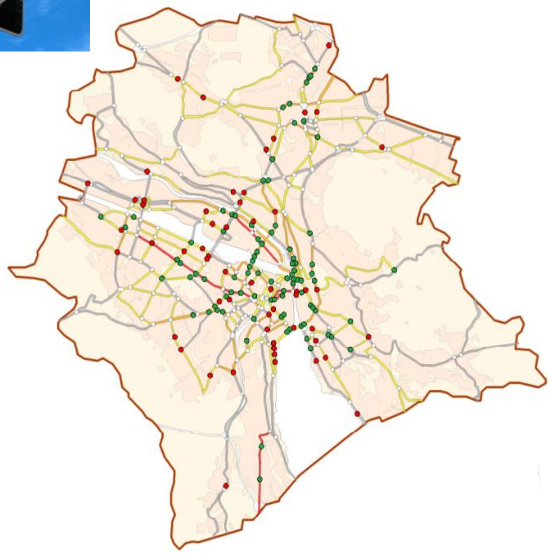

A Network Safety Management (NSM) tool for improving traffic safety in Zurich

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Abstract

Due to the great number of traffic accidents, it is essential for road administrators to know where some investments are necessary to improve the system. Network Safety Management (NSM) is a tool, based on the number of accidents, to detect locations with the highest potential for improving the road infrastructure. The area of study is the city of Zurich and the accidents in the period 2009 to 2013 are used.

The aim of the work is to properly analyse the existing results for NSM and to test different variations of input parameters. Information about the robustness of the model for inner urban areas should be provided. For that, the existing road network is explored in order to have an explicit distinction between traffic oriented roads and residential roads. On the basis of the assumptions of different accident cost rates, the avoidable accident cost per year is calculated and a prioritization of the three road network elements traffic oriented roads, nodes and residential zones is made. The results show that mostly network elements with numerous conflict points have the highest infrastructure potential for improving traffic operation. Due to the great sensitivity of the model parameters, different samples of inputs are tested. Not only new cost rates for the city of Zurich are calculated, but also a variation of the size of nodes, the traffic volume and the aggregation of section creation are examined.

Furthermore, an overlay with the widely adopted road safety tool of Blackspot Management (BSM) is done to verify the detected accident clusters. The findings are used to make pragmatic recommendations on the use of NSM as a safety analysis tool.

Keywords

Network Safety Management (NSM), infrastructure potential, accident cost, sensitivity analysis

