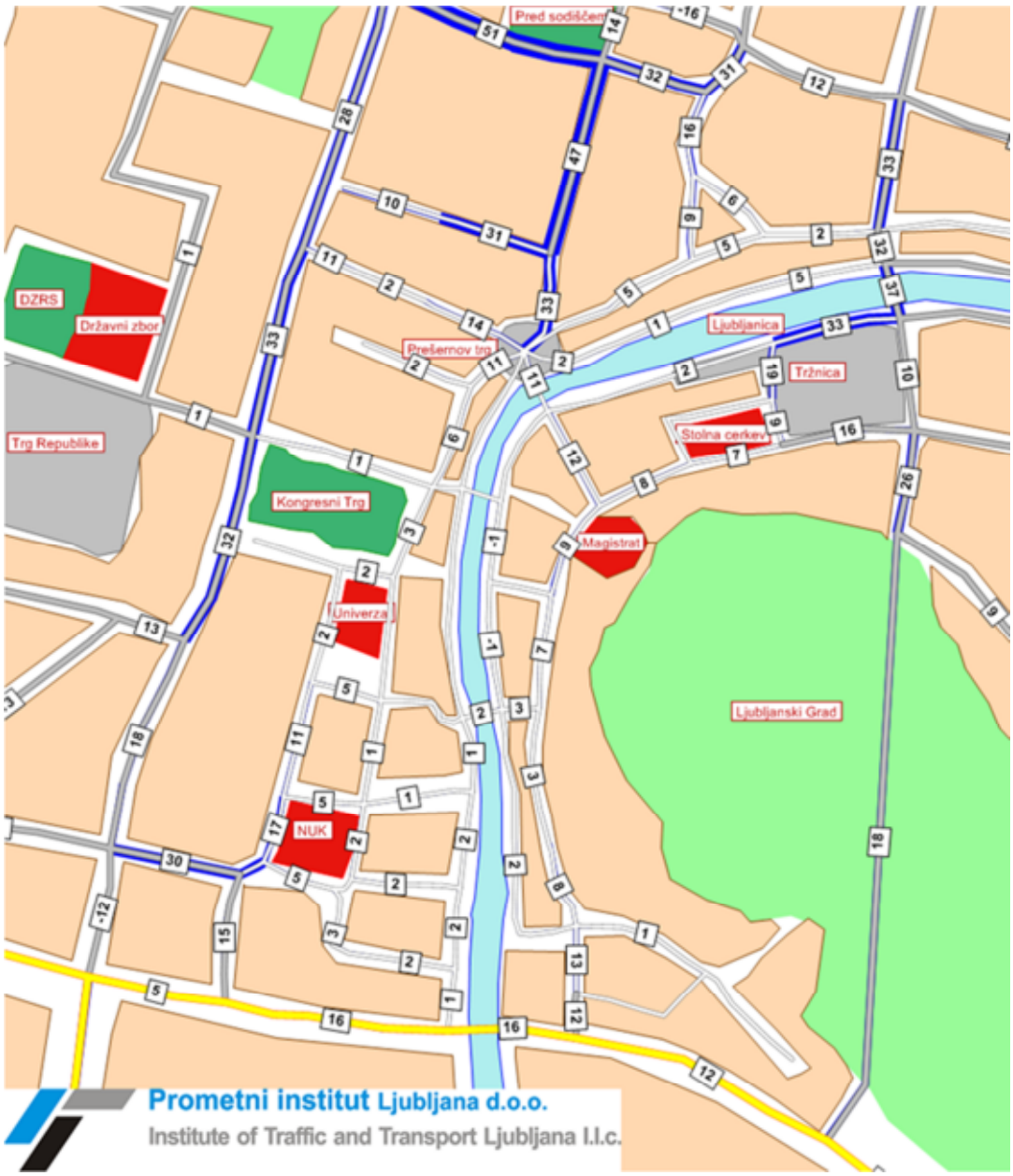
The range of electric vehicles currently is ca. 160 km, so, there is no need to recharge the batteries during day. For the successfully implementation of the consolidation centre one electric delivery vehicle would be required.

3.5. EMISSION SAVINGS IN PEDESTRIAN AREAS

3.5.1. Estimation of the reduction of the total number of delivery runs

Based on the consolidation of delivery vehicles and the construction of new matrices and calculated resistance network a simulation was carried out over the choice of run. The distribution of traffic within the network was carried out by the same equilibrium method as in the current situation. The figure below shows the reduction of the numbers of delivery vehicles runs, powered by liquid fuel.

