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Getting an insight into the effects of traffic calming measures on road safety

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Abstract

The objective of this paper is to assess the significance of urban traffic calming and to get an insight into the safety impacts of local and area-wide traffic calming interventions enabling a better understanding and therefore 'better-informed' decisions on different schemes. Safety effects of traffic calming initiatives have been analysed on a city-level for larger Hungarian cities and an in-depth research has also been carried out for a more detailed case from the capital of Hungary. Results show that traffic calming initiatives have a very significant role in enhancing road safety of urban areas. Meanwhile the case study of Budapest explains observed effects in detail allowing for more accurate appraisal tools to be developed.

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Keywords: Road safety; traffic calming; evaluation

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1. Introduction

Urban transport systems in the developed countries are still dominated by private cars and most cities are suffering from the side effects of this car-orientation. In spite of traffic calming measures gradually spreading since the 1960s, further initiation of these interventions is on the agenda of cities with the set purpose of creating liveable urban areas. Besides the goal to break down the dominance of private cars and encourage a multimodal optimum,

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improving traffic safety has retained its significance as an aim in itself. In connection with the programme laid down in the EU White Paper on Transport (2011), road transport policies have an important role to play in achieving the goal of a smart, clean and safe transport system. In this pursuit stressed attention needs to be paid to urban transport in regards to its vulnerable road users: pedestrians and cyclists. (European Commission, 2011)

In the last 50 years several traffic calming techniques evolved alongside the establishment of basic principles and general guidelines of application. However, as previous studies of this research programme pointed out, strategic aspects of application are relatively ambiguous, which is blocking further progression. (Juhász, 2014)

The objective of this paper is to assess the significance of urban traffic calming and to get insight into the safety impacts of local and area-wide traffic calming interventions enabling a better understanding and therefore 'better-informed' decisions on different schemes.

First the paper describes the safety effects of traffic calming measures. In the next chapter nine Hungarian cities with over 100,000 inhabitants are analysed concerning population, length of the road network, volume of road traffic, modal split, share of traffic calmed areas and personal injury accidents between 2005 and 2012. Relationships between road safety indicators and the above mentioned variables are sought on the city level focusing on the role of traffic calming. In the case of Budapest an in-depth research has been performed for a smaller study area based on a more detailed model. Territorial analyses have been carried out in order to compare safety performances before and after certain traffic calming interventions, while filtering out external effects. Results show that traffic calming initiatives have a very significant role in enhancing road safety of urban areas. Meanwhile the case study of Budapest explains observed effects in detail, making more accurate modelling and appraisal tools to be developed. In conclusion the paper points out the importance of network-level approaches considering area-wide impacts of traffic calming schemes. The special role of pedestrians and cyclists is also emphasized.

2. Road safety effects of traffic calming measures

The concept of calming road traffic gives some cause for confusion, as its definition is rather ambiguous. A study from Kjemtrup and Herrstedt (1992) clarifies these issues and reviews the development of traffic calming over time. In their interpretation calming means to reduce car accessibility and passability for a set purpose (or purposes). It can be manifested in many ways, through the application of different measures from road signs to physical measures and to road pricing. In other words it is the opposite strategy of giving priority to road traffic.