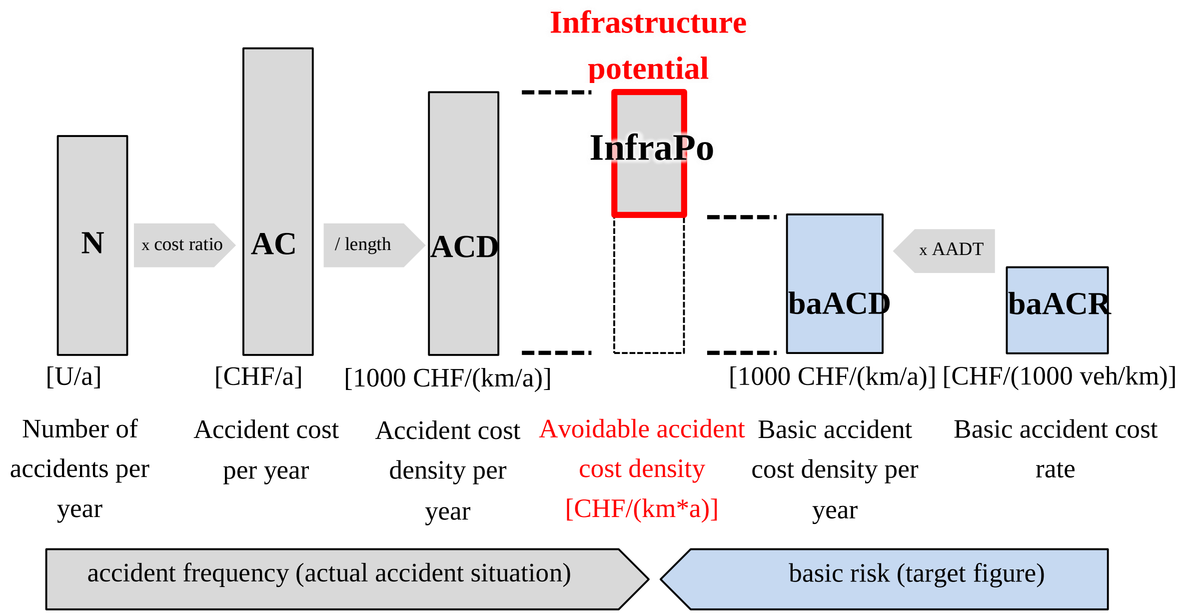
1. Introduction

In the past, road administrators have defined a hazardous part of the road network based on a certain amount of accidents. These parts, called black spots, were usually mitigated by improving the local traffic situation. In order to analyse the accidents on a larger scale, the Federal Roads Office (FEDRO) in Switzerland has started to implement Network Safety Management. This Network Safety Management (NSM) is a method to assess the crash reduction potential of locations in a road network (Schermers, Cardozo, & Elvik, 2011). It is one of the six infrastructure safety tools that FEDRO is applying to improve road network safety (FEDRO, 2013). The objective of NSM is to prioritize different network elements such as road sections or nodes to guarantee that investments in infrastructure are as cost efficient as possible (Bundesanstalt für Strassenwesen (bast), Service d''Études technique de routes et autoroutes (Sétra), 2005).

The pilot projects of NSM in Switzerland have started in 2013. FEDRO, in collaboration with the "Research and Standardization in the field of road and transportation" (VSS), created a Swiss rule (SNR 641 725) which defines the process of implementing NSM in Switzerland. Additionally, the most relevant parameters were determined. Four different pilot sites are chosen, they include two rural areas (Berne and Aargau) and two urban areas (Basel and Zurich). The first results were presented at the end of 2014. According to the Swiss rule, the main goal of NSM is to calculate a so called "infrastructure potential". This means, the possible optimization which can be done by the infrastructural side, compared to a best practice design.

To calculate this infrastructure potential, two main steps are necessary: First of all, it is important to build a well-prepared network model that represents the actual road situation as realistically as possible. The second step is implement the network parameters to the NSM model. Figure 1 shows schematically the process of calculating the infrastructure potential. It is divided into two parts. The left part represents the actual accident situation whereas the right part indicates a hypothetical prediction of accidents. When comparing both parts, the crucial terms are the accident cost density (ACD) and the basic accident cost density (baACD).

Figure 1 Methodology for calculating the infrastructure potential



Source: (SNR 641 725, 2013)

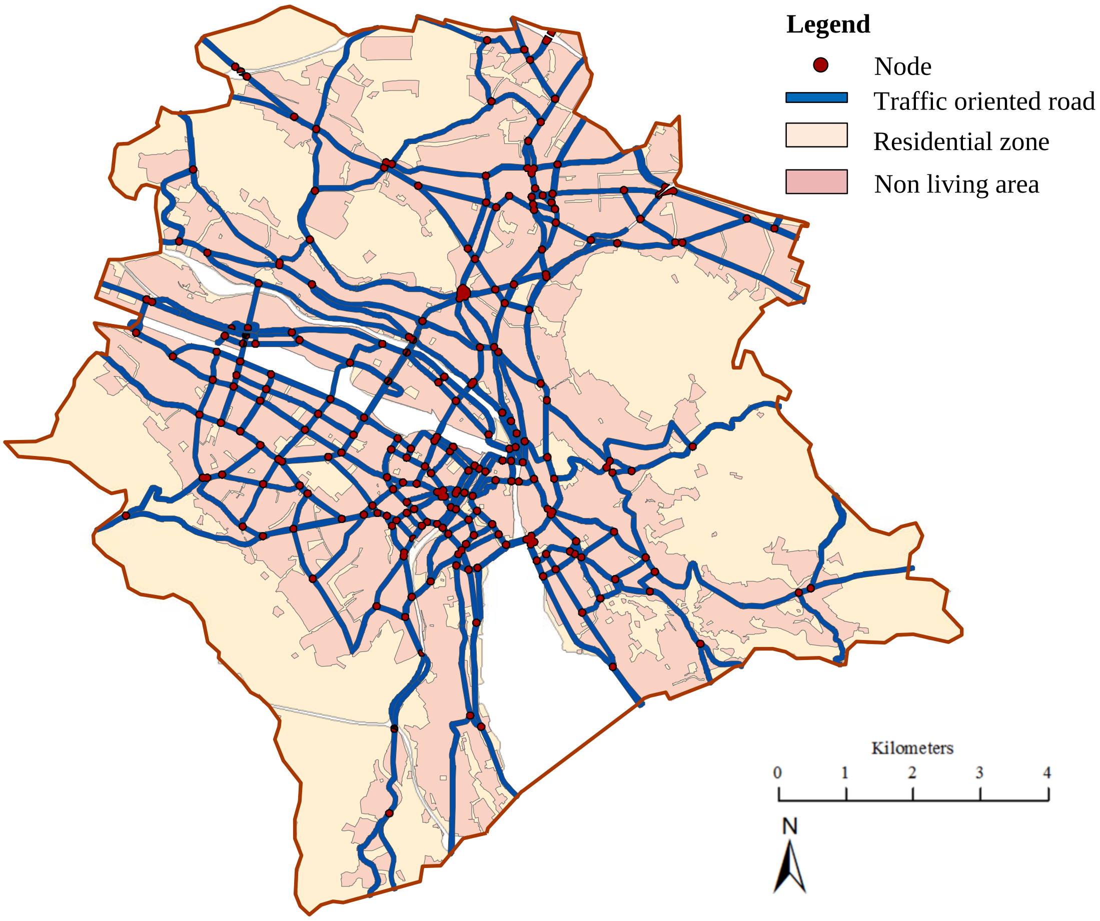
Based on the results of (Decurtins, 2014), this work aims to examine the influence of different parameters to the given approach of NSM, by analysing the existing network and by altering various input parameters. The outcomes of the present work shall be used by FEDRO as results of the pilot study in Zurich. In a further step, it can be conducted as a decision tool to convince policy makers to invest in road safety infrastructure. Moreover, it should contribute to establish more accurate parameters for inner urban areas.