Figure 18: Estimation of the reduction in the number of delivery runs



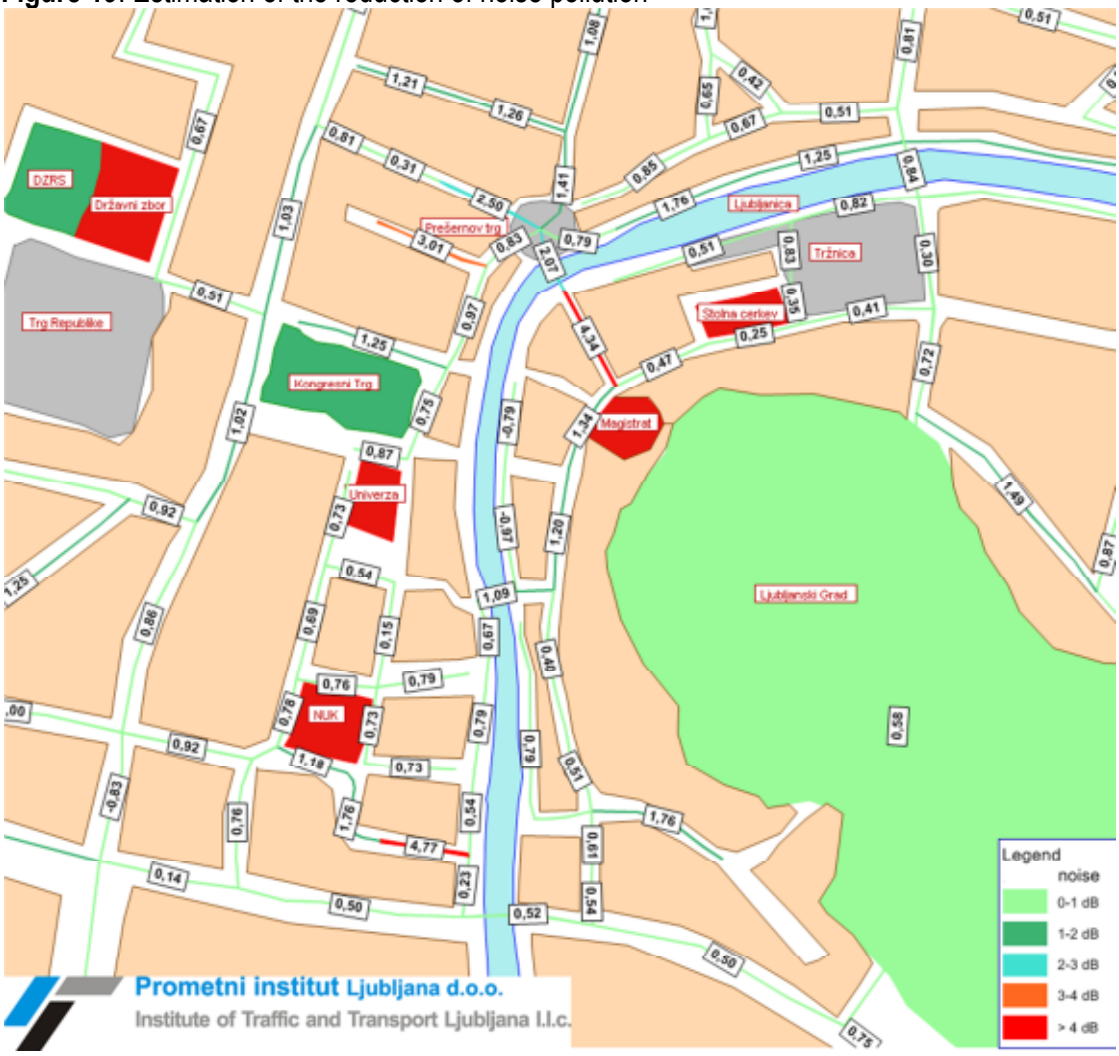
Source: Prometni institut Ljubljana d.o.o.

The previous figure shows the difference in the number of runs of delivery vehicles before and after the consolidation, on a daily basis. The electric vehicles are not included in the traffic volume.

3.5.2. Estimation of the reduction of noise pollution

An assessment of the noise pollution of the delivery vehicles is determined by a calculation on the basis of traffic volume data, road links, the structure of the traffic and vehicle speed. The figure below shows the noise reduction in decibels.