The birth of traffic calming dates back to the 1960s when car ownership and car use increased significantly. Road congestion became a constant problem in most cities especially in Western Europe. Queuing was not acceptable for many car drivers; therefore they looked for local streets to take a shortcut. Local residents were disturbed by higher volumes of road traffic and could hardly get accustomed to it. Road safety problems also intensified and especially vulnerable road users were endangered. The universal 'answer' of transport planners was the separation of different road users, which became the dominant planning principle for the 1970s. It was cumbrous to realize this strategy as it required a lot of space and invested money while it seemed to be insufficient to overcome the prevailing problems. In 1968 a new approach appeared in the Netherlands. A group of local residents led by an urban planner arbitrarily reconstructed their street in the city of Delft in order to 'calm' road traffic. The basic principle was to integrate road users, which meant that private cars must reduce their speed. The design took the name 'Woonerf' and it gradually spread around Europe with some adjustments to different cases (speed management in Sweden, 'shared areas' and 'silent roads' in Denmark, etc.). Some examples of the effects of 'shared spaces' from Germany and the Netherlands are given by Gerlach et al. (2008). Later on in the 1980s and 90s, other branches of techniques were also invented for roads with higher volumes of traffic (e.g. 'environmentally adapted through roads'), while the aesthetics of the design also improved (e.g. Bezák 2006). Other special solutions of traffic calming called 'car free areas' could be found in several European cities (e.g. Gaffron et al., 2005). The latest stage of development is the appearance of travel demand management (TDM) with an extended toolbox involving fiscal instruments as well (e.g. parking and road charges). (Kjemtrup-Herrstedt, 1992; Leden et al., 2006; Hamilton-Baillie, 2008; Juhász, 2014).

The main goals of traffic calming initiatives can be summarized in the following:

- Improve traffic safety
- Improve environmental quality
- Improve the quality of public spaces

Experiences and case studies of traffic calming schemes showed that these measures can successfully reach their goals. However, the extent of different effects are context and case-specific, which makes their forecasting quite difficult. Nevertheless, rules of thumb have been defined based on vehicle-km specific accident rates or observed speed reductions (see Archer et al., 2008). Rune Elvik created a meta-analysis of studies on safety effects and came to the conclusion that area-wide traffic calming generally reduces the number of accidents by about 15% in the entire area affected by the measures (Elvik, 2001).

Nonetheless, the effect mechanism of traffic calming measures could be sketched in order to better understand the possible effects they may have. A standard calming initiative is basically altering the disposability (right to access, parking possibilities) and/or the passability (speed) and/or the capacity of a road. A change of these road characteristics and parameters then causes different effects for the road users. Travel times, direct travel costs and accident risks may alter. In this paper the focus is clearly on the change in accident risk, which is a consequence of reduced speed and traffic volume (direct effects), plus the modified layout of the road and its environment (indirect effects). There are obviously further effects in the latter part of the process as quality of road use and public spaces (represented by user costs) are changing. Therefore travel behaviour, land-use and activity patterns might transform. In most cases these effects are localized but wider impacts could follow as the transport system, real estate and other markets respond. In the long-term policy-makers also respond, which is a feedback loop in the process, and this is illustrated in Fig. 1.

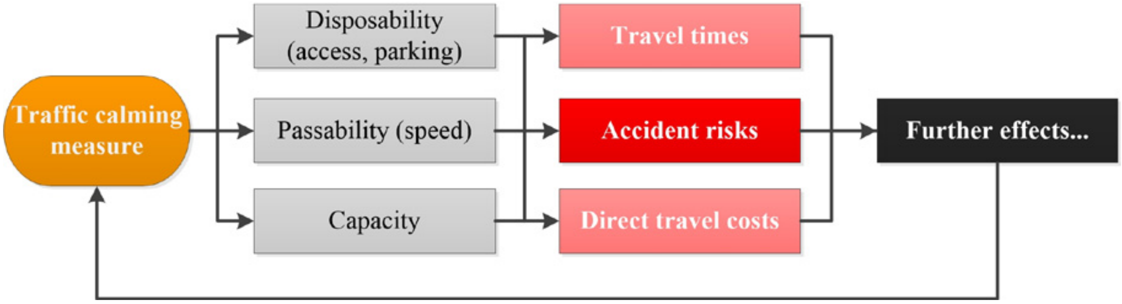

Fig. 1. The generalized effect-mechanism of traffic calming measures.

