Is There a Chance to Limit Transport in Slovenia in the Light of the Climate Change? Top Down Approach for Personal Vehicles

Marko Kovač, Matjaž Česen, Andreja Urbančič, and Stane Merše

Abstract—**Slovenia is a quite transport intensive country. Due to its geographic location it attracts a lot of transit traffic, however even bigger issue might be mostly car-oriented development of traffic in the last 50 and more years. The motorisation rate is still increasing, however even smaller cities are facing long congestions. Slovenian National Energy and Climate Plan anticipates large reduction of greenhouse gasses either through switch to sustainable transport or relying on alternative fuels as renewable electricity or synthetic gasses. The paper demonstrates the somewhat ambitious plan dissected to the local community level while taking local specialties into the account.**

Index Terms—**Transport, emission reduction, municipalities, statistics.**

I. INTRODUCTION

The amount of traffic in Slovenia is in perpetual increase for the last of 20 years. However, this trend can be traced even decades ago [1], [2] when city planners gradually decided to phase out not-bus public transportation, state neglected railway infrastructure and heavily supported road construction consequently supporting individual transport. Greenhouse gas emissions in the Slovenian transport sector have thus been increasing in recent decades as a result of economic development, country geographical position as a transit country, structure of settlements and, in most cases, inferior or even lack of alternative modes of passenger and freight transport.

Personal transport based on passenger car transport causes daily congestion in peak times, especially around Ljubljana [3]. These are noticeably increasing, further contributing to rising emissions. The increasing external costs caused by transport call for action beyond the scope of the fight against climate change.

The lack of integrated planning and, above all, lacking implementation of the in the past already planned measures caused the progress of reducing emissions to rely mainly on the progress of vehicle technology. Furthermore, Slovenia is crossed by number of international transport corridors, and being small country it has limited impact on the transit traffic.

Emissions from transport already exceeded the emissions from 1986 by more than 200% in 2008, subsequently declining slightly, but transport remains the only sector with such high emissions growth. According to the latest 2017 data [4], greenhouse gas (GHG) emissions are 5.54 Mt CO_2eq, which is 25% more than in 2005 (baseline emissions), with road transport accounting for 99.3% of total emissions in the transport sector, other transport (rail, air, other) less than 1%.

Slovenia had put their commitment towards reduction of GHG emissions into the National Energy and Climate Plan (NECP) [5]. The efficient plan is hence crucial in addressing the transport issue. In the first step, Slovenia will favor long-time neglected rail transport and sustainable mobility measures to tame the continued growth of road traffic (passenger and freight), following by strong support to promote other sustainable mobility options. This will reduce the carbon footprint in the transport sector and also relieve heavy traffic, which is quickly becoming unmanageable. None the less, the main measures that will provide emissions reductions will be efficiency improvement of vehicles and increasing the share of alternative drivetrains, mainly electric.

By 2050, the transport sector needs to be almost fully decarbonised with the net GHG emissions close to zero. This also causes that by 2030, the emissions are expected to decrease by 10% compared to 2017, however this would still exceed base emissions by 146%. In addition, by 2050, the emissions should fall to only 2.4% of base emissions. The latter data represents as many as two magnitudes smaller emissions than the present ones, which will undoubtedly be an extremely challenging feat that will require comprehensive and, above all, far more ambitious measures (not only financial but also social and long-time efforts) than we might imagine today.

Slovenia is combining local and national approaches to significantly reduce the diesel and gasoline in favour of electric (including plug-in) or hydrogen vehicles. Local incentives such as charging infrastructure, special quick lanes, free parking or no congestion charge and encouraging usage of public transportation seem to be easier to implement.

The statistical approach described in this paper helps better predict local specifics and hence improve the effect of incentives.

II. TOP-DOWN APPROACH

While nation-wide efforts are necessary for multi-government approach, the majority of transport problems are, at least in majority cases, quite local experience. For instance, personal public transport (PPT) in a city solves local congestion and emissions. At the same time the goals of

the NECP cannot be directly translated towards the local level due to local features [6]. Furthermore, local knowledge and understanding about those problems is usually quite larger than on regional or even national level, including already tried but unsuccessful solutions [7].

There were many attempts already addressing the situation: e.g., strategy for alternative fuels [8], renewable energy regulation [9] etc. The main problems with those approaches were that they tend to address only limited problems (e.g. emissions or traffic congestion etc.) while other related issues and limitations could be ignored.

