Simulation of the Effects of Different Speeds on Road Safety and Car Journey Times in Austria

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Abstract

Speed is a main risk factor in road safety as it increases both the likelihood and the severity of a crash. In Austria, inappropriate driving speed remains one of the most frequent causes of road accidents. At the same time, Austria still has higher maximum permissible speeds (particularly on roads outside urban areas), higher driving speeds and lower penalties for speeding than other countries. In the public debate, measures to reduce the maximum permissible and actual driving speeds are often met by fears from motorists that they would unreasonably extend journey times, despite the fact that the actual differences are not known. To date, there has been a clear lack of research into the effects of changed driving speeds, maximum permissible speeds, tolerance limits or penalties on car journey times and road safety in Austria. To fill this gap, our study uses six scenarios to examine the effects of speed changes and the impact of various parameters (e.g., maximum permissible speed, penalties) on car journey times and road safety in Austria. This was done using microscopic traffic flow simulations on four sample routes in Austria and their extrapolation to typical car journey distances, reconstructions of actual road accidents and collision avoidance analyses. The results show that a reduction in the speeds driven in motor vehicles has considerable potential for reducing the numbers of fatalities as well as severe and minor injuries on Austria's roads. Accordingly, a general reduction in the maximum permissible speed should be considered. Higher penalties, driving suspensions even for minor speeding violations, longer driving license suspensions and a removal of the enforcement tolerances should likewise be implemented. In future, however, more will be required than just changes to the legal framework, namely a mix of measures to adapt the road infrastructure, provide more training and raise awareness.

Keywords: traffic safety; speed limit; crash; simulation; Austria, car travel times

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1. Introduction

Speed and speed limits are an emotional topic despite being key factors in road safety and the severity of road accident injuries: the severity of a crash increases with speed, as the degree of kinetic energy at the time of the collision is higher [1,2]. However, in comparison with other countries – and especially Switzerland, which is similar to Austria in many aspects – Austria still has higher maximum permitted speeds, in particular on non-urban roads (100 km/h in Austria vs. 80 km/h in Switzerland), higher tolerance limits for traffic checks and lower penalties for speeding [3]. Moreover, surveys show that Austrians demonstrate a comparatively high tolerance of speeding by other motorists, and Austrian motorists often admit to not complying with speed limits [4]. Failure to comply with the speed limit is justified by the fear of losing time [5], and there is little agreement among Austrians on reducing speed limits, e.g., from 100 km/h to 80 km/h, or on zero tolerance for penalties [6]. In addition, inappropriate speed was listed as one of the most frequent causes of fatal road accidents in Austria from 2018-2020, although this is only based on the initial reports filed by the police [7]. Nonetheless, lowering the statutory speed limits is a common measure used by governments and road authorities to improve road safety [1,8], and several studies to date have examined the road safety effects of speed limit reduction.

Elvik [9], for example, uses a before-and-after study to examine the effects of reducing speed limits from 80 to 60 km/h on arterial roads in Oslo, Norway. His results show that this reduces the number of injury accidents by about 25-35%. De Pauw et al. [1], in turn, use a comparison group before-and-after study to investigate the safety effects of reducing speed limits from 90 to 70 km/h on 61 sections of highways in Belgium. Their findings indicate that this decreases overall crash rates by 5% and crashes resulting in serious injuries or fatalities by 33%.

Some studies have also investigated the effects of increasing speed limits and find that this has an unfavorable impact on road safety. Farmer [10], for example, examines such a scenario in the US and finds that a 5 mph increase in the maximum speed limit is associated with an 8% increase in fatality rates on interstates and freeways and a 4% increase on other roads. Vadeby and Forsberg [11] use a before-and-after study to investigate the road safety effects of both increasing and reducing speed limits in Sweden. Their results show that raising the speed limit from 110 to 120 km/h on motorways increases the number of seriously injured road users by about 15 per year. In contrast, reducing the speed limit from 90 to 80 km/h on rural roads decreases the number of fatalities by 14 per year. Based on these and other empirical studies, Nilsson [12] and Elvik et al. [13] describe the relationship between speed and road safety mathematically, with higher speeds increasing accident risk and severity.