3. Comparison of traffic safety in Hungarian cities - the role of traffic calming

In this section the result of a Hungary-specific analysis is presented, which was carried out among larger cities. The aim of the research was to explore those causes, which can explain certain differences in the road safety performance of different cities. Finding these explanatory variables has its own obstacles:

- To analyse these things on a system-level a certain city size is needed and there are only 9 cities in Hungary in which the population exceeds 100,000;
- 8 of these cities are similar in size (their population is between 100,000 and 200,000) but the capital is the odd one out with its 1.7 million residents, while there is no transition between these size groups;
- There is a very limited set of data: accident statistics are available from 2005 but characteristics of road networks are sometimes missing (e.g. number of intersections, type of traffic control) and especially traffic data is very limited (e.g. modal split data, traffic volumes, average travel distances);
- Certain aspects of accident statistics are sometimes unreliable (e.g. positioning).

Despite all of these limitations, some basic assumptions for explanatory variables have been analysed based on the available data and on some reliably presumable estimations. However, due to the above mentioned issues a strong correlation cannot be expected as a result of this analysis. Nevertheless, the role and effect of different variables and approximate strength of correlations might be explored. This should be taken into consideration when someone reviews these results.

It is quite obvious that several factors (can) influence road safety performances beyond those that were analysed in this research. Anyway, if we recall the threefold driver-vehicle-road concept of road safety and assume that drivers and vehicles have a similar distribution in terms of driving ability and technological equipment over all of the different regions of the country then causes of differences should be sought in the infrastructure part. It is naturally difficult to objectively measure the level of safety of an urban road network but the analysis of some presumed impact factors can be carried out. Examples for these factors can be seen in the following: such as the ratio of roundabouts or traffic calmed areas or state-owned roads.

From the ones analysed the relation between the modal share of private cars and accident density[1] is quite unambiguous. It suggests that the share of cars is a dominant factor of road safety. Another obvious relationship is the one between the ratios of traffic calmed areas and accident densities with negative correlation. However, there are a few interesting results such as the negative relation of the ratio of roundabouts, or the neutral effect of city size, GDP, level of bypass roads and the ratio of state-owned roads.

In addition, the effects of the modal share of cycling and walking on the accidents caused by these transport modes are also very interesting. Analyses show that the share of cyclists has a similar effect like the share of cars, i.e. the higher ratio of cyclists resulted in a higher specific number of accidents caused by cyclists. On the contrary, a negative correlation can be revealed between the share of walkers and the density of accidents caused by them. An explanation could be that an increase in the number of pedestrians encourages cautiousness and a more conscious attention to each other from all users.

Table 1. Analysis of the supposed explanatory variables for road safety performances of major Hungarian cities.

Supposed explanatory variable	**Type of correlation**	**Informative strength of relationship (R^2)**	**Comment**
Analysed dependent variable: Average density of accidents 2005-2012			
Size of the city (population, length of road network): “economies of scale” for safety performance	No correlation	-	Only a very weak positive relationship if the capital is excluded
Modal share of private cars	Positive	0.578	
Modal share of public transport	Negative	0.584	
Modal share of cyclists	Negative	0.570	
Modal share of pedestrians	Negative	0.414	Unreliable modal share values due to the difficulty of measurement
Ratio of roundabouts and signalized intersections	Negative	0.664	
GDP	No correlation	-	Only a very weak positive relationship if the capital is excluded
Ratio of area-wide traffic calming to total territory	Negative	0.539	
Level of bypass roads	No correlation	-	Minimal effect of bypass possibilities
Ratio of state-owned roads	No correlation	-	
Analysed dependent variable: Average density of accidents caused by cyclists 2005-2012			
Modal share of cyclists	Positive	0,796	
Analysed dependent variable: Average density of accidents caused by pedestrians 2005-2012			
Modal share of pedestrians	Negative	0,770	

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[1] Accident density = number of accidents / length of road network. Accidents are personal injury accidents throughout the analysis as only this type of data is reliable in Hungary.

Results of the above mentioned analysis are summed up in Table 1. One can note that dependent variables are average accident densities in all cases. The reason for this is that the average accident density for the analysis period (2005-2012) made the comparison of cities possible for the most part. With other dependent variables or in shorter periods of time the mentioned relationships can also be shown but their strength has its highest value in the presented case.

