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Investigating the impacts of urban speed limit reduction through microscopic traffic simulation

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A R T I C L E I N F O

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A B S T R A C T

Road traffic congestion has become an everyday phenomenon in today's cities all around the world. The reason is clear: at peak hours, the road network operates at full capacity. In this way, growing traffic demand cannot be satisfied, not even with traffic-responsive signal plans. The external impacts of traffic congestion come with a serious socio-economic cost: air pollution, increased travel times and fuel consumption, stress, as well as higher risk of accidents. To tackle these problems, a number of European cities have implemented reduced speed limit measures. Similarly, a general urban speed limit measure is in preparatory phase in Budapest, Hungary. In this context, a complex preliminary impact assessment is needed using a simulated environment. Two typical network parts of Budapest were analyzed with microscopic traffic simulations. The results revealed that speed limits can affect traffic differently in diverse network types indicating that thorough examination and preparation works are needed prior to the introduction of speed limit reduction.

1. Introduction

A number of measures exist to reduce road traffic congestion and externalities in cities: parking regulations, restricting traffic movement, public transport priority, traffic management measures, overloaded vehicles detection, and speed limit reduction (Hensher, 2006; Janota et al., 2016; Fernandes et al., 2019). This paper investigates the latter, i.e. mitigation of road traffic externalities via general speed limit reduction.

Taking a look at the international literature, changing urban speed limit has mixed effects. However, the relation between traffic accidents and speed limit is beyond doubt. A study by Nilsson (2004) evaluates how the severity of accidents is linked to the maximum allowed speed based on Swedish statistical data. The results, in line with other studies (Archer et al., 2008; Pei et al., 2012; Aarts and Van Schagen, 2006), have shown that there is a strong correlation between the value of speed reduction and the risk of accidents as well as the severity of accidents.

This correlation is supported by a Brazilian study (Ang et al., 2020) conducted in 2015. The speed limits were reduced in São Paulo, from 90 to 70 km/h on inner city motorway segments, and from 60 to 50 km/h on urban main roads. The results were clear: during an 18-month period, the number of accidents decreased by 21.7%. According to historical statistical data, this contributed to the prevention of 1889 traffic accidents.

A study of Tang et al. (2019) examines the impacts of reducing the speed limit from 50 to 30 km/h. Their results show that the emission of nitrogen oxides (NOx) and particulate matter (PM) increase due to speed limit reduction. However, the extent of the increase depends on network topology, and the characteristics of traffic.

Folgerø et al. (2020) share the results of speed limit measures in Oslo between 2004 and 2011. The maximum allowed speed was reduced from 80 to 60 km/h on the main urban roads. The study evaluates the change in air pollution and average travel time due to the traffic management action. The most significant result discussed in the paper is that the average speed decreased by nearly 6 km/h. This should also cause the level of NOx and PM emissions to decrease because of the average characteristics of internal combustion engines. However, the results did not confirm this.

In 1992, a general speed limit was introduced in the city of Graz, Austria (Sammer, 1994). During the two-year trial, the speed limit on priority roads remained 50 km/h, but it was reduced to 30 km/h on every other road. Concerning traffic safety issues, there has been a 12% decrease in accidents, and 20% fewer persons were seriously injured after introducing the reduced speed limits. Another important finding of the impact assessment was that the maximum speeds have decreased significantly on both the 30 km/h speed limit roads and on the priority

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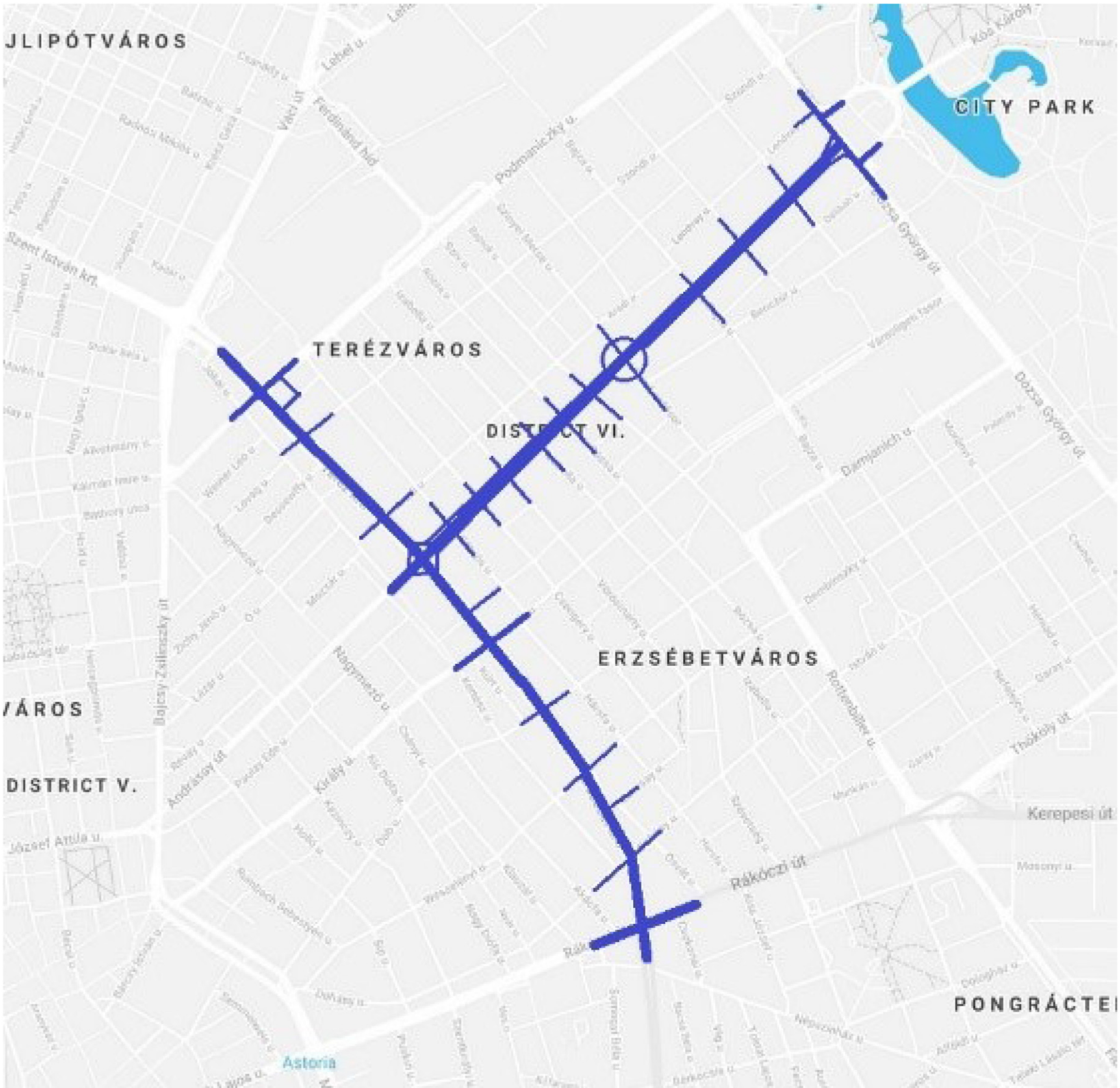

Fig. 1. The examined urban road network (Budapest, Nagykörút and Andrássy út) GPS coordinates: 47.505 468 742 561 52, 19.063 680 866 053 346.

roads. Furthermore, the noise levels and NOx emissions also dropped (by 2.5 dB and 25%).

When the speed limits of Boston were lowered from 30 mph to 25 mph in 2017, a study concluded the following (Hu and Cicchino, 2020). Although the mean speeds did not reduce significantly (only by 0.3%), the odds of vehicles exceeding 25 mph, 30 mph, and 35 mph decreased (by 2.9%, 8.5%, and 29.3%, respectively). As the speeding probability is directly linked to the number and severity of traffic accidents, it can be stated that even a 5 mph (8 km/h) reduction in the speed limit can have a considerable impact on traffic safety.