In addition to before-and-after studies, Imprialou et al. [14] use a simulation approach to first establish the relationship between crashes and speed on motorways in the UK and then estimate the road safety impact of a potential increase in the speed limit from 70 to 80 mph. Their results show predicted annual increases of between 6.2 and 12.1% for fatal or serious injury crashes and between 1.3 and 2.7% for minor injury crashes.

Overall, previous studies show that lowering speed limits reduces road accidents and fatalities. Most such studies control for confounding factors and trend effects, i.e., elements that change before and after the speed limit reduction and could have an contributory effect on the occurrence of accidents (like road safety campaigns or stronger enforcement [1]), and only report the effects of the speed limit reduction on road safety. Combining the reduction of the speed limit with other measures such as increased enforcement, i.e., more checks, higher penalties and lower tolerance limits, tends to further increase the favorable effects on road safety [11,15].

Despite the above, very little research has been conducted to date on the safety effects of reducing speed limits and increasing enforcement measures in Austria. Given the high relevance of this topic, such research would, however, serve to demonstrate the potential of such measures, establish a better decision-making basis for the government and road authorities and, at the same time, increase public acceptance [16]. In addition, reducing the maximum speed limits and actual speeds driven, which would be beneficial to road safety and has already been implemented in other countries (e.g., Spain [17] and France [18]), is often met in Austria with concerns on the part of motorists that this would raise journey times. Although earlier studies (e.g., Archer et al. [19]) show that speed limit reductions have only a marginal impact on journey times, no assessment of the real changes this would produce has as yet been carried out in Austria. Indeed, there is a clear lack of studies showing the effects of changed speeds, speed limits, tolerance limits or penalties on road safety and journey times in Austria.

To fill this gap, this paper investigates the effects of speed changes and different legal framework conditions with regard to speeding (e.g., maximum permissible speed, penalty levels) on journey times and road safety (number of accidents and injury severity) in Austria.

2. Methodology

To investigate the effects of speed changes and different legal framework conditions with regard to speeding (e.g., maximum permissible speed, penalty levels) on journey times and road safety, six scenarios were used. Based on these scenarios, microscopic traffic flow simulations were carried out using the PTV Vissim traffic simulation software on four representative sample routes in Austria to investigate the effects on car journey times. The sample routes were then extrapolated to average car journey lengths in Austria based on the distribution of such journeys reported in an Austria-wide household mobility survey. To assess the effects on road safety, reconstructions of real accidents and collision avoidance analyses were carried out using the scenarios. Speed profiles obtained from comprehensive speed measurements in Austria and Switzerland were used as the basis for the simulation of the different scenarios.

2.1 Scenarios and simulation approach

Table 1 provides an overview of the six different scenarios used in the study. Starting from the status quo in Austria (S1A), an investigation of the effects of speed changes was performed under the assumption of fewer speed limit violations, e.g., through heavier penalties (as in Switzerland) (S1B), and an actual zero tolerance, i.e., no speed limit violations (S1C), while maintaining the current maximum speed limits. The maximum permissible speed was subsequently reduced by 20 km/h in the other scenarios (from 50 km/h to 30 km/h on urban roads and from 100 km/h to 80 km/h on non-urban roads), with a distinction again made between the situation in Austria (S2A), fewer speed limit violations, e.g., through heavier penalties (as in Switzerland) (S2B), and no speed limit violations (S2C).

Table 1: Overview of the scenarios and the various framework conditions with regard to speeding

	Maximum permissible speed			**Tolerances**	**Penalty levels**	**Driving licence suspension times**	**Speed violations**
		Urban roads	**Rural roads**				
S1A – 50/100: situation in Austria (status quo)	No change in maximum permissible speed	50 50 km/h	100 100 km/h	No change	No change	No change	No change
S1B – 50/100: fewer speed limit violations, e.g., through heavier penalties (as in Switzerland)		50 50 km/h	100 100 km/h	Lower	Higher	Sooner and longer	Share of violations as in Switzerland
S1C – 50/100: no speed limit violations		50 50 km/h	100 100 km/h	No change	No change	No change	No violations
S2A – 30/80: situation in Austria	Reduced maximum permissible speed	30 30 km/h	80 80 km/h	No change	No change	No change	No change
S2B – 30/80: fewer speed limit violations, e.g., through heavier penalties (as in Switzerland)		30 30 km/h	80 80 km/h	Lower	Higher	Sooner and longer	Share of violations as in Switzerland
S2C – 30/80: no speed limit violations		30 30 km/h	80 80 km/h	No change	No change	No change	No violations