Figure 19: Estimation of the reduction of noise pollution



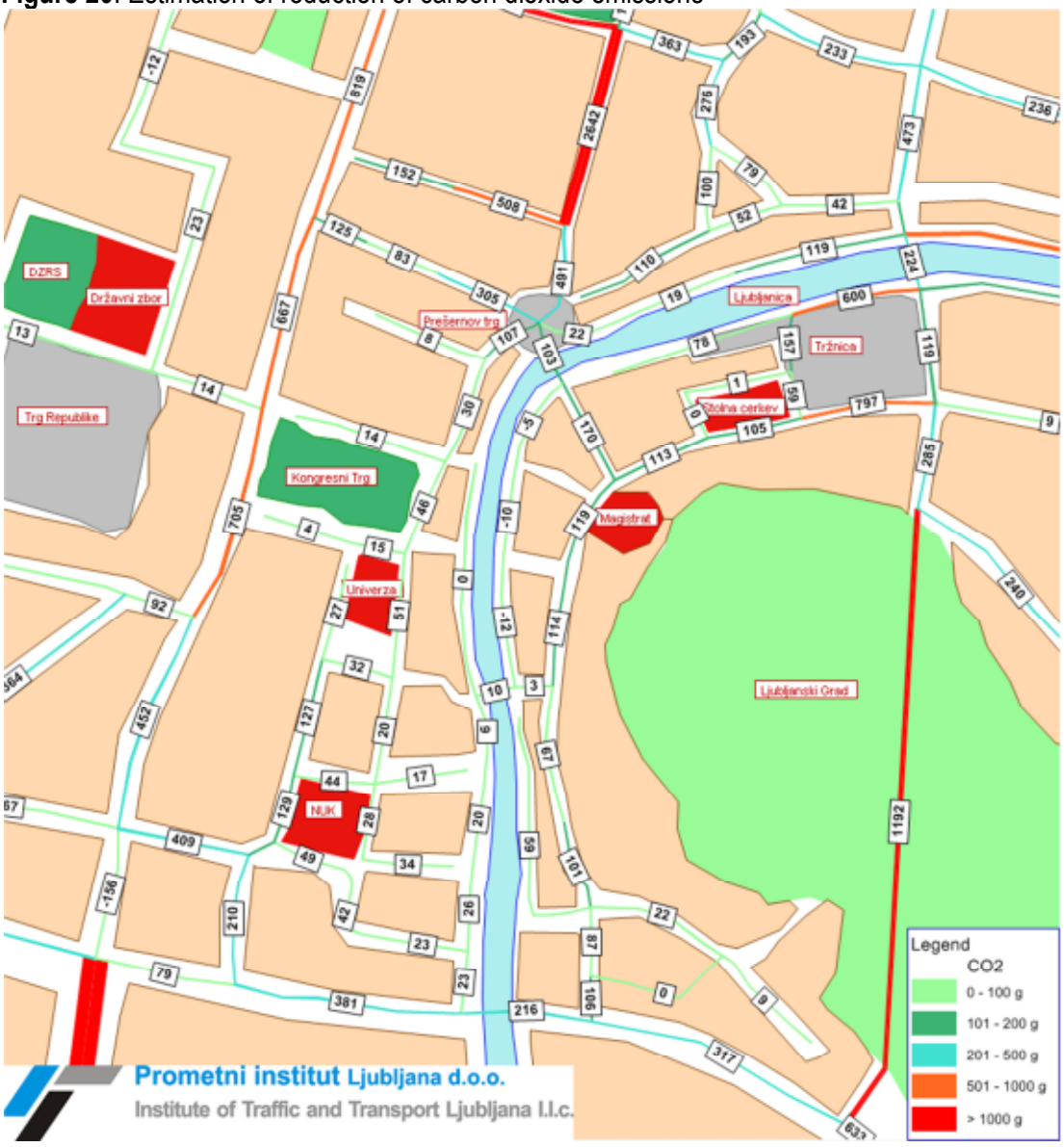
Source: Prometni institut Ljubljana d.o.o.

The previous figure shows the difference regarding noise pollution in the city centre before and after the consolidation. The electric vehicles are not included in the reduction of noise pollution.

3.5.3. Estimation of reduction of CO_2 emissions

The reduction of carbon dioxide emissions in the pedestrian area is a result of the reduction of transport delivery vehicles running on liquid fuels. Differences in emissions are given in grams and depend on the length of the road section and traffic volume.