During a 2011 study in Antwerp, Belgium, the possible environmental effects of speed limit reduction were modeled (Madireddy et al., 2011). The test subnetwork was the residential area of Zurenborg, which is located adjacent to a freeway and a major road. The local traffic planning authorities were considering lowering the speed limits from 100 to 70 km/h on the freeway, from 70 to 50 km/h on the major road, and from 50 to 30 km/h on the residential roads. The microscopic traffic simulation combined with air pollutant emission modeling determined that CO2 and NOx emissions could be reduced by 25% when lowering the speed limits.

The mixed results of the studies discussed above signal that detailed simulations are necessary to evaluate the impacts of maximum allowed speed reduction measures in a designated area. This means that no clear conclusion can be drawn from the available body of scientific literature about the amounts, or even the direction of the changes. Each city that is set to introduce speed limit reduction measures has to be examined individually.

Besides mobility and environmental impacts, noise pollution effects can be also investigated in relation with the average traffic speed (Maghrour Zefreh et al., 2018; Ögren et al., 2018), however, this is not concerned by our research.

In the past few decades, several cities have introduced measures to decrease the allowed speed on the traffic networks. These actions were implemented to increase traffic safety, raise environmental awareness, and drive a modal shift to cycling, walking, and public transport. Generally, the speed limits were introduced according to the followings:

- from 50 km/h to 30 km/h in the inner city/residential areas,
- from 80 km/h to 70 km/h or from 60 km/h to 50 km/h on main and arterial roads.

Altering the maximum allowed speed is usually expected to reduce externalities and increase traffic safety. However, the possible outcomes

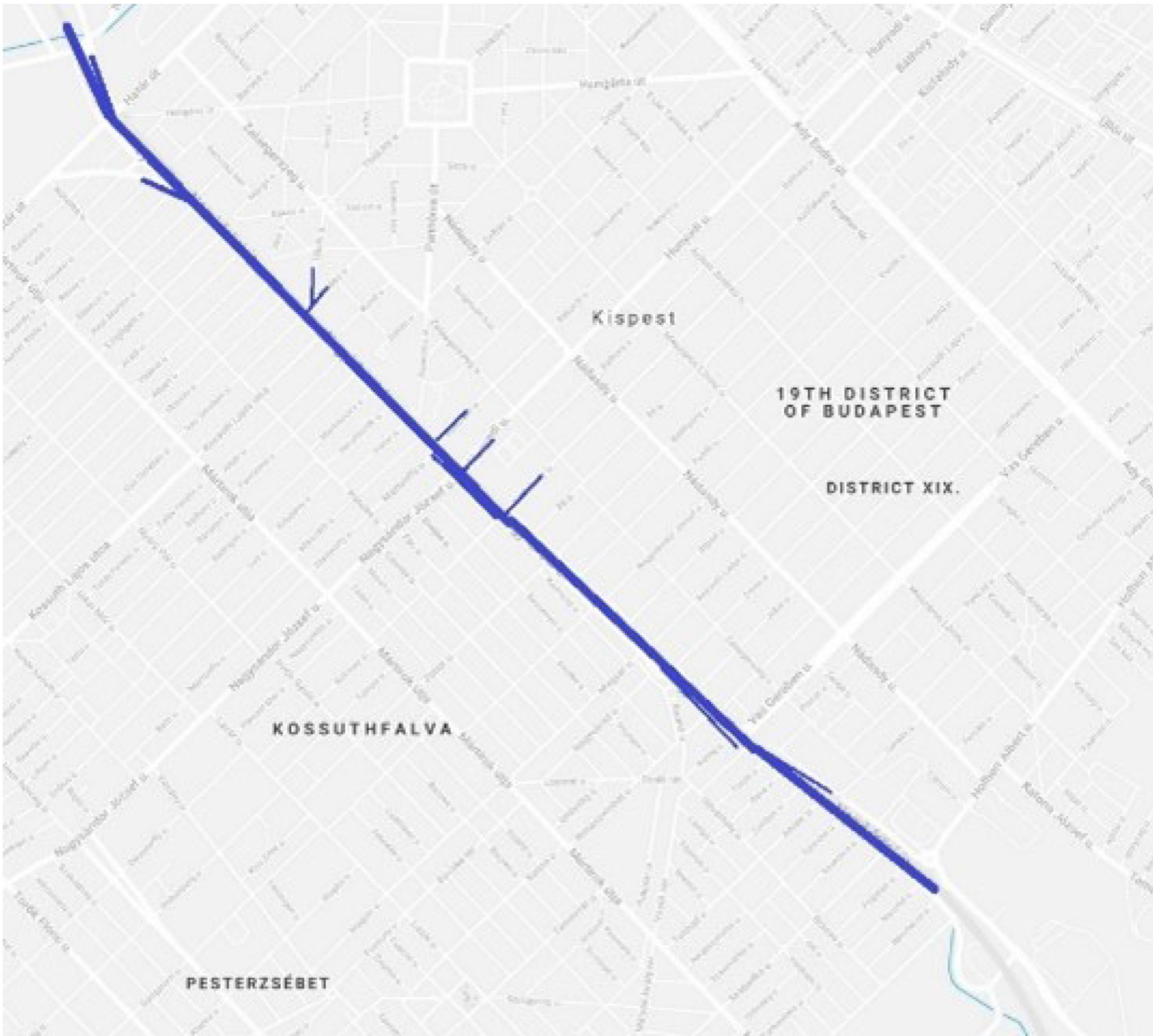

Fig. 2. The examined urban motorway (Budapest, Nagykőrösi út) GPS coordinates: 47.446 272 958 269 34, 19.127 074 270 717 763.

have to be investigated in a complex way, using traffic engineering tools. Beyond expected safety statistics, a number of objective factors have to be examined: the effects on air and noise pollution, average speed, traffic capacity, and congestion. These parameters typically do not change in the same direction due to a traffic management action. Therefore, it is necessary to consider several criteria and socio-economic factors before implementing speed limit reduction in a city.

In 2021, the European Parliament adopted the resolution on EU road safety based on the Stockholm Declaration (Government of Sweden, 2020). The EP resolution includes an EU-wide speed limit reduction to 30 km/h in residential areas and areas where there are high numbers of cyclists and pedestrians. In view of this, it is even more important to investigate the possible outcomes of urban speed limit reduction.

Following contemporary trends, Budapest opted for speed limit reduction too. The case study is motivated by these recent debates on speed limit reduction in Budapest, Hungary. In this paper, the impacts of general urban speed limits are evaluated by applying validated microscopic traffic simulation software (PTV VISSIM). VISSIM is widely used for diverse problems by traffic engineers in practice as well as by researchers. The simulation based assessment involved two typical test networks:

- downtown network type with maximum allowed speed reduced from 50 km/h to 30 km/h,
- urban arterial road with maximum allowed speed reduced from 70 km/h to 50 km/h.

The aim of the analysis is to determine the impacts of speed limit on traffic and emission parameters. The simulations involved testing with different traffic demands, but modal shift induced by varying traffic demand has been disregarded. The modal shift effect might be worth investigating as future work. To circumvent the question of modal shift (which cannot be investigated with microsimulation tools alone), we take a sensitivity analysis approach. We investigate different traffic demand levels that could reflect the effect of modal shift and changes in traffic demands and patterns.

2. Methodology

In this section, the microsimulation environment and the test road networks are discussed in detail.