The impact mechanisms and effects of individual speed-reducing measures (e.g., with regard to penalty levels and tolerance limits), i.e., an isolated assessment of the effects of individual speed-reducing measures, were not clearly identifiable. Moreover, due to many determinant framework conditions and a lack of data, these mechanisms and effects could only be inadequately applied to the conditions in Austria. Consequently, the decision was taken to implement and simulate the scenarios based on speed profiles (measured speeds and share of violations) obtained from extensive speed measurements in Austria [20] and Switzerland [21] (Figure 1).

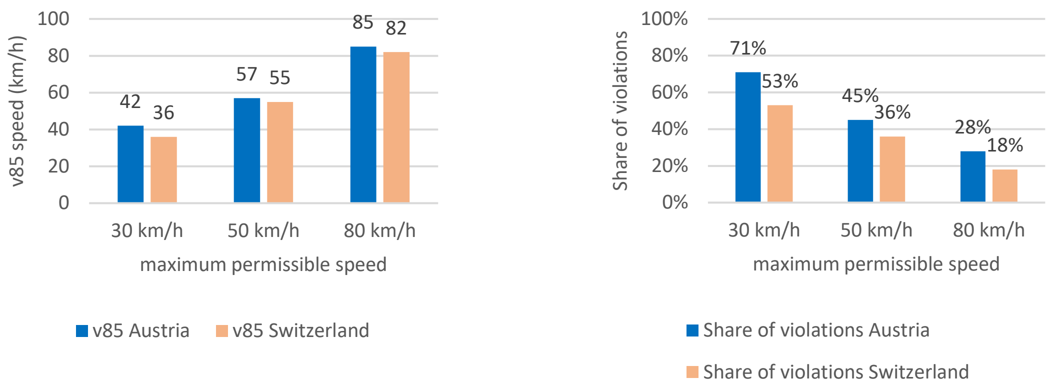

Figure 1: Speed profiles, i.e., v85 (left) and share of violations (right), in Austria and Switzerland at different speed limits; Source: [20,21].

For scenarios S1B and S2B, the speed profiles from Switzerland (reflecting lower penalty levels and tolerance limits) were transferred to Austria: the differences determined from the speed measurements in Switzerland at different speed limits, i.e., the shares of violations, were compared with those from the measurements in Austria and transferred to the sample routes. Since there were no values for a speed limit of 100 km/h on rural roads in Switzerland, the values were extrapolated approximately and compared to those for Austria.

For scenarios S1C and S2C, it was assumed that no vehicles exceed the maximum speed limit on urban roads and rural roads but that the scenarios have no influence on those vehicles that already adhere to the speed limit or drive more slowly, i.e., there is a strong harmonization of the speeds driven. For scenarios S2A, S2B and S2C (where the maximum speed limit is reduced), it was assumed that the change to the speed limit has already been successfully implemented, i.e., drivers behave as if the reduction has been in place for a long time. Changes in the infrastructure, e.g., narrowing lane widths or design measures to support speed reduction, were not considered. Moreover, with regard to the reduction in the maximum speed limit, no changes to the share of violations and the speed travelled were assumed ex-ante.

Table 2 provides an overview of how the speeds driven on urban and non-urban roads in Austria would change based on these assumptions and the respective scenarios. In addition to the v_{85}, the v_{50} and the v_{95} are also given. The speeds indicated represent average values for the v_{85}, the v_{50} and the v_{95} for the whole of Austria.

Table 2: Speed on Austrian roads per scenario for urban and non-urban roads[2]

Urban roads		Speed (km/h)		
		v_{50}	v_{85}	v_{95}
S1A	50: situation in Austria (status quo)	49	57	62
S1B	50: fewer speed limit violations, e.g., through heavier penalties (as in Switzerland)	48	55	59
S1C	50: no speed limit violations	49	50	50
S2A	30: situation in Austria	35	42	46
S2B	30: fewer speed limit violations, e.g., through heavier penalties (as in Switzerland)	31	36	41
S2C	30: no speed limit violations	30	30	30
Rural roads		**Speed (km/h)**		
		v_{50}	v_{85}	v_{95}
S1A	100: situation in Austria (status quo)	87	99	107
S1B	100: fewer speed limit violations, e.g., through heavier penalties (as in Switzerland)	81	93	100
S1C	100: no speed limit violations	87	99	100
S2A	80: situation in Austria	74	85	92
S2B	80: fewer speed limit violations, e.g., through heavier penalties (as in Switzerland)	72	82	88
S2C	80: no speed limit violations	74	80	80