Figure 20: Estimation of reduction of carbon dioxide emissions



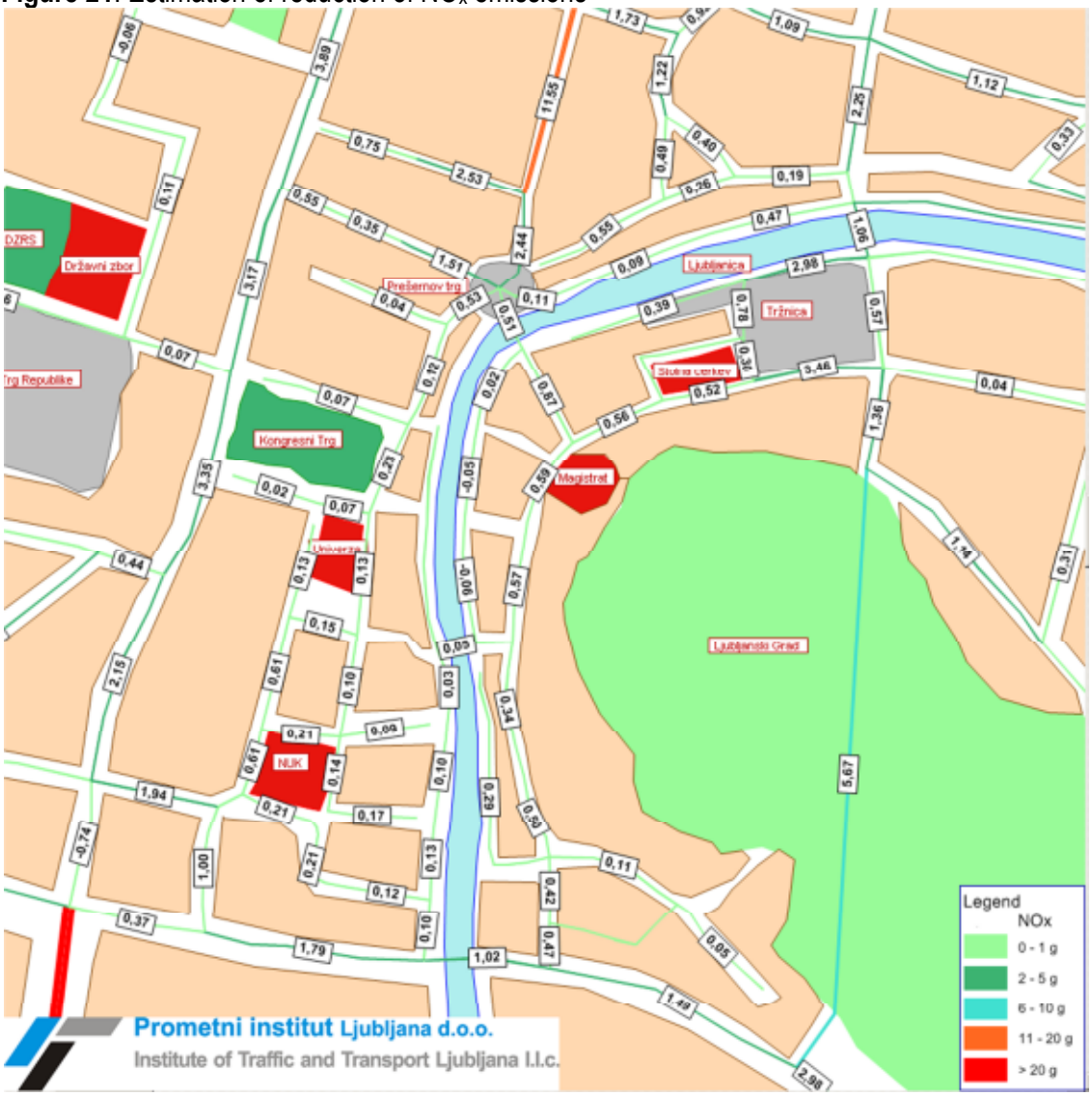
Source: Prometni institut Ljubljana d.o.o.

The largest reduction of carbon dioxide was detected on roads with higher traffic volume - Miklošičeva street, and tunnel under the Ljubljana Castle. CO_2 emissions in the area of pedestrian zones are reduced, with the exception of Cankarjevo nabrežje, where a slight increase due to a different redistribution of the traffic.

3.5.4. Estimation of reduction of NO_x emissions

The estimation of the reduction of NO_x emissions is given according to the difference in the number of vehicles before and after the consolidation. The estimated differences of nitrogen oxide emissions are given in the following figure. The difference is given in grams, depending on the length of the road section and traffic volume.