The main aim of the presented paper is the transfer of the national goals related to personal transportation to the level of municipalities. These enables local authorities to combine efforts and taking local issues into the account (specific issues due to development; local & regional, roads density combined with existing transportation modes, plans for future development etc). Quite important are also synergies with other long-time efforts and strategies connected to traffic (e.g., road safety, population aging etc). Support of the local efforts is therefore necessary to achieve national wide goals.

A. Description of Data

For the purpose of this research we used different data sources in public domain. They are available for each municipality (214 of them) and consist of [10]:

- Municipality road density
- Categorization and length of the road network
- Motorization rate
- Population with dissection regarding age (active, younger, older)
- Average monthly pay
- Share of cars with different drive (e.g., ICE, BEV etc.)

TABLE I: THE CORRELATION ANALYSIS ON SOME MUNICIPALITY DATA

	BEV share	Motorization rate	Share of active population	Average monthly pay
BEV share	1.000			
Motorization rate	0.116	1.000		
Share of active population	-0.084	0.060	1.000	
Average monthly pay	0.045	-0.055	-0.122	1.000

The first step was to find possible correlations between mentioned data set. Multiple factor correlation analysis was performed. The results are shown in Table I.

In addition, Fig. 1 shows correlations of sets of motorization rate, share of active population, average monthly pay and share of BEV for all Slovenian municipalities. The largest Slovenian towns are marked with labels and linear trendline is shown, however no significant correlation could be obtained.

The analysis shows only very limited correlations between those data therefore multi regression analyses was needed. However, municipalities in Slovenia are quite heterogeneous, therefore some modal split of municipality size might be of interest. For instance, municipality size

could be divided into three sizes: large (over 20 000 inhabitants) and small towns (over 10 000 inhabitants) and smaller municipalities (less than 10 000 inhabitants). For some parameters, such as weighted road density and average monthly pay, the size of municipality plays hardly any role, as shown in Fig. 2.
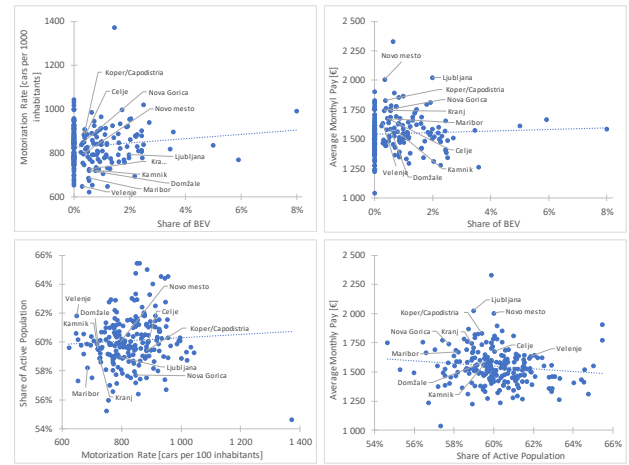

Fig. 1. Correlations of sets of motorization rate, share of active population, average monthly pay and share of BEV.

Fig. 2. Correlations of sets of BEV share, weighted road density and municipality size.
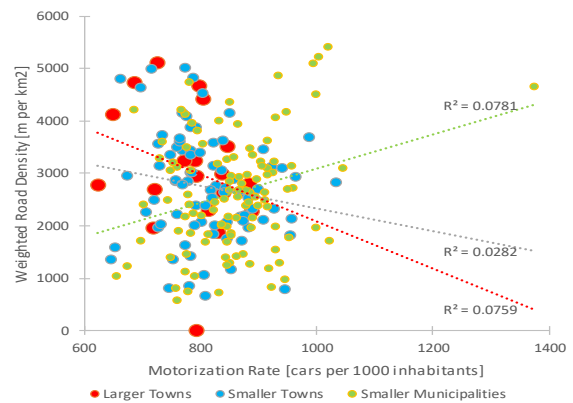

Fig. 3. Correlations of sets of motorization rate, weighted road density and municipality size.

Fig. 3 shows correlations between the sets of motorization rate, weighted road density, keeping the same split on municipality size. For smaller municipalities the motorization rate is corelated with road density (this is common know effect that more roads attract more traffic especially in areas where public transportation is weak or none-existent). For larger towns this relation is quite reversed – higher density causes less motorization rate since part of the

traffic can be made with public transport and sustainable mobility.