As a specific topic, the role of traffic calming in achieving better road safety is illustrated by Fig. 2. The ratio of traffic calmed areas should be construed from a territorial point of view: it is calculated by dividing the total area of area-wide traffic calming territories with the total area of the city.

Further details of the analysis can be found in Juhász 2015.

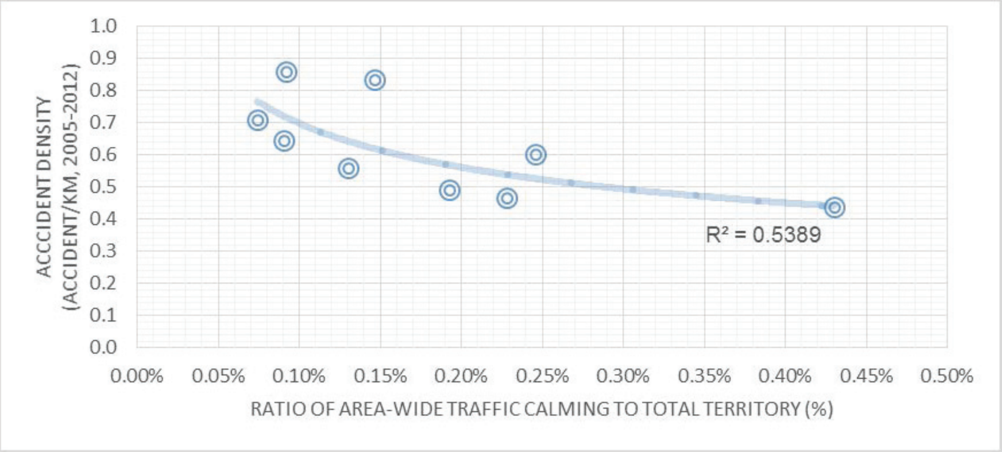

Fig. 2. The relationship between accident density and the territorial ratio of area-wide traffic calming.

4. The case study of Budapest

In the case of Budapest it was possible to carry out an in-depth research for a smaller study area. The main idea was to perform a more detailed study for a major area-wide traffic calming project. The urban rehabilitation of the city centre in Budapest started in 2008 with the so-called ‘Heart of Budapest’ and ‘New High Street of the City Centre’ projects. By early 2010 most of the constructions were completed and now after 5 years this is a unique opportunity to analyse the results in details. The second phase of these projects were implemented in 2013-2014 but it has not jeopardized our analysis.

The goal of the mentioned projects was to improve the liveability of the city centre (District 5) by restricting road traffic and enhancing the urban quality of streets. Restriction of road traffic was meant to be reached by the banishment of through car traffic and focus on residential demands and on other modes of transport. Main network elements (inner ring road, east-west axis of Kossuth Street, embankments) retained their role, which is to provide road capacity. However, minor adjustments have been made on the inner ring road in order to improve cycling and walking conditions. The biggest modification was to ban through traffic from the south-north one-way axis of Petőfi Street, which used to be a shortcut in the case of congestion on other roads (see the blue stripe in Fig. 3). Retractable bollards were installed at two key intersections to filter through traffic, while an underpass which had previously provided a left turn option was demolished.

The basic idea of the analysis was to compare safety performance before and after the intervention on a territorial basis. It is important to note that some elements of the projects were implemented in the second phase (2013-2014) but they have not changed the characteristic of either the previously calmed (and analysed) route or the affected area (the southern part of District 5). Indeed in 2013 the underpass (which could be used only by residents and local buses in that time) was replaced by a level-crossing and another intersection was reconstructed.

A standard road safety indicator was calculated for the comparison. The weighted injury rate was chosen to reflect (1) traffic performance, (2) injuries and (3) severity. Damage only accidents were excluded, as there is not any reliable data. The period of 2004-2008 was labelled as the ‘before case’, while 2010-2013 as the ‘after case’. 2009 was excluded due to the construction works. Accident and traffic data were collected for the mentioned periods. Traffic data was provided by macroscopic transport modelling for which we used PTV Visum software. Modelling was based on traffic counting data but in order to calculate the complete traffic performance of the area it was needed to fill in the missing links artificially.