Figure 21: Estimation of reduction of NO_x emissions

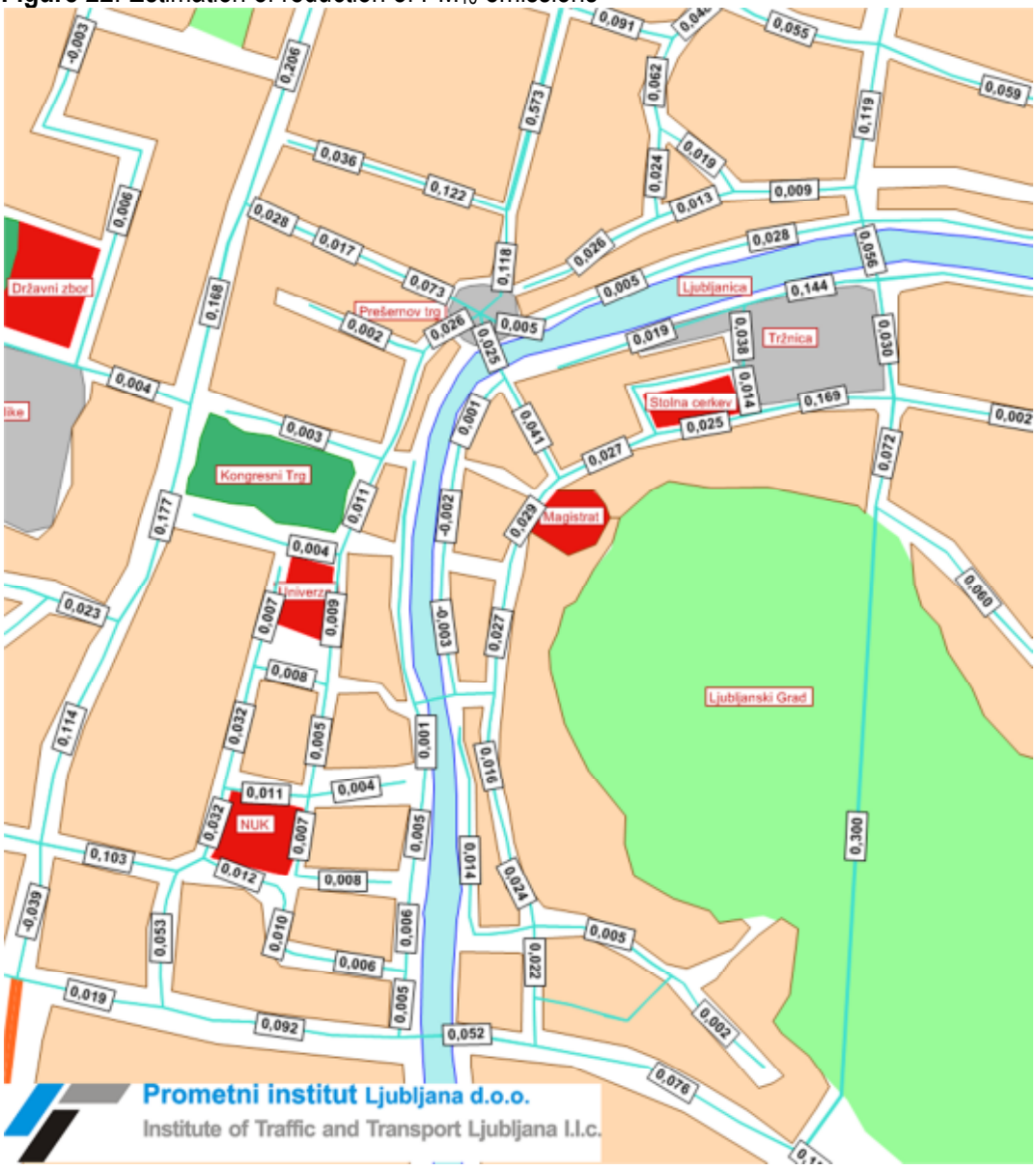


Source: Prometni institut Ljubljana d.o.o.

3.5.5. Estimation of reduction of PM_{10} emissions

The estimation of emission reductions of particulate matter PM_{10} is given in accordance to the difference in delivery vehicles, before and after the consolidation. The estimated difference of nitrogen oxide emissions is given in the following figure in grams.