2.2 Microscopic traffic flow simulation

To calculate the effects of the scenarios on journey times, first microscopic traffic flow simulations on four representative sample routes in Austria were carried out using the PTV Vissim traffic simulation software. The sample routes were selected based on number of accidents, speed measurements and parameters like curviness or number of intersections. Ultimately, the aim was for the sample routes to embody the "typical traffic situation" in urban and non-urban areas. Criteria such as curves, different vehicle types (e.g., share of HGVs), through-roads and changing speed limits (non-urban areas) as well as complex intersections and crossing situations and the occurrence of different road users (urban areas) should all be present to a relevant extent. Based on the data collected and the criteria mentioned above, the sample routes shown in Table 3 were selected for the traffic flow simulations.

Table 3: Overview of the selected representative sample routes and their characteristics

Route number	Federal State	Area	Name	km from	km to	~ADTw [veh./24h]	~length[km]	Number of accidents 2013-2019
1	Lower Austria	Urban area	Daniel-Gran-Straße	Praterstraße/ Goldegger-straße	Eybner-straße	13,000	1.0	47 (on road section and intersection areas)
2	Lower Austria	Outside urban area	L35	24.5	27.2	1,800	2.7	7
3	Burgenland	Outside urban area	B50	55	63.4	8,000	8.4	39
4	Styria	Outside urban area/ urban area	B54	92.5	107.8	13,000	15.3	135

For the simulation, the sample routes were first calibrated to the current situation, i.e., the current traffic volumes and speed distributions for the sample routes were modeled. This was done on the basis of speed measurements at the various measurement points on the sample routes for the period 2018-2020 [20]. To simulate the different scenarios, the traffic flow was modeled for each sample route based on the varying speed profiles, i.e., the measured speeds and shares of violations (see Table 2), and the car journey times when passing through the corridors (both directions) were determined.

[2] Own assumptions. Values for S1A and S2A based on measured values from KFV [21]; values for S2A and S2B based on measured values from Switzerland [20]; values for S1C and S2C based on measured values from KFV and the assumption that the maximum permissible speed is not exceeded.

In order to be able to relate the findings regarding car journey times from the sample route traffic flow simulations to Austria as a whole, the route-specific journey time changes were extrapolated based on the results of a nationwide mobility survey [22]. To transfer the sample route journey time evaluations to the trip length classes, the corresponding changes were weighted with the potential route shares of car journeys by type of location. The extrapolation took into account that the determined journey time effects are only due to speed-reducing measures on urban and non-urban roads, while there is no change in speed conditions on highways.

2.3 Accident and collision avoidance analyses

The investigation of the effects of the defined scenarios on road safety was based on both the reconstruction of real accidents and on collision avoidance analyses. For this purpose, the accidents were reconstructed twice. The first reconstruction built the "baseline" and was based on evidence at the scene of the accident and the injuries sustained by the persons involved. The initial speed and collision speed were calculated using the accident reconstruction software PC Crash. The initial speed was subsequently adjusted to the respective scenarios (see Table 2), and collision avoidance analyses performed in a forward simulation (referred to as a "treatment"). The number of avoided collisions was determined in a pre-post evaluation of the baseline and treatment, i.e., the difference between the number and severity of accidents in the baseline and the number and severity of accidents based on the respective adjusted intial speed in the treatment. i. Real accidents contained in the IGLAD accident database [23-25] were used for the collision avoidance analyses, with only those accidents for which the speed limit was given included. Accidents on non-urban roads with a speed limit of 100 km/h and urban roads with a speed limit of 50 km/h were considered.

In order to determine the total reduction potential for minor injuries, severe injuries and fatalities, appropriate weighting factors were used to extrapolate the sample to total accidents in Austria as indicated in the official road accident statistics. Based on the reduction potentials thus determined, an assessment of the accident costs was also carried out in accordance with Austrian accident cost accounting procedures [26].