2.1. Microscopic traffic simulation

Microscopic traffic simulation means that the longitudinal dynamics of every single vehicle are defined and modeled. Traffic can be examined in detail with the aggregation of these individual vehicle dynamics over the road network. The microscopic traffic simulator software used in this paper (PTV VISSIM) provides the tools for modeling road networks with

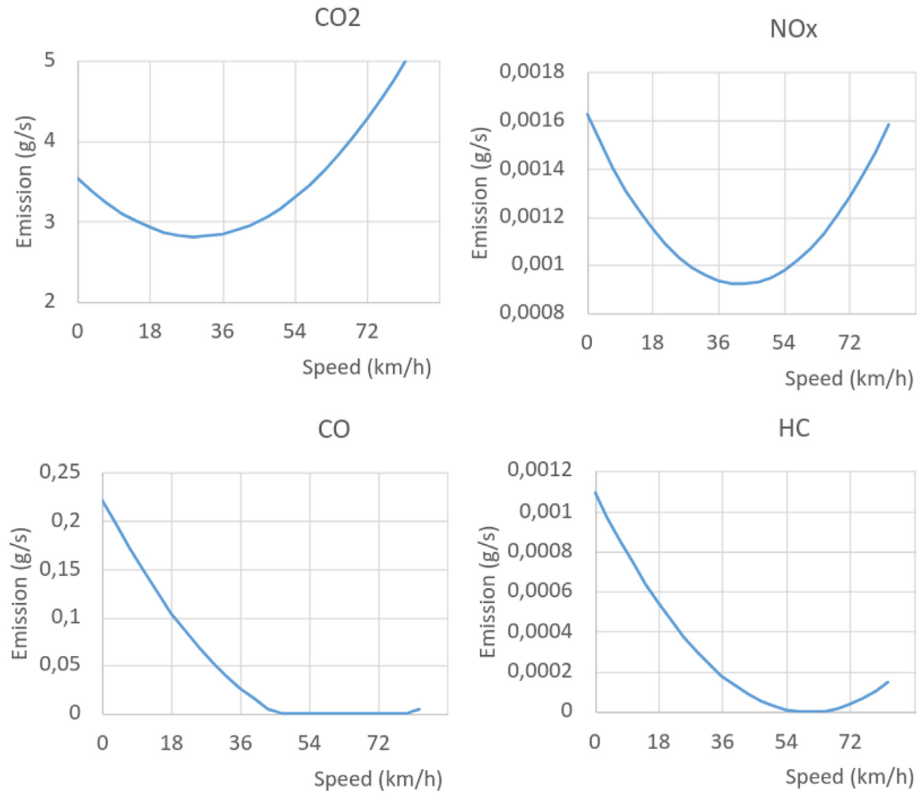

Fig. 3. Emission graphs of private cars based on HBEFA3 model.

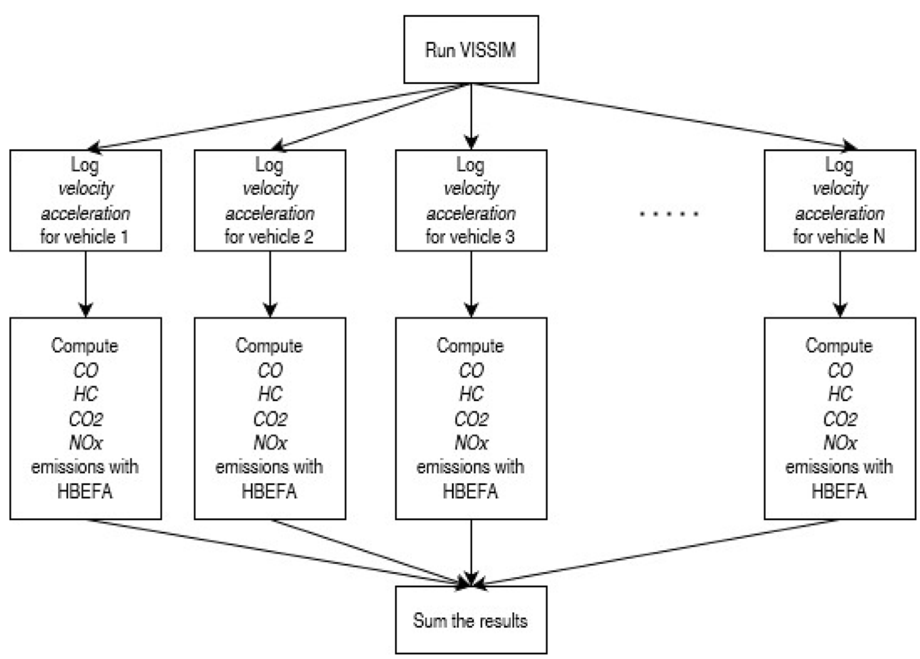

Fig. 4. Computing network emissions.

Table 1
Distribution of vehicle categories on the urban network (Nagykörút).

Private car	80%
Heavy goods vehicle	15%
Bus	5%

Table 2
Expected speed of vehicles on the urban network (Nagykörút).

Speed limit (km/h)	Minimum (km/h)	Maximum (km/h)
30	28	45
50	45	60

Table 3
Distribution of vehicle categories on the urban motorway (Nagykőrösi út).

Private car	75%
Heavy goods vehicle	20%
Bus	5%

Table 4
Expected speed of vehicles on the urban motorway (Nagykőrösi út).

Speed limit (km/h)	Minimum (km/h)	Maximum (km/h)
50	45	60
70	60	90

different settings (traffic volumes, routes, traffic signal programs).

Two different road networks were investigated during this research. The first one is located between Blaha Lujza tér and Nyugati pályaudvar, accompanied by Andrássy út (Fig. 1). These urban road segments have relatively high traffic demand with a number of signalized intersections. The speed limit was reduced from 50 to 30 km/h on this network. The second simulated area was an urban motorway, a segment of Nagykőrösi út between Határ út and Hoffner Albert utca (Fig. 2). In this simulation area, the speed limit was reduced from 70 to 50 km/h, and the outbound traffic direction was investigated.

Three separate traffic demands were needed, because modal shift induced reduction in traffic was not modeled during the research. Thus, the three traffic demands were determined based on macroscopic parameters: undersaturated, saturated, and oversaturated traffic states (Gazis, 2002).

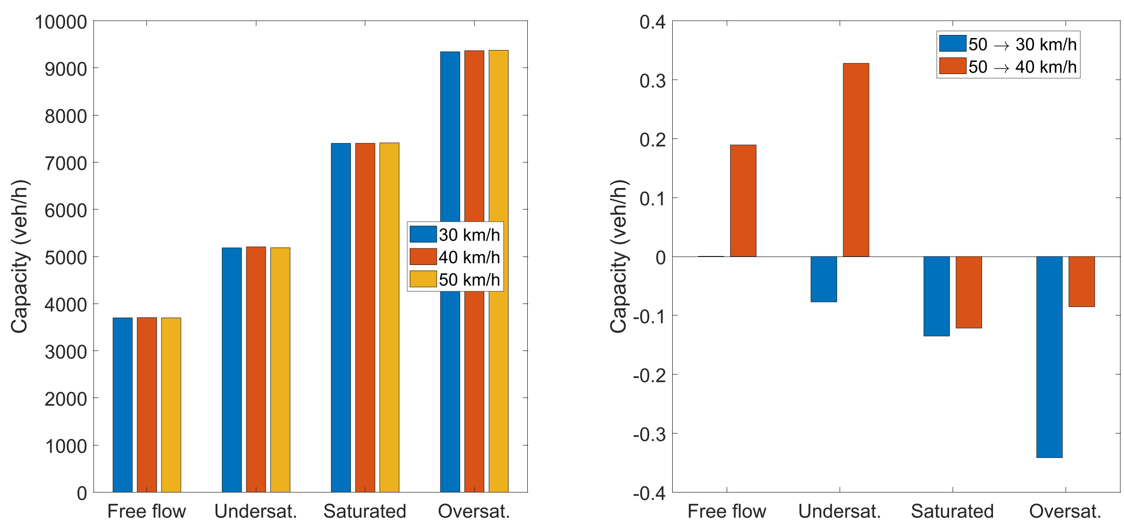

Fig. 5. Capacity on the urban road network (Budapest, Nagykörút).