2. Network model

Although NSM is a broadly used method in road safety management, the input data has to be adapted individually for each investigation. The heterogeneity of a network accounts for different accident patterns in a city than in rural areas. Zurich with over 13’000 registered accidents of all severity categories between 2009 and 2013 has a large and dense inner urban road network, compared to the rest of Switzerland.

The methodology requires a proper distinction between the three network elements traffic oriented roads, residential roads and residential zones. The existing data did not consider this classification. Therefore, different criteria, such as road owner, speed limit or the traffic volume are used for determining these network elements (see Figure 2).

Figure 2 Input network model for NSM



Source: (Rothenfluh, 2015)

The specific input network configuration was created manually on the basis of the provided street axes. In order to simplify the assignment of each accident's location to a corresponding network element, all entities are digitalized as polygons. Nodes themselves are represented as circles with a 50m radius (exception larger nodes, such as Bellevue, Bucheggplatz, Stauffacher etc).

By defining an individual entity of a traffic oriented road between each node, the network density would result in numerous short section lengths. Therefore, a range ($length_{min} = 0.5km$, $length_{max} = 2km$) of an optimal section length for traffic oriented roads is determined. This section creation was made on the basis of the homogeneity of individual road geometries. The key values of length and the aggregation of sections ensure a reasonable comparison between different road sections and comparable values for the calculated accident cost densities.

The traffic model of the canton of Zurich (Vrtic, Weis, & Fröhlich, 2012) has some limitations on residential roads regarding the traffic volume. In contrast to the other two network elements, the Swiss rule does not provide a value for the basic accident cost density for residential zones. Therefore, a comparison of the historical accident situation and theoretical values is not taken into account. Instead, the final ranking is made according to a zone's area[1] and the sum of the lengths of residential roads.

3. Results

The previously described input network model serves as the basis for all the following analyses. The goal is to implement the presented NSM methodology and to properly test different input parameters.

3.1 Prioritization with the given input parameters

In order to know where future investments tend to be highly cost efficient, NSM provides road owners with a ranking of each network entity regarding its safety potential. The rankings of each network element are prioritized into three categories. The differentiation is done according to the cumulative percentage[2] of the calculated avoidable accident cost (avAC) per year. By assuming the given input parameters, Table 1 shows the locations that are highly prioritized within all network elements.

Table 1 Highly prioritized network elements

Traffic oriented road				
Ranking	Name	AADT [veh/d]	No. of acc [Acc/5a]	avAC [CHF/a]
1	Badenerstrasse East	9'579	89	2'123'800
2	Badenerstrasse West	10'474	68	1'913'200
3	Limmatstrasse	2'008	67	1'653'900
4	Albisstrasse	11'280	99	1'623'800
5	Uraniastrasse	14'571	78	1'417'600
6	Sihlstrasse	11'048	70	1'375'800

[1] Minimal area of 0.22km^2 and minimal network length of 0.6km per residential zone

[2] Upper 20% of the avoidable accident cost (avAC) per year is dedicated as *high*; 20 – 60% of avAC = *medium;* 60 – 100% of avAC = *low* priority