3. Analysis and Results

3.1 Car journey times

The results for the four sample routes (Figure 2) show that the journey times did not increase much in all scenarios. For the sample routes in non-urban areas, the increase in journey time was marginal (around 1 to 13 seconds per kilometer traveled). Even for the urban sample route (route 1) – which showed a higher increase in journey times than the non-urban routes – only a small increase (around 2 to 34 seconds per kilometer traveled) could be observed. The estimated increase in journey time would be especially low for scenario S2C (reduction in maximum permissible speed and fictitious implementation of measures that would lead to full compliance with the speed limit).

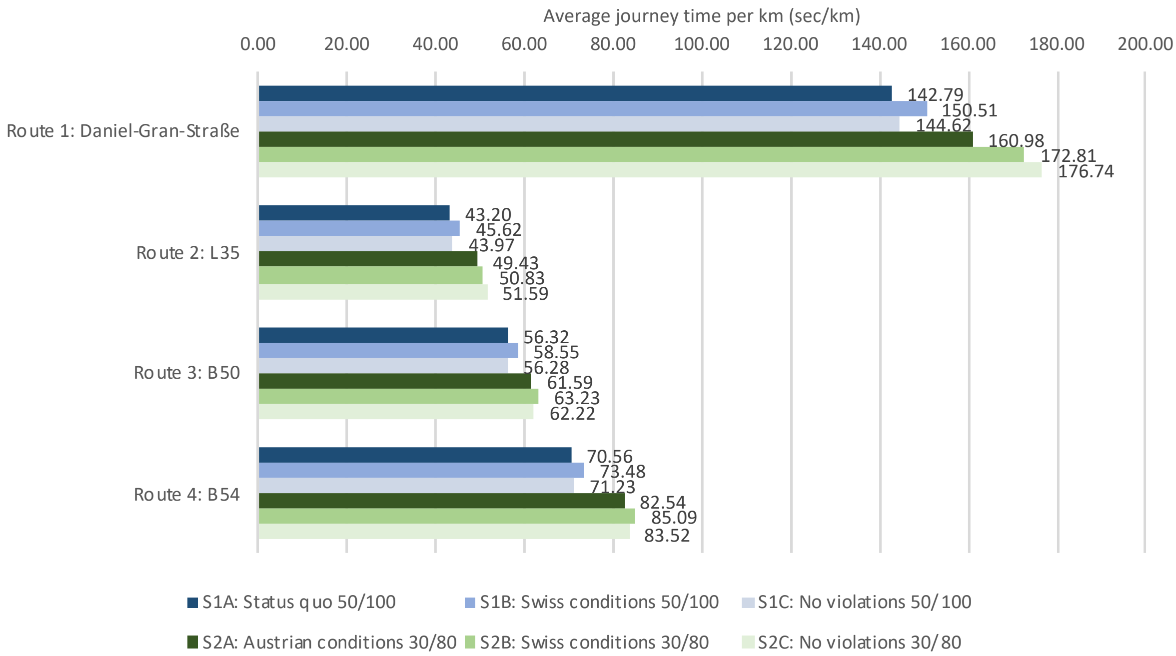

Figure 2: Comparison of average journey times per km for the different sample routes and scenarios

Based on the extrapolation of the effects on journey times from the sample routes to Austria as a whole (Figure 3), it becomes apparent that the increase in journey time is significantly less than 1 minute per journey for all scenarios and especially for short trips of up to 5 kilometers (which corresponds to 40% of all car journeys in Austria [22]). The potential change in journey time in relation to the average car journey length of 15.7 kilometers in Austria is between 0.09 minutes (5 seconds; S1B) and 1.90 minutes (S2B) depending on the scenario. Overall, a maximum increase in journey time of between 0.2 minutes (12 seconds; S1C) and 4.5 minutes (S2B) per journey can be assumed for 95% of all car journeys (up to 50 km) in Austria.