The same division of municipality by size also effects the battery electric vehicle (BEV) share, shown in Fig. 4.
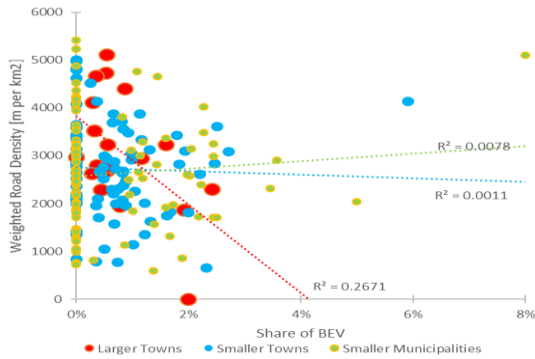

Fig. 4. Correlations of sets of BEV share, weighted road density and municipality size.

Hence, other influences on the BEV share were not discovered. The main reason for that is probably still low penetration of BEV in Slovenia. The market share is around 1 %, while the fleet share is 0.1 %. However, both shares are increasing so better results could be obtained in a reasonable time.

The influence of the analysed parameters on the BEV share is summed in Table II.

TABLE II: THE INFLUENCES ON BEV SHARE IN SLOVENIA

Influence	Qualitative	Note
Town/Municipality size	YES	Up to 30%
Motorisation rate	NO	~1%
Share of active population	NO	<1%
Average monthly pay	NO	<1%
Weighted density of road network	NO	~1%

Vehicle stock replacement dynamics can be partially connected to current car stock age. Fig. 5 shows age of current car stock.
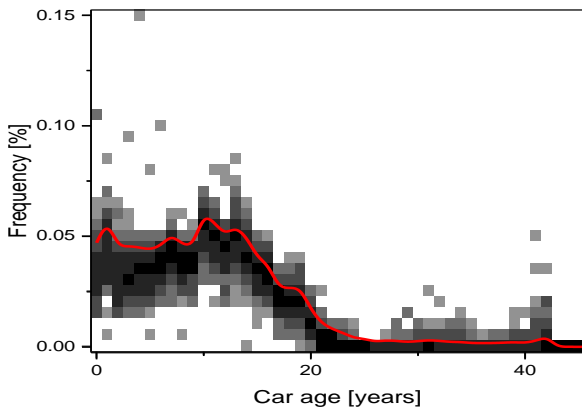

Fig. 5. Average age of the cars with heat map regarding frequency.

There is a large spike in cars older than 12 years old. This is the consequence of open market on imports of used cars from other EU countries after Slovenia joined the EU. This can be – if necessary – modelled as one-off moment. Some

bumps in cars age can be also contributed to market crises or/and change of tax laws, which could boost sell of new cars on particular year by some margin. Therefore, due to large number of special sales occurrences, the special (i.e., car-by-car) model would be an overkill, we relied on projections as part of NECP.

B. Car Number Growth/Decline

Number of cars N_i^m for each municipality m by year is defined by year-to-year basis as:

$$N_i^{\ m} = N_{i-1}\bullet(1+y_g)\bullet y_m \qquad (1)$$

where i defines the year and γ_g is general growth/decline, while γ_g defines municipality specific growth. This is defined as simple linear function dependend on starting growth γ_0 and incremental change $\Delta\gamma$:

$$y_{g,i} = r_0 + \Delta r \bullet i \qquad (2)$$

However, the size-specific growth is defined that at the end of period (year 2050) the number of the cars is the same as in case without size-specific growth:

$$N_{2050}^{\ m} = const, m = \{1,2,3\} \qquad (3)$$

III. RESULTS AND DISCUSSION

Fig. 5 shows projection of number of personal vehicles until 2050 in Slovenia regarding their energy storage. The prevailing diesel and gasoline engine will be replaced with BEV and partially by PHEV and hydrogen vehicles. However, even PHEV are expected to be phased out latter in the century. In addition, we expect some decrease on the number of the whole fleet of personal vehicles after some positive measure for PPT, sustainable mobility and mobility as a service are well received.
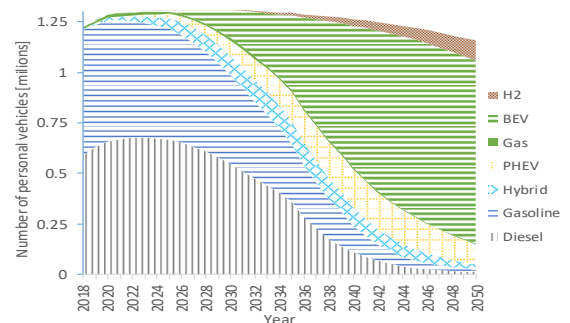

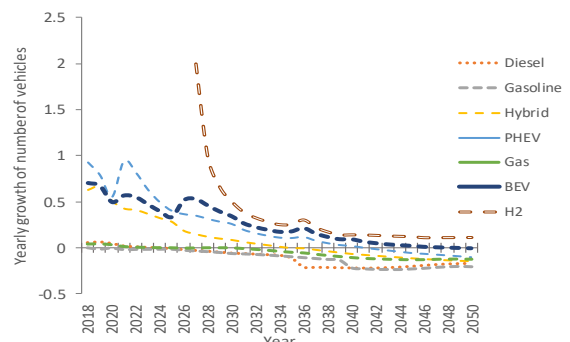Fig. 5. Projection of number of personal vehicles until 2050.