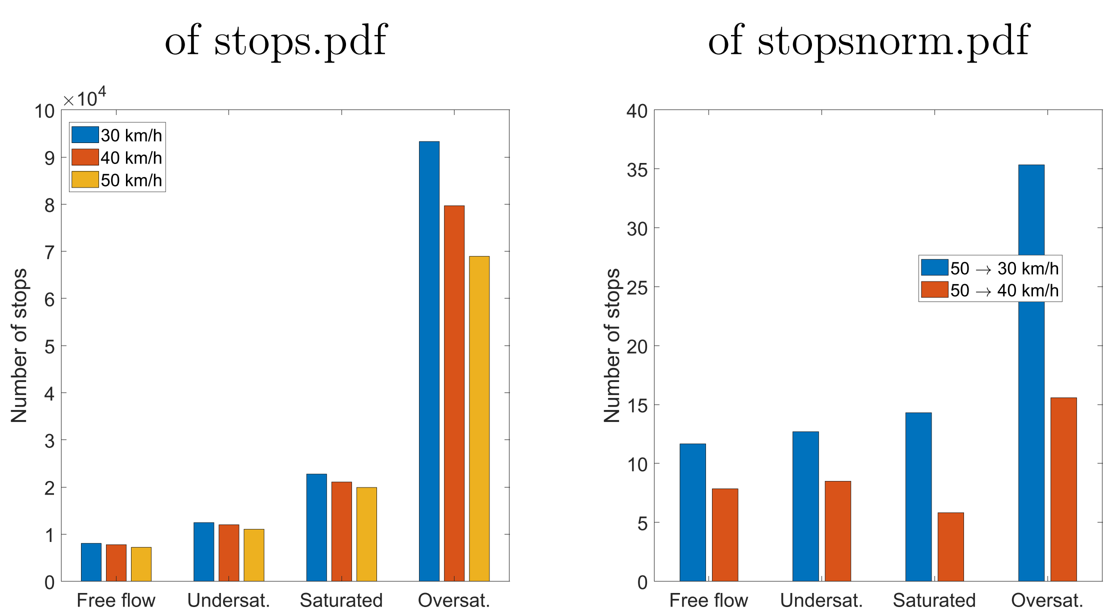

Fig. 6. Number of stops on the urban road network (Budapest, Nagykörút).

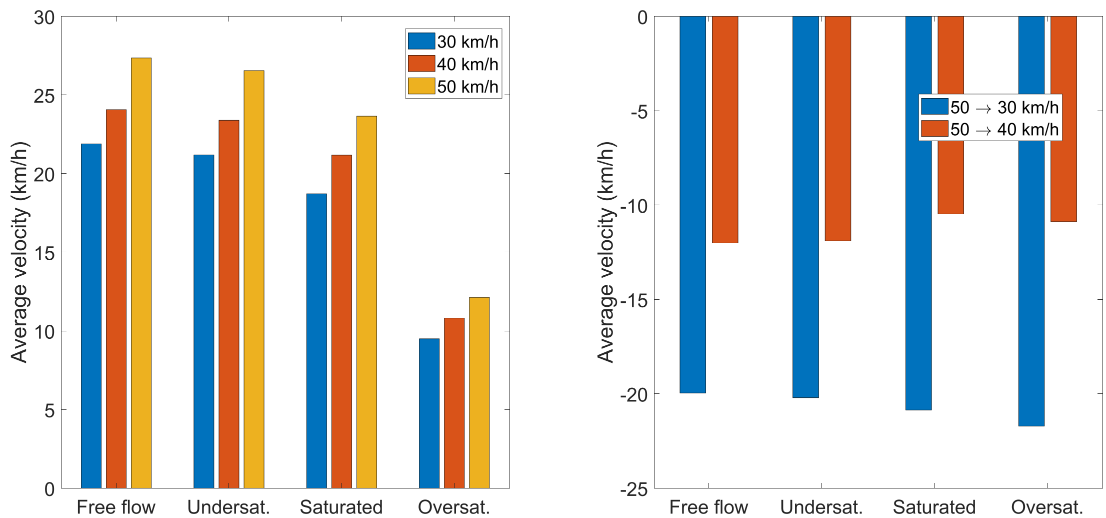

Fig. 7. Average velocity on the urban road network (Budapest, Nagykörút).

Table 5
Emission results on the urban test network (Nagykörút).

	CO	HC	CO2	NOx
50 ⇒ 40 km/h	+8.371 7%	+8.117 1%	+2.205 6%	+3.590 1%
50 ⇒ 30 km/h	+21.267 7%	+22.202 2%	+7.965 3%	+11.800 1%

- Undersaturated traffic: all vehicles can pass the signalized intersection under one green phase. There is little traffic, few interactions between vehicles and every vehicle can move at its desired speed.
- Saturated traffic: the exact vehicle number appears at an intersection, for which the signal program is designed. Every direction clears under exactly one corresponding green phase. The intersection operates at full capacity.
- Oversaturated traffic: at least one direction cannot clear under one green phase. Vehicles have to wait for at least two cycles to pass the intersection.

Undersaturated and oversaturated traffic volumes were defined to be 70% and 130% of saturated traffic. The traffic flows in this research were based on the traffic demands and turning rates in the Budapest Transport Model (Mátrai et al., 2015, 2016; Juhász et al., 2017; Mátrai et al., 2015). This model is a planning tool and serves as a basis for a number of transport related development projects, e.g. examining long-term transport strategies, complex infrastructural projects, or investigating the effects of traffic management actions. The model is constantly maintained and updated by the Centre for Budapest Transport (BKK) with the latest traffic data gathered from extensive traffic counts and advanced modeling procedures.

The simulator was calibrated on the current data, as the speed limit reduction measures have not been introduced yet. The calibration was carried out considering existing guidelines (Antoniou et al., 2014; Punzo et al., 2014; Ciuffo et al., 2008).

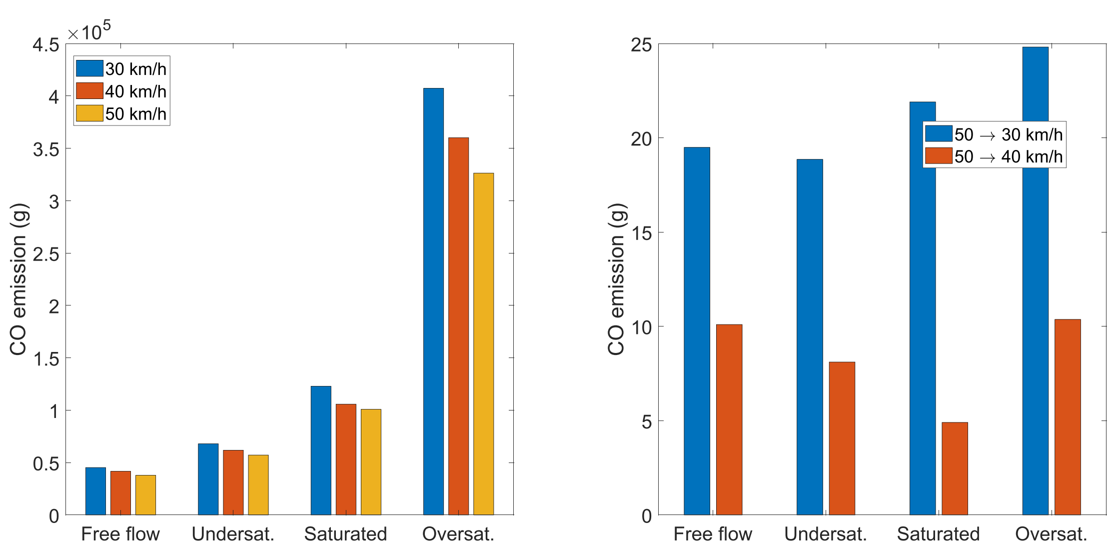

Fig. 8. CO emission on the urban road network (Budapest, Nagykörút).