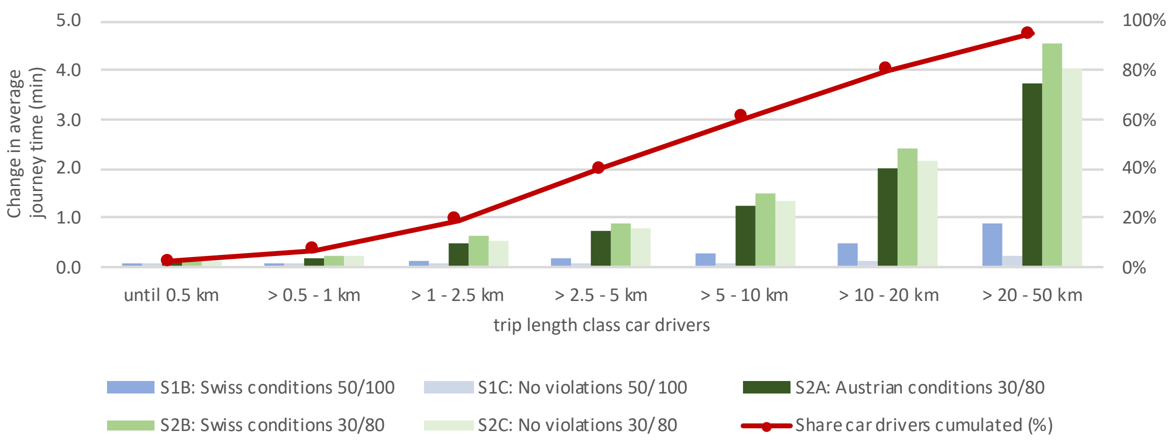

Figure 3: Potential changes in journey time per scenario and journey length for cars compared to the status quo based on the national household mobility survey "Österreich unterwegs 2013/14"

3.2 Road safety

With regard to the effects on road safety, the scenarios show reductions in the numbers of fatalities, severe and minor injuries both for car occupants and pedestrians. The highest reduction in the number of victims can be observed for the scenarios with a reduction of the speed limit to 30 km/h in urban areas and 80 km/h in non-urban areas. Fatalities among car occupants could potentially be reduced by about 8% (S1B and S1C) to 19% (S2C). Pedestrian fatalities of pedestrians could be reduced by about 9% (S1B) to 15% (S2B and S2C), with reductions in severe and minor injuries and the corresponding (annual) accident costs particularly apparent in scenarios S2B and S2C.

Table 4: Potential reduction (relative and absolute) in minor, severe and fatal injuries to car occupants (non-urban areas) and pedestrians (urban areas) per year (2013-2019) and corresponding (annual) accidents costs in Austria

	Scenario	Car occupants				Pedestrians			
		Minor injuries	Severe injuries	Fatal injuries	Accident costs	Minor injuries	Severe injuries	Fatal injuries	Accident costs
S1B	50/100: fewer speed limit violations, e.g., through heavier penalties (as in Switzerland)	- 15.6% / - 706	- 6% / - 51	- 7.7% / - 9	- € 75.82 million	- 2.1% / - 29	- 6.9% / - 30	- 8.7% / - 2	- € 21.05 million
S1C	50/100: no speed limit violations[3]	- 14.1% / - 635	- 4.5% / - 39	- 7.7% / - 9	- € 67.59 million	- 4.7% / - 65	- 6.9% / - 30	- 11.9% / - 3	- € 24.72 million
S2A	30/80: situation in Austria[4]	- 17.2% / - 776	- 9% / - 77	- 11.5% / - 13	- € 104.39 million	- 10.8% / - 149	- 14.6% / -63	- 11.9% / - 3	- € 42.83 million
S2B	30/80: fewer speed limit violations, e.g., through heavier penalties (as in Switzerland)	- 18.8% / - 847	-11.9% / - 102	- 15.4% / - 17	- € 132.97 million	- 16.1% / - 221	- 17.2% / - 74	- 15.2% / - 4	- € 52.79 million
S2C	30/80: no speed limit violations	- 18.8% / - 847	- 11.9% / - 102	- 19.2% / - 21	- € 147.43 million	- 26.6% / - 365	- 22.4% / - 96	- 15.2% / - 4	- € 67,77 million

4. Discussion and Conclusions

This paper investigates the effects of speed changes and different legal framework conditions with regard to speeding (e.g., maximum permissible speed, penalty levels) on car journey times and road safety (number of accidents and injury severity) in Austria for the first time.