Fig. 6. Growth/decline of projected number of cars until 2050.

Fig. 6 shows growth/decline of projected number of cars until 2050 in Slovenia regarding their energy storage (in a form of γ_g – general growth/decline, see eq. (1)). The data shows increase of share of cars with less emissions (BEV, PHEV and hybrid cars), while fossil fuel cars will almost vanish by the mid of the century.

By taking eq. (2) and eq. (3) into the account, relative yearly growth of number of BEV cars can be calculated for three different municipality sizes. Fig. 7 shows the results for large and small towns and smaller municipalities.
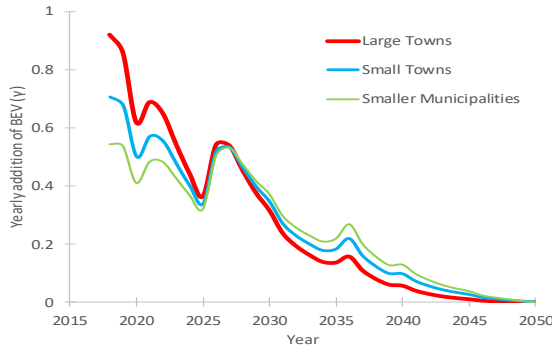

Fig. 7. Relative growth of projected number of BEV cars until 2050.

The growth can then be calculated into BEV car figures or at least car index, since exact car figures would be different from one municipally to the next. Fig. 8 therefore shows indexes of projected number BEV cars in Municipalities of different sizes based on its size.
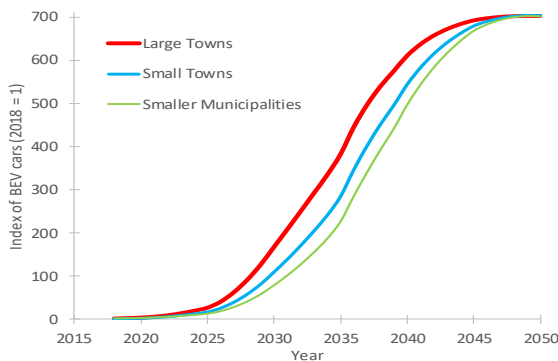

Fig. 8. Index of BEV cars until 2050.

While this prediction looks a bit rough since only relies on couple of data: municipality size, starting number of BEV and national wide projection of growth of numbers of BEV cars, it can still help different municipalities to plan accordingly.

This sort of information also helps with guiding local efforts for targets on emission. It seems that emission control again is a bit simpler in larger towns (where somewhat useful public transportation exists) than in smaller communities.

Table III shows projection of number of BEV in some typical municipalities. The representatives for large towns are Ljubljana or Novo mesto, for small towns Ajdovščina or Železniki, while smaller municipality is represented by Borovnica or Vransko.

From the results one can see that there is a large emphasis of this method on number of BEV already in the municipality, however this number is not statistical related to other data (see Table I). Therefore, some additional statistical data is needed to give a better local evaluation of number of BEV or

other statistics, which might help us to be better prepare for the future at local level.