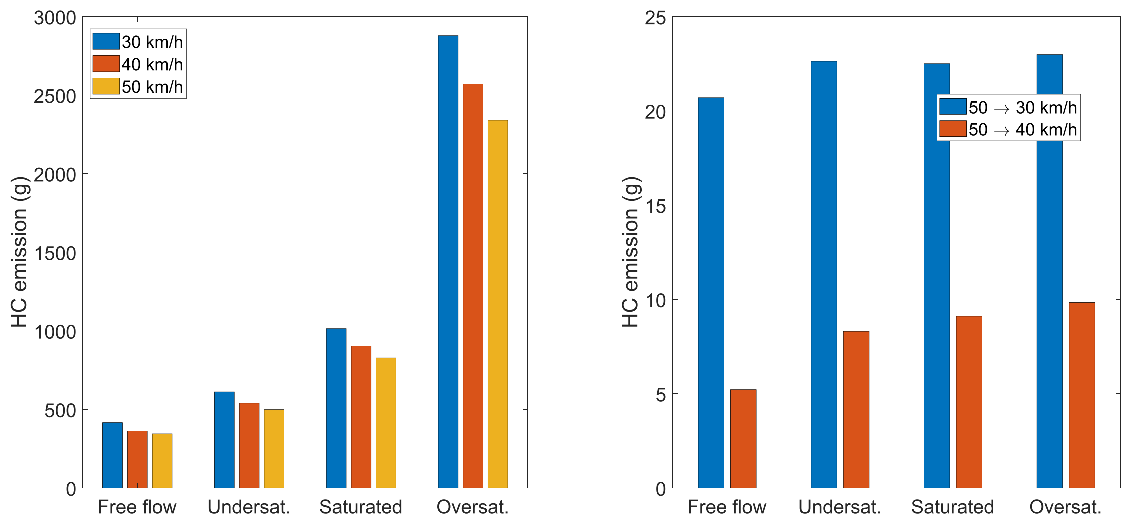

Fig. 9. HC emission on the urban road network (Budapest, Nagykörút).

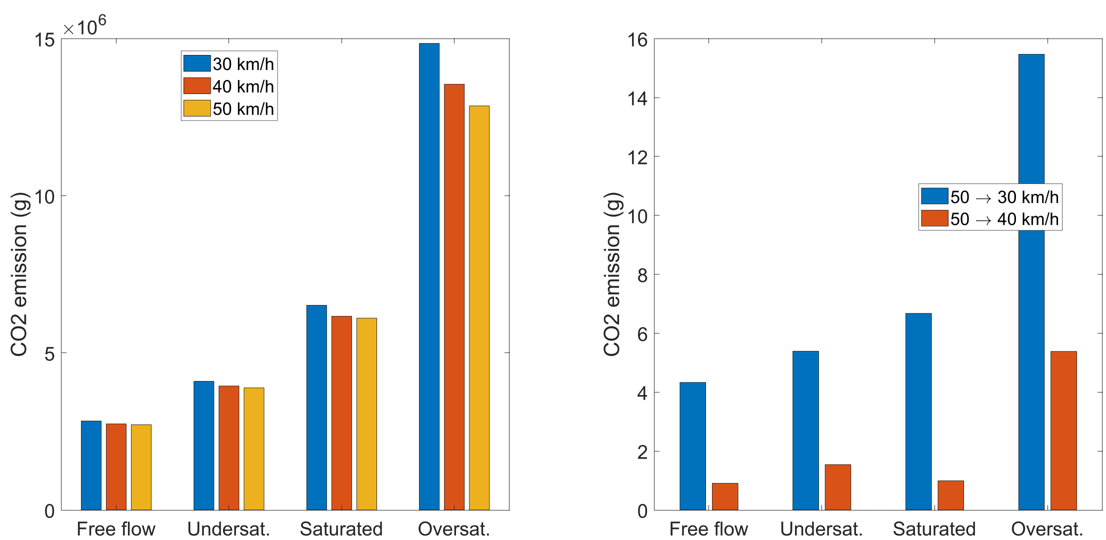

Fig. 10. CO2 emission on the urban road network (Budapest, Nagykörút).

2.2. HBEFA3 microscopic emission model

The instantaneous speed and the acceleration of vehicles evidently play a central role in fuel consumption (Ahn et al., 2002). However, different pollutants have different characteristics. During this research, pollutant emissions were calculated using the HBEFA3 microscopic emission model (Keller et al., 2017). It determines the current emissions of each individual vehicle based on polynomials containing the current speeds and accelerations. Different vehicle types and emission categories are defined in the model. The polynomials are as follows:

$$e = f_1 + f_2\, a\, v + f_3\, a^2\, v + f_4\, v + f_5\, v^2 + f_6\, v^3 \quad (1)$$

where e is the emission, a is the acceleration, v is the speed of the vehicle, and f_1, f_2, …, f_6 are parameters of the model. Three typical vehicle categories were considered during the modeling of emissions: private car (petrol, Euro 4 standard), heavy goods vehicle (diesel, Euro 3 standard), bus (diesel, Euro 5 standard). The examination extended to four different pollutants: carbon monoxide (CO), carbon dioxide (CO2), hydrocarbon (HC), and NOx. Relative to the current speed, the polynomial emission graph shows a U-shaped curve. Depending on the pollutant, the minimum of the emission is between 30 and 70 km/h, given that the acceleration is 0 m/s^2. Maintaining higher speed values can be achieved with higher engine power to overcome running resistance factors (rolling resistance, air resistance). Higher engine power increases fuel consumption, and therefore the level of emission. Considering the efficiency of the engine, lower speeds can also induce higher emission values. Two opposing impacts on emissions are expected during the speed limit simulations. Firstly, individual instantaneous emissions of the vehicles could decrease, given that their previous speed is higher. The second effect derives indirectly from the speed: lowered speeds cause vehicles to spend more time on the network, polluting for longer. The aggregated result of the two impacts can only be determined with simulations. The emission graph for the private car is depicted in Fig. 3.

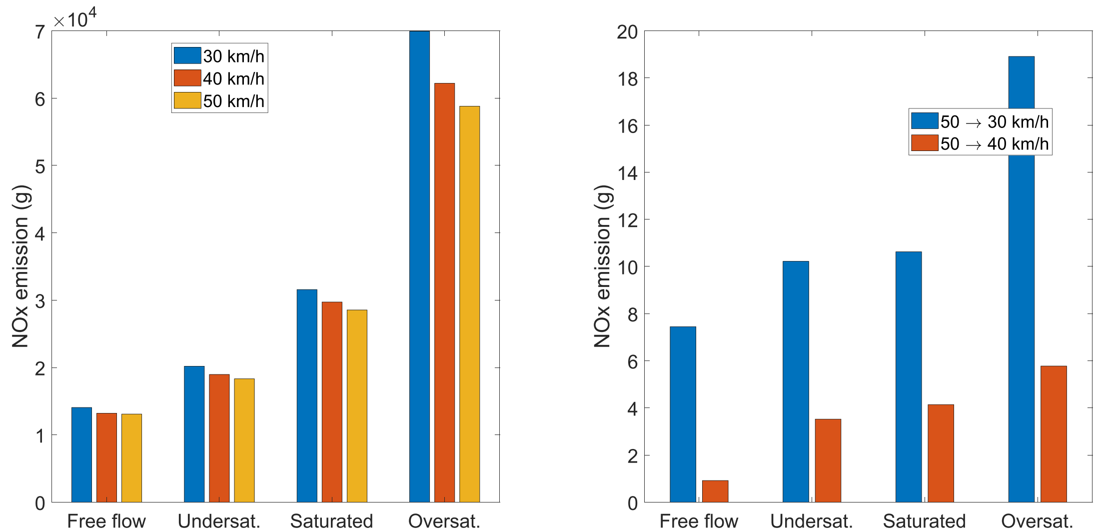

Fig. 11. NOx emission on the urban road network (Budapest, Nagykörút).

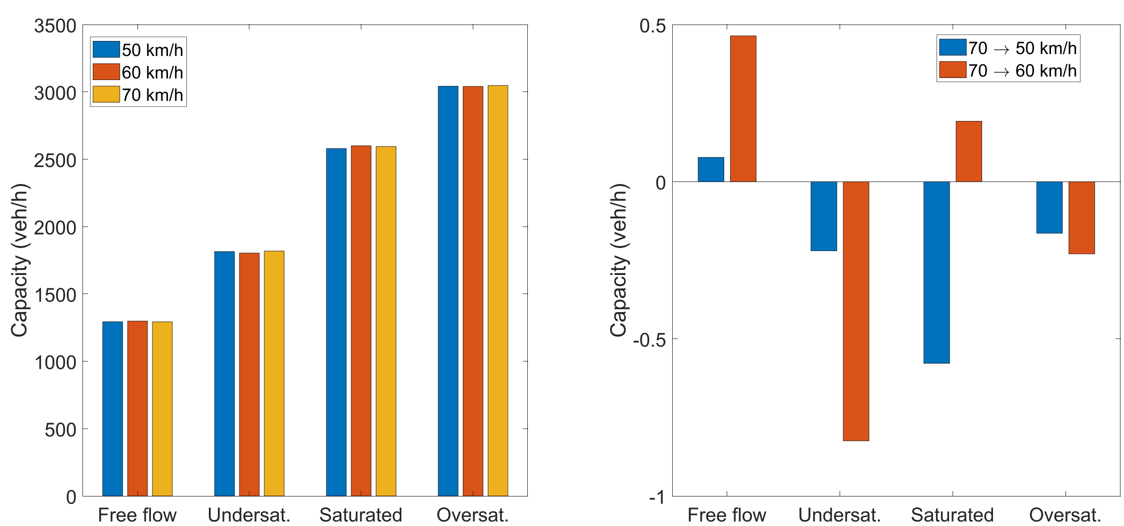

Fig. 12. Capacity on the urban motorway road network (Budapest, Nagykőrösi út).