Fig. 3. Traffic calming in the city centre of Budapest.

It was also intended to filter out external effects making it easier to concentrate purely on the impacts of the projects. Therefore control groups were sought. We have not found proper control groups in a statistical sense as accident numbers are significantly fluctuating year to year. Despite this fact, routes and areas have been found with similar traffic roles, characteristics and historical road safety trends to make assumptions on a ‘without project’ case for both the analysed route and the area. The above mentioned transport modelling procedure was completed for the control groups as well.

Table 2 shows the results of the projects in both absolute and relative numbers of injuries per year. Weighted injuries were calculated with the following (Reinhold) weights based on KTI (2000): fatal – 26, serious – 14, light – 1. In terms of absolute values, a significant improvement of road safety can be observed both on the analysed route and in the affected area. The weighted number of injuries decreased by around 70% on the route and by around 60% in the area. However, relative indicators provide a more sophisticated description of the effect. The results of the performed analyses is illustrated by Fig. 4. These indicators show that in relative terms road safety improvement is more significant in the area (56%) than on the route itself (23%), which is the opposite of what might be first expected.

The causes of improved road safety can also be examined (see Fig. 5). The safety effect on the analysed route is quite conceivable. Around 90% of it can be explained by the decrease of traffic volume and the speed limit. After the projects traffic volume decreased by 58% in average compared to the average of the previous 5 years. The effect of the lower speed limit was based on the speed-injury rate function from Archer et al. 2008: an observed 12.5% decrease in the mean speed decreases the injury rate by around 32%. 10% of the effect (‘other’) is probably a consequence of the road layout (see Fig. 6). Concerning the area, the biggest impact is presented by these other, ‘extra’ causes as traffic volume decreased by only 9%, while the estimated effect of the speed limit based on the aforementioned method is 8% (please note that only the speed limit of the mentioned route was reduced in the projects). It seems that the feeling of a ‘calmed area’, a more conscious paying attention to each other and the presence of only local drivers can all explain the phenomenon but there could be hidden causes as well.

Table 2. Safety indicators before and after the traffic calming projects.

	Before (Average 2004-2008)	**After (Average 2010-2013)**
Analysed area (southern part of District 5) Total length of roads: 7.95 km		
Traffic performance (10^6/vkm/yr)	10.62	9.67
Weighted injuries (wi/yr)	76.6	30.8
Weighted injury rate (wi/10^7vkm)	73.8	32.3
Control area (north-western part of District 6) Total length of roads: 3.94 km		
Traffic performance (10^6/vkm/yr)	5.81	6.47
Weighted injuries (wi/yr)	78.6	85.8
Weighted injury rate (wi/10^7vkm)	133.5	131.9
Analysed route (Kecskeméti Street – Petőfi Street – Bécsi Street – Erzsébet Square) Total length of roads: 1.36 km		
Traffic performance (10^6/vkm/yr)	5.76	2.41
Weighted injuries (wi/yr)	41.2	13.0
Weighted injury rate (wi/10^7vkm)	74.0	56.9
Control route (Szondi Street) Total length of roads: 1.50 km		
Traffic performance (10^6/vkm/yr)	1.60	1.79
Weighted injuries (wi/yr)	21.8	23.5
Weighted injury rate (wi/10^7vkm)	132.1	126.1