Figure 22: Estimation of reduction of PM_{10} emissions



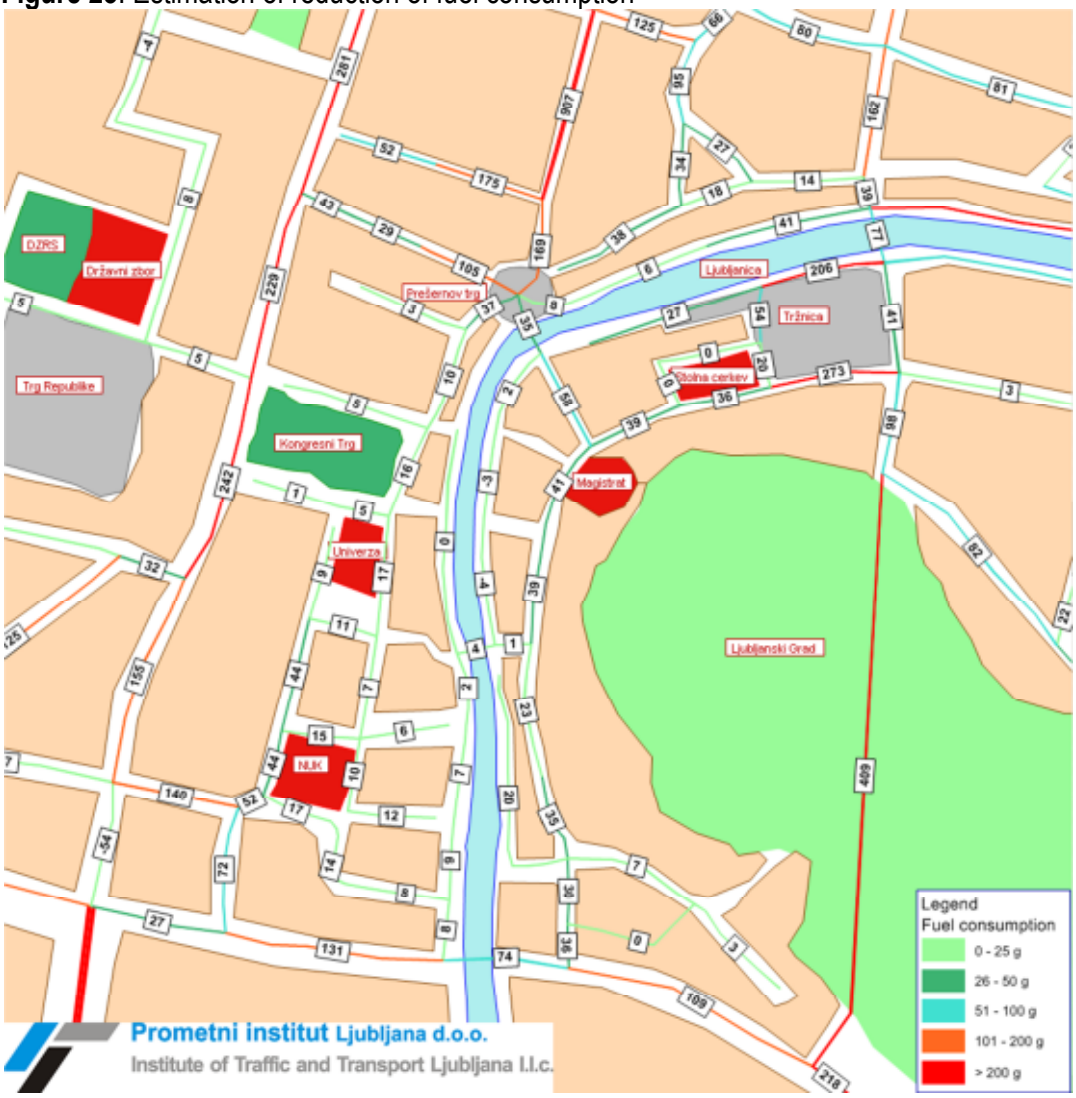
Source: Prometni institut Ljubljana d.o.o.

Differences in the emissions of particulate matter do not exceed 1 g per road section in the pedestrian area.

3.5.6. Estimation of reduction of fuel consumption

As part of the consolidation of deliveries an important factor is also the reduction of fuel consumption for vehicles, powered by liquid fuels. The following figure shows an estimation of the reduction of fuel consumption in grams.