Overall, the results show that the reduction in speeds for motorized road traffic, which were simulated based on different legal speeding framework conditions as well as the speeding behavior of road users in several scenarios, can make a key contribution to reducing the numbers of fatalities, severe and minor injuries on the roads. At the same time, none of the scenarios investigated are expected to have a significant and noticeable impact on travel times for the majority of Austrian car drivers in everyday life. This indicates that the subjective feeling of losing time due to a lower speed limit that is used by car drivers as an argument in the public debate in Austria is mostly unfounded and that the perceived loss in time is higher than the actual loss of time determined in the simulations. Furthermore, with reductions in fatalities of up to 19% for car occupants and up to 15% for pedestrians, the results of the study contradict the common subjective belief of car drivers that reducing the speed limit or introducing measures to combat speeding only has marginal effects on road safety.

In addition, when looking at the results of the different simulated scenarios, it is evident that a harmonization of the speeds driven (as assumed in S1C and S2C) had positive effects on car journey times. Accordingly, the increases in journey times were lower for S1C and S2C than for S1B and S2B. At the same time, further positive effects on road safety, i.e., higher reductions in fatal, severe and minor injuries to car occupants and pedestrians, could be observed for S1C and S2C.

Although a simulation approach was used in the study, the results regarding the effects on road safety (reductions in severe and fatal injuries to car occupants of up to 12% and 19% respectively; reductions in severe and fatal injuries to pedestrians of up to 22% to 15% respectively) are also in line with previous before-and-after studies on the road safety effects of speed limit reductions (e.g., [1,8]), which indicate a corresponding reduction in the numbers of injuries and fatalities in the range of 25% to 35%. Similar to Archer et al. [19], the results of our study also only indicated marginal effects on car journey times.

[3] The lower potential reduction in minor and severe injuries to car occupants in scenario S1B vs. scenario S1C stems from the higher v_{85} (S1C: 99 km/h; S1B: 93 km/h). Scenario S1C is based on the status quo in Austria (v_{85}: 99 km/h) and assumes there are no speed limit violations. Scenario S1B is based on the situation in Switzerland: a lower v_{85} (93 km/h) and also fewer speed limit violations.

[4] Unchanged percentage of speed limit violations; unchanged v_{85}.

The traffic simulations and accident reconstructions performed in this study using the different scenarios are clearly only approximations of reality. Moreover, since it was difficult to investigate the specific effects of different individual factors (e.g., higher penalty levels, lower tolerance, etc.), an approach was chosen that simulated a combination of these factors by transferring the v_{85} and the share of violations for different speed limits from speed measurements in Switzerland (where such a combination is in place) to Austria. However, using a simulation approach did also have the advantage of investigating the effects of different combinations of measures, i.e., reduction in speed limit only or reduction in speed limit in combination with heavier penalties, which also allowed us to investigate the isolated effects of specific individual measures like reducing the speed limit. Such an assessment is difficult using before-and-after studies because real-life speed limit reductions are generally implemented in combination with additional infrastructural or educational measures. Furthermore, the investigation of the effects on road safety and car journey times relied on different scenarios for which several assumptions regarding measures had been made. Different combinations of assumptions (e.g., vehicles exceeding the speed limit in S1C and S2C instead of no vehicles exceeding the speed limit or speed limit reduction only on urban roads or only on non-urban roads) would have been possible.

Nevertheless, the results presented show that a reduction in the speeds driven by motor vehicles has considerable potential for reducing the numbers of fatalities as well as severe and minor injuries on Austria's roads, while at the same time having no significant impact on journey times for the majority of Austrian car drivers. Based on these results – and given that inappropriate speed is the most frequent stated cause of fatal road accidents in Austria – policymakers should focus on measures to reduce speeding and speeding-related accidents. These should include not only a possible reduction in the speed limit on specific sections of non-urban roads (as is the case in Switzerland) but should be accompanied by speed enforcement measures and an increase in fines. This applies in particular for excessive speeders who drive at significantly higher speeds. These should be subject to higher fines, a reduction in the thresholds for driving license revocation, longer driving license revocations as well as vehicle impoundment measures, e.g., for excessive speeding in dangerous conditions. This is all the more important at present as the COVID-19 pandemic and related containment measures have resulted in reduced traffic volumes and less crowded streets and increased the problem of speeding in many countries [27,28].

Acknowledgements

We would like to thank Steffen Niemann from BFU (Beratungsstelle für Unfallverhütung) for the provision of the data for calculating the results for the "Swiss conditions".

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