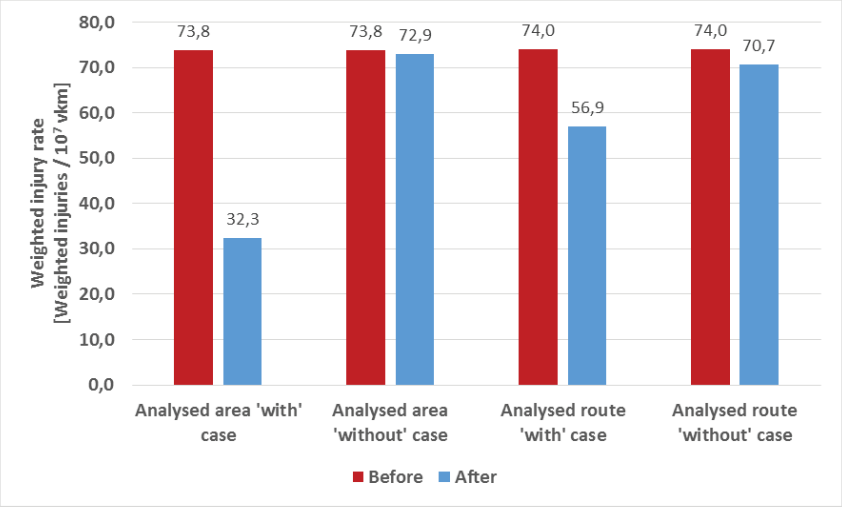

Fig. 4. The effect of the traffic calming projects on the weighted injury rates for the analysed area and route.

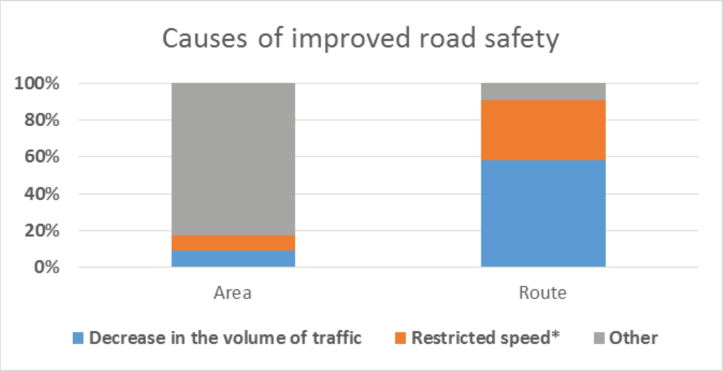

Fig. 5. Causes of road safety impacts of the traffic calming projects (* = restricted speed only applies for the analysed route)

Fig. 6. The layout of Petőfi Street after the interventions.

There are modelling issues and consequences as well. Forecasting travel demands and modelling mode and route choices have their own uncertainties. There should be doubts concerning the forecasts of road safety effects as well (e.g. the use of specific accident and injury rates). Despite the fact that these rates can guarantee quite accurate results on motorways and main roads assuming a constant update, they might not be relevant for urban areas. The reasons for that is obvious: urban transport systems are more complex, there are numerous types of roads and most importantly there is a higher level of interaction (and conflicts) between road users. These inaccurate estimations could totally distort the results of economic (e.g. cost-benefit) calculations and therefore decision-making on projects.

Table 3 presents the specific road injury rates based on current Hungarian data from national roads (Koren, 2015), those applied in the UK (DfT, 2014a; DfT, 2014b) and those city-specific ones that could be suggested based on our research. Current Hungarian guidelines specify only two categories of roads in urban areas. It has to be mentioned that these roads are all sections of national roads within built-up areas, which might not be fully representative of the whole urban network. Furthermore we found some differences between the Hungarian and British values, which might be explained by differences in the state of development. With the intention of more sophisticated forecasting we specified four categories for urban roads: major roads (main roads with a significant through traffic), standard minor roads (distributive or local roads with standard layout and regulation), restricted minor roads (distributive or local roads with slight restrictions, e.g. speed limitations) and traffic calmed roads (local roads with significant restrictions). Our test calculations show that more sophisticated categorization could contribute to a better estimation of traffic calming effects. Differences of results for the analysed case are demonstrated by Fig. 7 and 8.

Table 3. Current and proposed injury rates (sources: Koren, 2015; DfT, 2014a; DfT, 2014b).