Figure 23: Estimation of reduction of fuel consumption



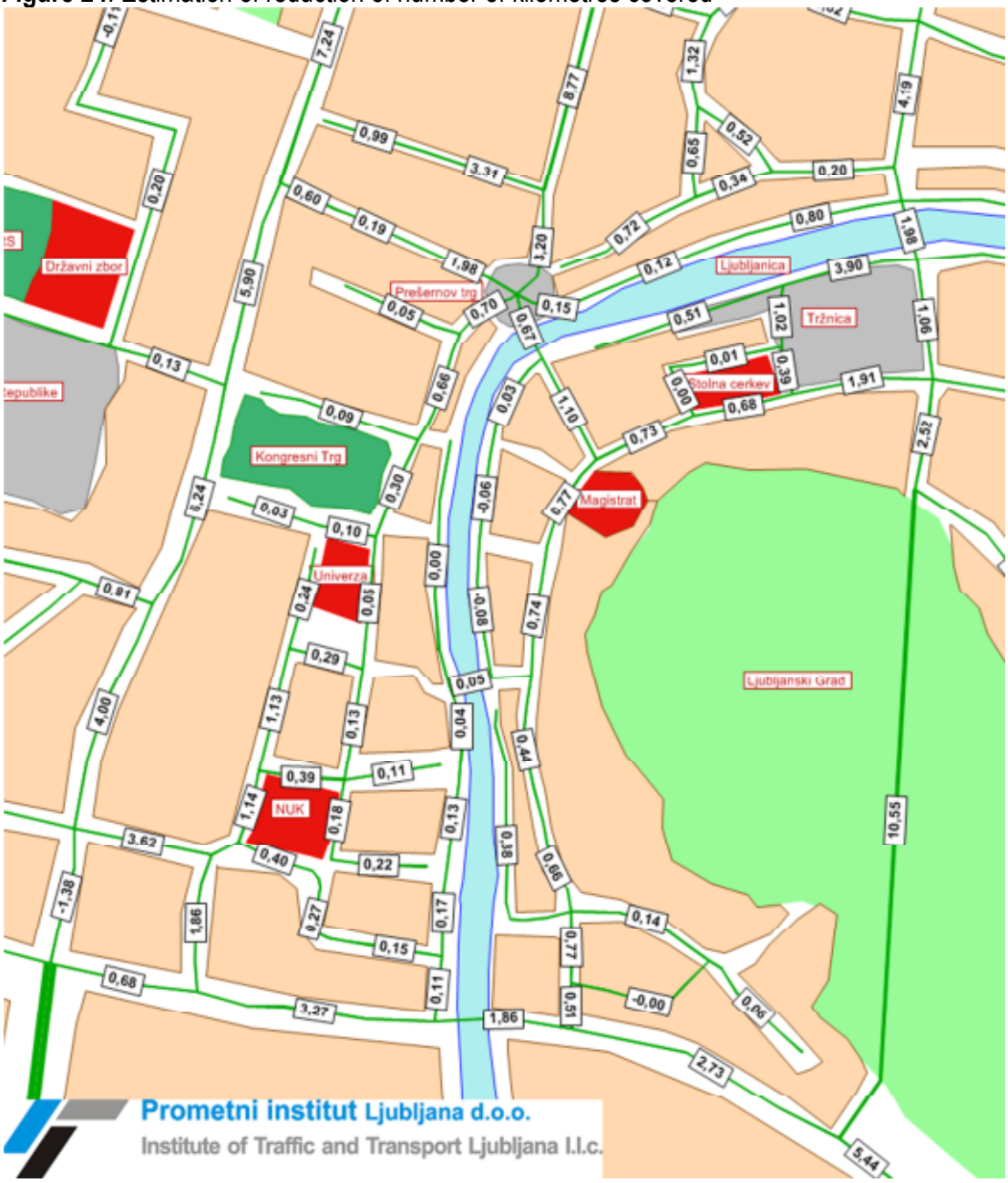
Source: Prometni institut Ljubljana d.o.o.

The average density factor for converting grams of fuel in litres is 820 g/dm^3.

3.5.7. Estimation of reduction of number of kilometres covered

The reduction of the number of kilometres covered based on the volume of traffic delivery vehicles before and after the consolidation. Electric vehicles kilometres are not taken into consideration.

Figure 24: Estimation of reduction of number of kilometres covered



Source: Prometni institut Ljubljana d.o.o.

3.6. CONSOLIDATION SAVINGS ABSTRACT

In accordance with the objectives of measure 7.2-LJU of the CIVITAS ELAN project it is planned to reduce the number of delivery runs and emissions caused by delivery vehicles, powered by liquid fuel. The target values of the reduction are as follows:

- Reduction of number of runs by 20 %,
- Reduction of CO_2 emission by 15 %,
- Reduction of NO_x emission by 15 % and
- Reduction of particulate matter PM_{10} by 15 %.