TABLE III: PROJECTION OF NUMBER OF BEV IN SOME MUNICIPALITIES

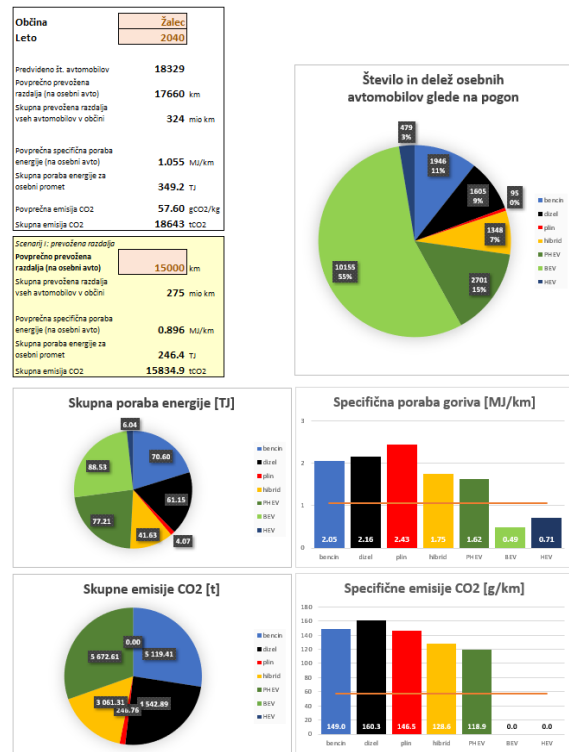|	2018	2020	2030	2040	2050
Ljubljana	221	666	36828	134819	155211
Novo mesto	4	12	667	2440	2809
Ajdovščina	8	20	873	4349	5618
Železniki	1	3	109	544	702
Borovnica	2	4	156	993	1405
Vransko	0	1	47	298	421

Fig. 9. Municipality dashboard.

The presented approach can be used to create simple tools – such like a dashboard, which can be used by municipalities for quick overview of the situation (prediction of EV share, emissions etc.) as shown in Fig. 9. This enables quick recall of local targets and limited what-if scenario to set the properly timing and extent of the local incentives for encouraging electrification of transport (such as public charging infrastructure, parking spaces, congestion charges [11]).

IV. CONCLUSIONS

The aim of this research was to help municipalities and local communities to get information about change in their personal vehicles fleet. This information can enable them to predict and execute measures in the transport sector, which are in accordance with National Energy and Climate Plan (NECP), This will enable efficiently reduce the emissions of greenhouse gasses on the local and also national level (bottom-up approach) but also help acting upon raising local traffic problems (such as congestion, pollution etc.)

The approach showed how the national wide data could be

used together with additional locally specific data to obtain more focused projections. This data could in essence help shape up the local enforcements like replacement of classic fossil fuels stations with less upsetting charging stations (due to lack of necessary safety precautions while dealing with flammables).

For this purpose, we rely on statistical approaches that helped determined significant parameters (e.g., town/municipality size). Another important data, which might get used in the future, is quite homogenous non-influence of large other data (e.g., pay height, road density etc.). It seems that, at least for case of Slovenia, the most important influences are the national wide-ones, while local influences are limited.

The results were showed as typical fleet number (i.e., index) in representative municipalities (larger and smaller town, smaller municipality) from now until 2050.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Andreja Urbančič conceived a general idea and encouraged Marko Kovač to developed the calculation and performed the computations. Matjaž Česen is the source of data and future projections. He also verified the analytical method. Stane Merše supervised the findings of this work. Marko Kovač and Matjaž Česen wrote the paper. All authors had approved the final version.

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Marko Kovač has bachelor's degree in mechanical engineering from Faculty of Mechanical Engineering and Ph.D in nuclear engineering from Faculty of Mathematics and Physics, both of University of Ljubljana.

He is at the moment employed as a senior researcher at Efficiency Emergency Center of Jožef Stefan Institute. His research interests are automotive (mostly electric) and photovoltaics.

Dr. Kovač won several rewards by Slovenian Chamber of Commerce and industrial companies.

Matjaž Česen has a bachelor's degree in meteorology from Faculty of Mathematics and Physics of University of Ljubljana, Slovenia.

He is at the moment employed as a Senior researcher at Efficiency Emergency Center of Jožef Stefan Institute with research interests of statistical models and general automotive.

Mr. Česen has participated as a reviewer of national communications and biennial reports under UNFCCC, also as a head reviewer.

Andreja Urbančič has a master's degree in mathematics from Faculty of Mathematics and Physics of University of Ljubljana, Slovenia.

She is employed at Efficiency Emergency Center of Jožef Stefan Institute and works on energy system modelling and analyses in the support of decision-making in climate and energy policy. She is the project coordinator of LIFE project Climate Path 2050 – Slovenian Path Towards the Mid-century Climate Target.

Ms. Urbančič coordinated the European expert group for future activities within the working group on environment during the period of Slovenian Presidency of the European Union.

Stane Merše has a master's degree in electrical engineering from Faculty of Electrical Engineering of University of Ljubljana, Slovenia.

He is a head of Energy Efficiency Centre of Jožef Stefan Institute since 2008. He is an expert in holistic energy planning and recently especially in efficient heating and cooling, heat and power cogeneration (CHP) and district heating.

Mr. Merše is a lecturer at EUREM training and program manager of annual energy managers conference "Dnevi energetikov".