Number of injuries / 10^7 vehicle km (probability of injuries)			
		Severity of injury	
	Fatal	**Serious injury**	**Light injury**
Current Hungarian data (values from 2010-2012, Koren, 2015)			
Main roads in built-up areas	0.082	0.964	2.569
Minor roads in built-up areas	0.113	1.115	2.861
Values from the UK			
TSGB Urban roads 2008	0.054	0.77	6.85
TSGB Urban roads 2013	0.036	0.65	5.91
COBALT 2014.3 WebTAG: other S2 roads	0.045	0.84	7.18
Proposal of this research for Budapest			
Major urban roads	0.059	2.213	7.032
Minor urban roads (standard)	0.181	5.377	17.158
Minor urban roads (restricted)	0.164	3.675	10.986
Traffic calmed urban roads	0.040	1.682	7.821

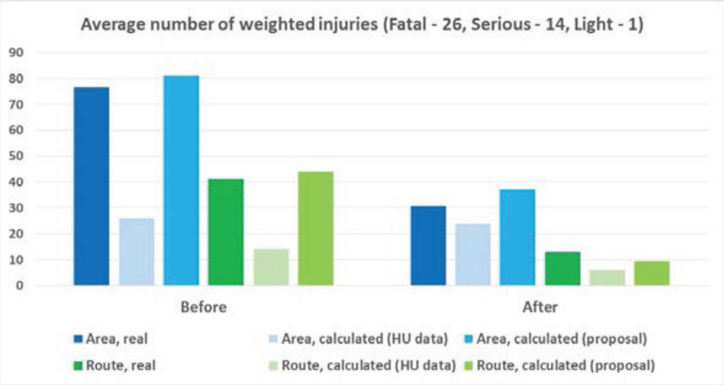

Fig. 7. Average number of weighted injuries before and after the traffic calming projects based real data and calculations with current and proposed Hungarian accident rates.

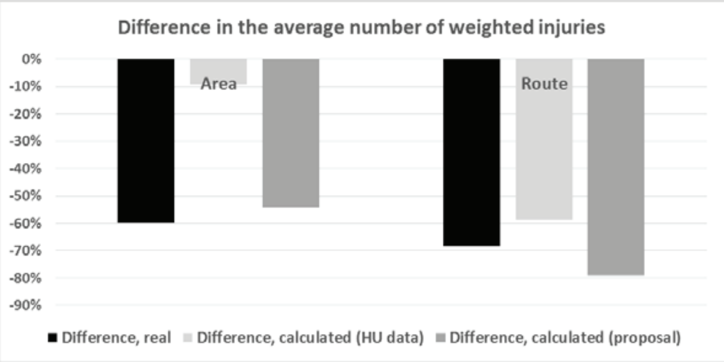

Fig. 8. Impacts on road safety based real data and calculations with current and proposed Hungarian accident rates.

5. Conclusions

Previous studies pointed out that traffic calming schemes have a very important role to play in enhancing road safety of urban areas. This research has also confirmed that an urban-scale analysis of larger Hungarian cities is needed. An in-depth study of a traffic calming case from Budapest highlighted (1) the significance of area-wide traffic calming and (2) the uncertainties surrounding the forecast of impacts on urban road safety.

Ex-post analyses like this one are badly needed in order to better understand the effects of certain measures and to enhance appraisal techniques and the specific values in use. However, modelling of urban road safety can be problematic as it was in our case due to the following:

- Reliable data is only available on accidents involving personal injuries;
- Fortunately there are only a small number of fatalities on urban roads, which unfortunately impedes the detailed analysis of fatal accident rates in smaller study areas;
- Transport modelling of construction periods and low-traffic roads is difficult.

Finally, to draft further work: more and deeper ex-post evaluations should be done on the topic with a particular attention on area-wide measures and on the special role of vulnerable road users (cyclists and pedestrians). In this quest network-level approaches should be utilised and further developed with the goal of improving modelling and appraisal methods.

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