A comparison of the number of runs by vehicles (powered by liquid fuel) before and after the consolidation shows:

No. of runs before consolidation	→	1.045
No. of consolidated runs	→	188
No. of runs after consolidation	→	857
Percent of reduction	→	18%

It should be noted that electric vehicles are not included. Given the two studied variants of electric vehicles, the total weight up to 3.5 tonnes and more than 3.5 t, the following runs should be considered:

"Var 1": No. of runs electric van up to 3.5 t	→	18
"Var 2": No. of runs electric van over 3.5 t	→	8
Percent of reduction of runs "var 1"	→	16.3%
Percent of reduction of runs "var 2"	→	17.2%

A comparison of the results of reducing the number of runs from the traffic model and the objectives of measure 7.2-LJU has shown minimal tolerance towards reducing the number of journeys. From this perspective it can be stated that the results of the transport model satisfies the basic measure objective of reducing the number of runs in the pedestrian area of the city centre of Ljubljana.

The traffic model has also made a difference in emissions for the existing situation (situation without consolidation) and the situation after the completion of the consolidation. Results are given in the table below on a daily basis.

Table 1: Emission comparison before and after delivery consolidation (daily)

	CO_2 (g)	NO_x (g)	PM_{10} (g)	Fuel consumption (g)	Number of kilometres covered
Current situation	30.250	147,206	7,230	10.387	197,164
Situation after consolidation	24.911	120,869	5,942	8.554	129,328**
Difference	5.339	26,337	1,288	1.833	67,836
Reduction %	17,6	17,9	17,8	17,7	34,4

Source: Prometni institut Ljubljana d.o.o.

** Electrical vehicle kilometres are not included in situation after consolidation.

After consolidation CO_2 emissions are reduced by 5.34 kg/day or 17.6%. NO_x emissions are reduced by 26 g or 18%. Emissions of particulate matter PM10 are reduced by 1.3 g or 17.8%. Fuel consumption decreases by 2.2 litres per day or 17.7%. Regarding the reduction of the number of kilometres covered it should be mentioned that the kilometres caused by electric vehicles are not taken into consideration. The kilometres after consolidation are higher by 55 or 25 km, depending on the choice of electric vehicles (up to 3.5t or over 3.5 t).

The situation of emission after consolidation of deliveries is reduced from 17 to 18%, which means that the results are in line with the objectives of measure 7.2-LJU.

When transferring daily data on an annual level, the number of deliveries during the working day and during the end of the weekend must be taken into consideration.

A comparison of emissions on an annual level before and after consolidation is shown in the following table.

Table 2: Comparison of emissions before and after consolidation (annual level)

	CO_2 (kg)	NO_x (kg)	PM_{10} (kg)	Fuel consumption (l)	Number of kilometres covered
Current situation	8,045	39.14	1.92	3,369	52,435
Situation after consolidation	6,625	32.14	1.58	2,774	34,394**
Difference	**1,420**	**7.00**	**0.34**	**595**	**18,041**

Source: Prometni institut Ljubljana d.o.o.

** electrical vehicle kilometres are not included in situation after consolidation

Based on annual data from the consolidation of goods on the pedestrian area 1,420 kg of CO_2, 7 kg of NO_x emissions, 0.34 kg of particulate matter PM_{10}, and 595 litres of fuel could be saved.

4. ANNEXES

4.1 Questionnaire for delivery drivers

Anketni list ❶

Ankete izvajal (ime in priimek) _____

CiViTAS ELAN

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Zap. Št.	Registrska oznaka	Podatki o vozilu Vrsta D-K-T	Pogon B-D	Vrsta blaga (napis na vozilu...)	Izkoriščenost (%) nakladalnosti vozila	Posamezna anketa izvedena v coni (glej sliko)	Začetna destinacija (mesto, del mesta, kraj ali ulica odhoda)	Naslednja destinacija (mesto, del mesta, kraj ali ulica odhoda)
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
11.								

4.1 Counting sheet (example for counting location Nr. 1)

CiViTAS ELAN

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ŠTEVNO MESTO ❶ - Trubarjeva ulica in Petkovškovo nabrežje

Začetek štetja (ura): _____

Konec štetja (ura): _____

Promet štel (ime in priimek): _____

Zap. Št.	Registrska oznaka	Podatki o vozilu Vrsta D-K-T	Pogon B-D	Vrsta blaga (napis na vozilu...)	Izkoriščenost (%) nakladalnosti vozila	Ustrezno obkljukaj Vstop	Izstop	Smer vstopa ali izstopa (glej sliko)	Cona vstopa ali izstopa (št. cone – glej sliko)	Ura vstopa ali izstopa
1.						☐	☐			
2.						☐	☐			
3.						☐	☐			
4.						☐	☐			
5.						☐	☐			
6.						☐	☐			
7.						☐	☐			
8.						☐	☐			
9.						☐	☐			
10.						☐	☐			
11.						☐	☐			