The emissions have to be evaluated in the whole examined sub-networks. It is done in two steps. First, the VISSIM simulation is run, and the accelerations and velocities of each vehicle are logged. Then, based on these offline logs, the emissions are computed with Eq. (1) for every vehicle. The emissions are then summed for the whole network. This process is depicted in Fig. 4.

3. Test networks

The typical test networks used in the simulation study are introduced in detail in the sequel.

3.1. Urban test network (Nagykörút)

For the urban test network, a busy signalized boulevard (Nagykörút) and its side streets were modeled. The current speed limit on the real-life network is 50 km/h. Traffic parameters were measured after decreasing the speed limit to 30 km/h, under three different sets of traffic intensity.

Undersaturated and oversaturated traffic volumes were defined to be 70% and 130% of saturated traffic. The current signal cycle lengths are 90 s across the boulevard. Temporary bicycle lanes have been disregarded. Table 1 shows the distribution of vehicle categories applied during the simulations (based on the Budapest Transport Model).

The expected speed of vehicles was determined to ensure even distribution (based on the default settings of VISSIM). Table 2 contains the range of the distribution.

Hourly vehicle inputs from every direction are shown in Table 7 in the appendix. Saturated traffic volumes were too based on the Budapest Transport Model. It is important to note that besides the main trips along the boulevard, shorter vehicle trips were also modeled (e.g. the side streets were origins and destinations as well).

Vehicle motions are determined by the Wiedemann 74 car following model, which is suitable to describe driver behavior on urban traffic networks (Olstam and Tapani, 2004).

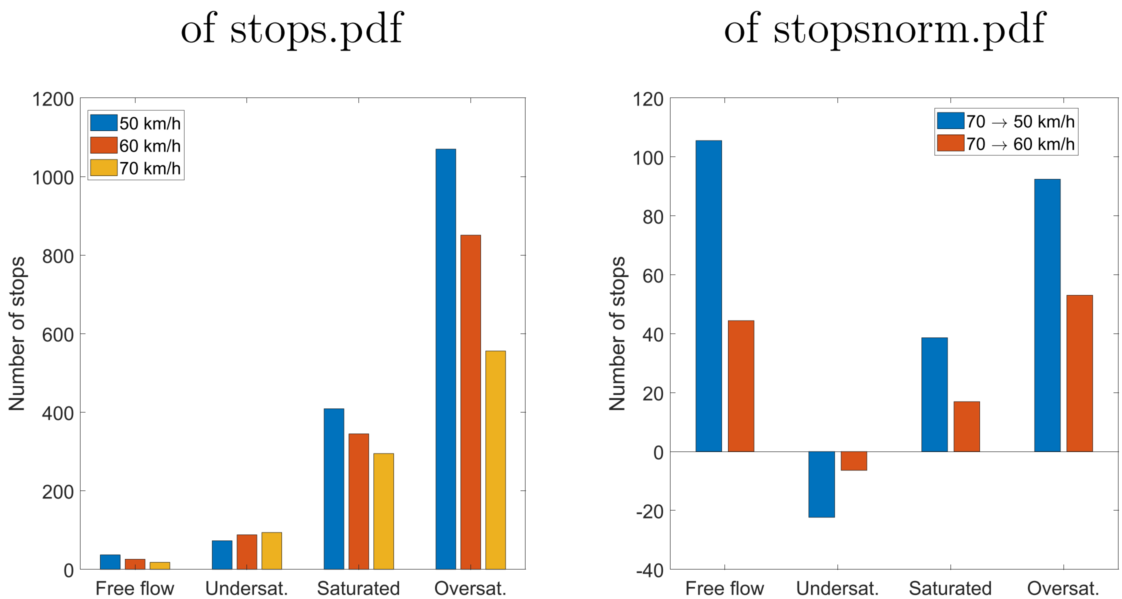

Fig. 13. Number of stops on the urban motorway road network (Budapest, Nagykőrösi út).

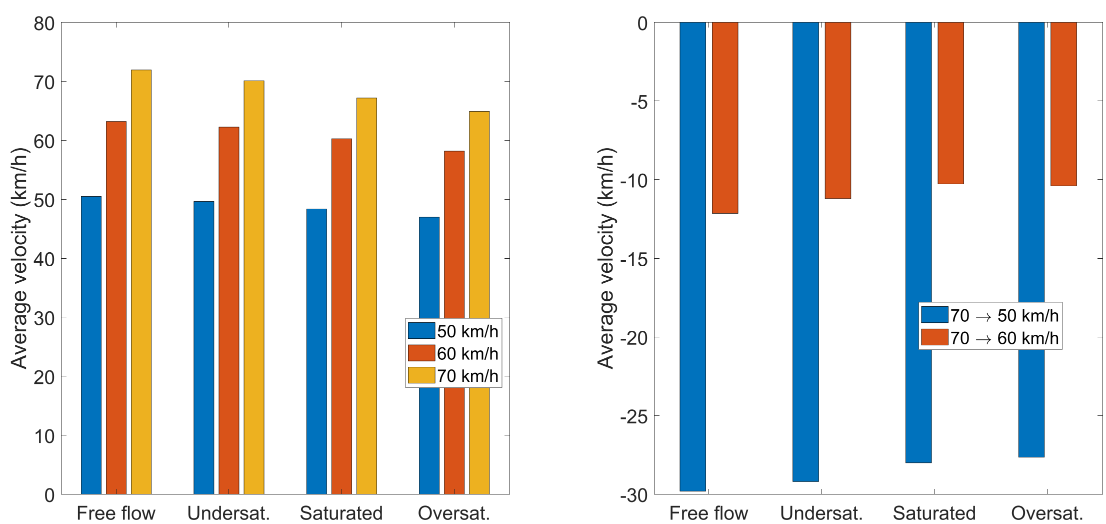

Fig. 14. Average velocity on the urban road network (Budapest, Nagykőrösi út).

Table 6
Emission results on the urban motorway test network (Nagykőrösi út).

	CO	HC	CO2	NOx
70 ⇒ 60 km/h	−14.546 9%	−2.127 4%	0.555 2%	3.643 4%
70 ⇒ 50 km/h	−2.816 5%	18.971 9%	8.153 2%	17.834 8%

3.2. Urban motorway test network (Nagykőrösi út)

The current speed limit on the examined urban motorway segment (Nagykőrösi út) is uniformly 70 km/h. Lowering it to 50 km/h was simulated and investigated during this research. Apart from a few ramps and exits, the road segment is a straight line with 2 lanes plus 1 bus lane. This means that the topology of the test network has a negligible effect on the simulation.

The distribution of vehicle categories is shown in Table 3.

The range of the expected speed of vehicles (with an even distribution) can be seen in Table 4.

Three different traffic volumes were determined for each input road. These hourly vehicle numbers are shown in Table 8 in the appendix.

Route choices are modeled to be in proportion with traffic volumes on the links. In the urban motorway environment, the Wiedemann 99 car following model was applied, which is suitable to describe motorway traffic behavior (Olstam and Tapani, 2004). In this model, the space between cars is typically larger compared to the Wiedemann 74.

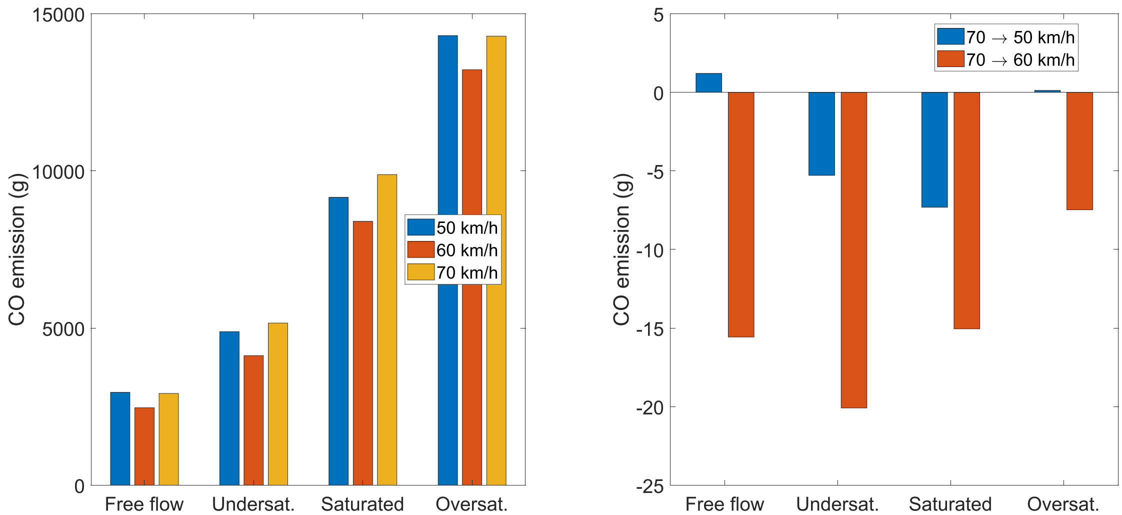

Fig. 15. CO emission on the urban road network (Budapest, Nagykőrösi út).

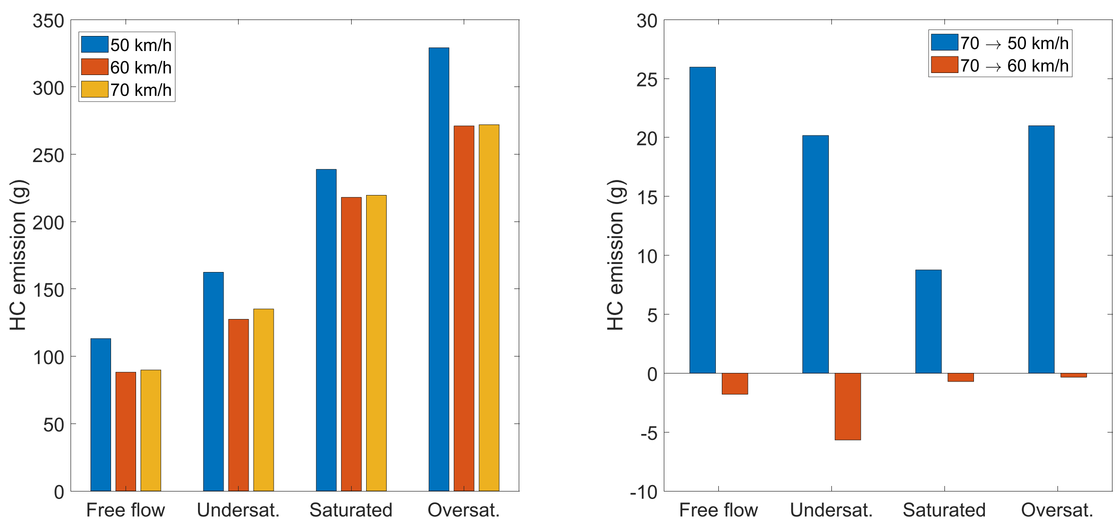

Fig. 16. HC emission on the urban road network (Budapest, Nagykőrösi út).

4. Simulation results

Simulations have been evaluated qualitatively based on the following metrics:

- capacity: the number of vehicles leaving the network during the simulation;
- number of stops – The average number of stops by one vehicle;
- average speed – The average speed of all vehicles on the network (1-h average;
- HC emission;
- CO emission;
- CO2 emission;
- NOx emission.

The results are displayed in two ways in case of all examined metrics throughout the evaluation sections. The charts on the left show the results of the current situation and the two lowered speed limits next to each other. The charts on the right depict the results compared to the current state, i.e. the differences from the current conditions.

4.1. Urban network results (Nagykörút)

As Fig. 5 clearly shows, the decrease in capacity is negligible in case of lower speed limits, because traffic signals let vehicles out of the system periodically, so the speed between intersections does not substantially influence the results. Secondly, the vehicle input volumes are constant concerning all examined speed limits. The conservation of vehicle numbers implies that the only varying factor is the traffic density (vehicles/km). Simply put, if the input is the same, and only the speed is limited, the output will be the same with traffic becoming denser. These factors provide an explanation to not having a significant difference in the simulated scenario results in terms of traffic capacity.

Fig. 6 shows the total number of stops during the simulations on the

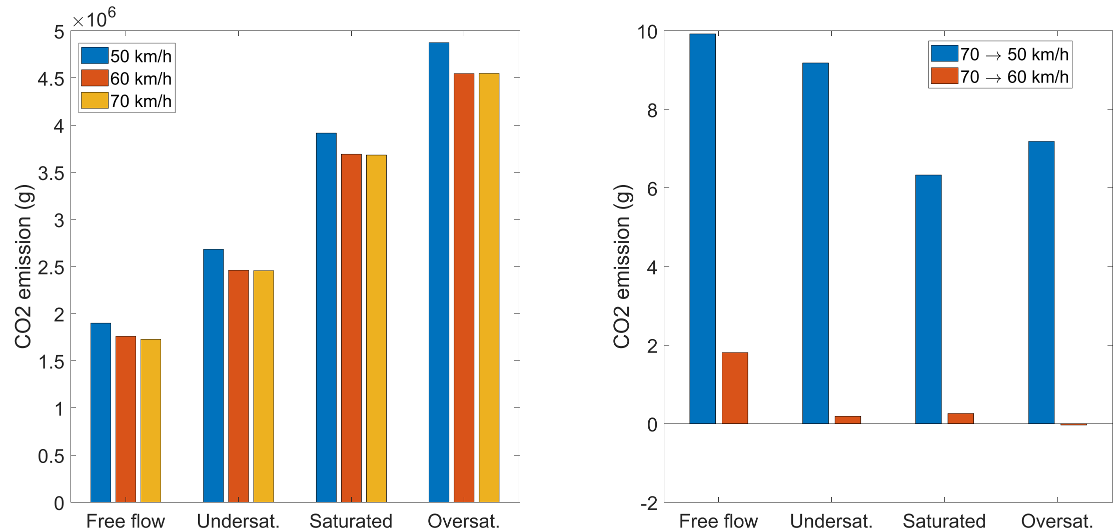

Fig. 17. CO2 emission on the urban road network (Budapest, Nagykőrösi út).

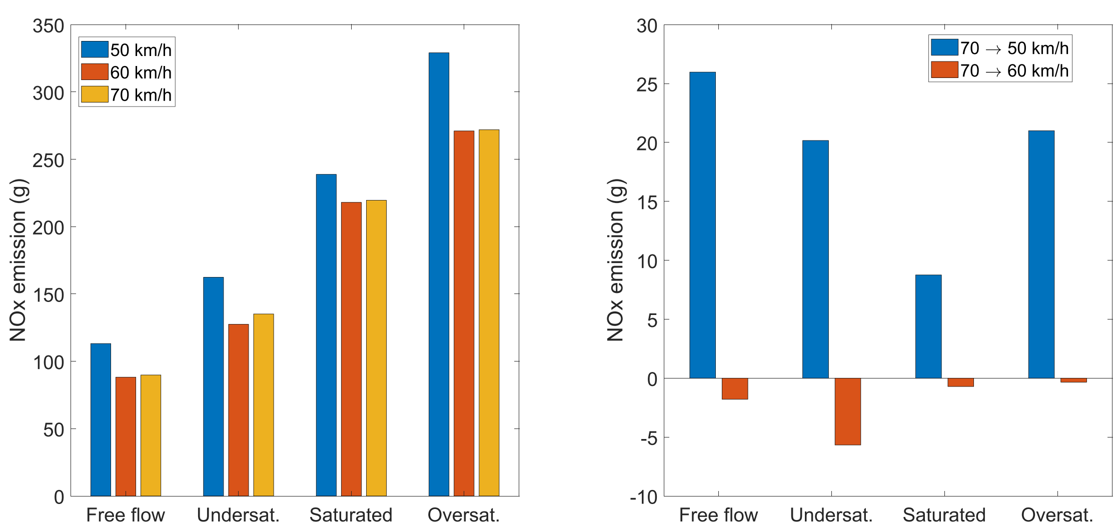

Fig. 18. NOx emission on the urban road network (Budapest, Nagykőrösi út).

urban network. The results reflect that the number of stops is mainly influenced by traffic signals. The number of stops increases due to the implementation of speed limits subject to the same vehicle inputs. This effect can be reduced by reprogramming the traffic signals to match the new limited speeds.

In case of higher traffic demand and a 30 km/h speed limit, the average vehicle speed shows a 20% drop (Fig. 7). This effect is less significant at undersaturated traffic conditions. The phenomenon is due to the lower number of interactions between vehicles. The diagram also depicts that the average speed did not reach 30 km/h regardless of the speed limit. This can be explained by the stops at traffic signals. Vehicles cannot speed up due to the speed limit, and, as the number of stops indicates, their waiting time at traffic signals is higher.

Next, emissions are evaluated in the network. Based on the HBEFA emission model, emission values rise by 8–22% in case of a 20 km/h speed limit reduction, as can be seen in Table 5. The pollutant levels do not increase to the same extent because of the different emission characteristics. For instance, CO2 (Fig. 10) and NOx (Fig. 11) levels rise to a lesser degree than CO (Fig. 8) and HC (Fig. 9) levels.

The reason for the increase in emission levels is that the average speed is lower, waiting times at traffic signals are higher. In this way, vehicles spend more time on the traffic network and pollute longer. Additionally, the number of stops increases resulting in more vehicle accelerations. In case of lower speeds, the impact of idling emissions is also more significant.

4.2. Urban motorway results, outbound (Nagykőrösi út)

The capacity of the outbound urban motorway does not change significantly due to the speed limit, as Fig. 12 clearly shows. The explanation is the same as in the first case: when the vehicle input volume is the same, and only the speed is limited, it will generate the same output volume, but with higher traffic density.

It must be emphasized that vehicle stopping (number of stops) on an urban motorway segment can only be due to a substantial level of congestion (apart from a traffic accident). In case of free flow and undersaturated traffic, vehicles travel around the speed limit, not having to slow down or stop. In an oversaturated traffic state, the number of vehicle interactions increases. This induces shock waves and makes drivers brake. These effects slow down or even stop vehicles, increasing waiting and travel times. The number of stops drops on an undersaturated or free flowing network and results in a smoother traffic flow (Fig. 13). Saturated and oversaturated networks induce an increased number of stops in case of applying speed limit. Lower speed causes higher traffic density (vehicles/km) which leads to more vehicle interactions. In this way, smaller perturbations can make the vehicles stop. Low traffic density and low speed means that drivers have sufficient time to react to a vehicle braking in front of them. This prevents shock waves from forming and decreases the number of stops.

Speed limits evidently cause vehicles to travel slower, as it is depicted in Fig. 14. The average speed also drops with the increase in traffic volume. In this way, the effect of speed limit on the average speed is less significant under dense traffic conditions.

This test network showed the largest decrease in average speed, and the number of stops was insubstantial. Depending largely on the average speed, the most significant decrease in emission was reached on this network (Table 6). Lowering the speed limit with 10 km/h induced a 14% drop in CO emission (Fig. 15) on average (considering all examined traffic scenarios). By contrast, NOx emission has risen by 17% at a 50 km/h speed limit (Fig. 18), but CO2 (Fig. 17) and HC (Fig. 16) levels have also increased. With higher speeds, the impact of air resistance becomes increasingly important. Slowing down decreases the effect of speed-dependent resistance. In this way, vehicles need less power to travel, reducing fuel consumption and therefore the exhaust emission. On the other hand, vehicles spend more time on the network, polluting longer.

5. Conclusions

The most important contribution of the study is that a thorough and in-depth transport engineering study is definitely needed before a possible speed limit reduction measure can be introduced, followed by professional and social discussion and then consensus. A city road network is always very complex. The introduction of speed limit reduction can be particularly beneficial on some roads and controversial on others. Although microscopic traffic simulation is a necessary tool to evaluate the effect of speed limit reduction, it is not sufficient. The modal shift and other externalizes induced by it require further discussion and the involvement of additional data sources and more stakeholders.

The main conclusions of the simulation studies are as follows. It is not clear in which direction the emission changes, because it depends on the current state of traffic (congested or not) and the composition of vehicles. However, in general, it can be said that the reduction from 50 to 30 km/h is essentially an increase in emissions, and the reduction from 70 to 50 km/h brings mixed results (rather a slight reduction in emissions). The average arrival time (delay time) and the number of stops will increase in general. The capacity of the road network is not fundamentally affected by changes in speed limits. This is explained by the macroscopic fundamental theorem of road traffic, i.e. $Q = \rho \cdot V$ (traffic volume Q (veh/h) is the product of the vehicle density ρ (veh/km) and the spatial average speed V). In practice, this means that a lower average speed due to a reduction measure will lead to a higher vehicle density, as drivers also keep a smaller following distance at lower speeds. That is, in the equation $Q = \rho \cdot V$, Q remains basically constant. Another important point to be considered prior to the introduction of speed limit reduction is that a great emphasis should be placed on the reconfiguration of the traffic management, e.g. reconfiguration of road markings, traffic light control programs, public transport timetables. In conclusion, the speed limit reduction is an effective tool, the application of which will be fruitful only if a careful design precedes its introduction.

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Appendix

Hourly vehicle inputs used in the simulations are tabulated into Tables 7 and 8

Table 7
Hourly vehicle volumes on the urban network (Nagykörút)

Vehicle input road segment	Undersaturated (0.7*Saturated, vehicle/h)	Saturated (vehicle/h)	Oversaturated (1.3Saturated, vehicle/h)
Andrássy út	317	453	589
Hősök tere	179	255	332
Wesselényi utca	143	204	266
Király utca A	238	341	443
Erzsébet körút	358	511	665
Király utca B	238	341	443
Dob utca	143	204	266
Rákóczi út	465	665	865
Podmaniczky utca A	179	255	332
Szondi utca A	107	153	199
Aradi utca	107	153	199
Dohány utca	143	204	266
Vörösmarty utca	143	204	266
Izabella utca A	107	153	199
Dózsa György út A	358	511	665
Izabella utca B	143	204	266
Szinyei Merse Pál utca A	71	102	133
Bajza utca	107	153	199
Dózsa György út B	191	273	354
Teréz körút	358	511	665
Podmaniczky utca B	358	511	665

(continued on next column)

Table 7 (*continued*)

Vehicle input road segment	Undersaturated (0.7*Saturated, vehicle/h)	Saturated (vehicle/h)	Oversaturated (1.3Saturated, vehicle/h)
Szondi utca B	179	255	332
Dózsa György út C	23	34	44
Podmaniczky utca C	179	255	332
Szinyei Merse Pál utca B	71	102	133
Szondi utca C	179	255	332
Izabella utca C	107	153	199

Table 8
Hourly vehicle volumes on the urban motorway network (Nagykőrösi út)

Vehicle input road segment	Undersaturated (0.7*Saturated, vehicle/h)	Saturated (vehicle/h)	Oversaturated (1.3*Saturated, vehicle/h)
Nagykőrösi út	1470	2100	2730
Ramp A	245	350	455
Ramp B	49	70	91
Ramp C	49	70	91

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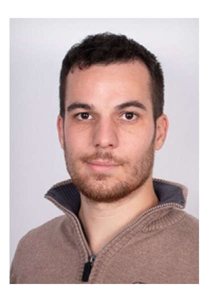

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