Nodes				
Ranking	Name	AADT [veh/d]	No. of acc [Acc/5a]	avAC [CHF/a]
1	Bellevue	58'182	135	2'565'100
2	Bucheggplatz	22'085	99	2'116'600
3	Heimplatz	37'234	140	1'937'100
4	Central	23'645	64	1'473'800
5	Limmatplatz	22'996	51	1'297'200
6	Bürkliplatz	49'590	61	1'247'800
7	Escherwyssplatz	18'724	80	1'166'100
8	Langstrasse/Lagerstrasse	22'190	50	1'133'000
9	Pfingstweidstrasse/Hardstrasse	18'860	33	1'087'800
10	Schwamendingerstrasse/ Dörflistrasse	21'014	35	1'072'600
Residential zones				
Ranking	Name	AADT [veh/d]	No. of acc [Acc/5a]	ACD [CHF/(a*km)]
1	Bahnhofstrasse/Rennweg	-	134	1'121'300
2	University quarter/Niederdorf	-	140	1'027'100

3.2 Variation of cost rate terms

In Figure 1, it can be seen that the outcome of NSM is depending on the chosen cost rates per accident (ACR) and the determined basic accident cost rates (baACR). For urban areas FEDRO distinguishes between the three different accident severity categories fatal/serious injury (FSI), minor injury (MI) and property damage only (PDO) (FEDRO, 2014). In order to further specify these categories, own accident cost rates (ACR) are calculated on the basis of the reported accident data in Zurich between 2009 and 2013. Thereby, different ACR for each network element category and for ten different accident types are calculated. Requirements for this include the number of involved persons in each accident and average cost values per casualty, which are provided by (FEDRO, 2014). The results of own accident cost rates[3] are presented in Table 2 and Table 3.

[3] It is assumed that each accident including humans also leads to a property damage.

Table 2 Calculated ACR corresponding to all accident severity categories

Network element	$ACR_{(FSI)}$ [CHF/acc]	$ACR_{(MI)}$ [CHF/acc]	$ACR_{(PDO)}$ [CHF/acc]
Traffic oriented road	692’000	84’144	44’824
Node	650’564	83’918	44’824
Residential zone	641’935	82’707	44’824
Road & node	675’132	84’055	44’824
Average	*664’908*	*83’706*	*44’824*

Table 3 Calculated ACR corresponding to all accident types

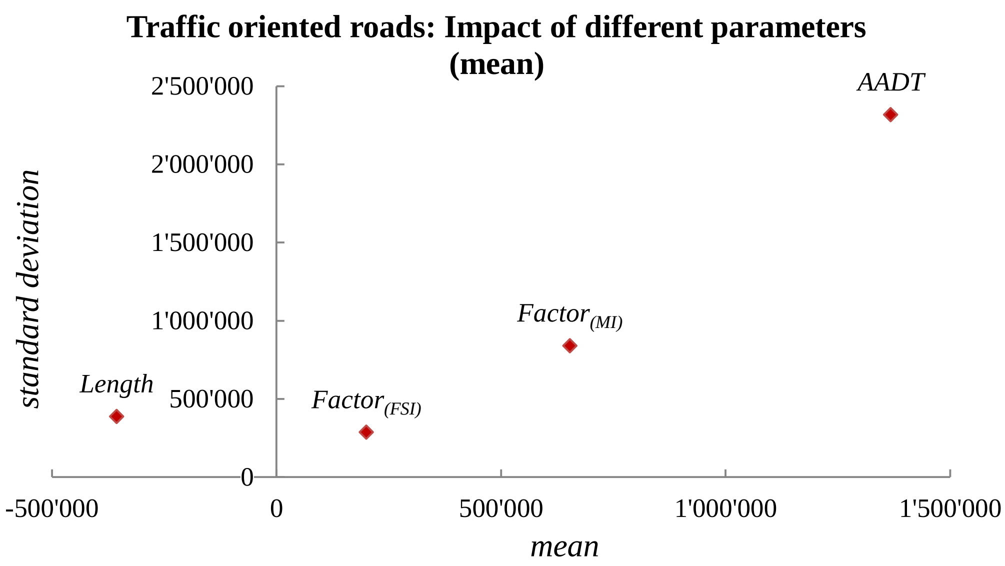
Network element	Traffic oriented roads & Nodes $ACR_{(FSI+MI+PDO)}$ [CHF/acc]	Residential zones $ACR_{(FSI+MI+PDO)}$ [CHF/acc]
Driving accident	110'248	114'485
Lane changing	67'242	70'657
Collision	74'352	65'447
Turn off	110'510	110'094
Turn into	104'848	89'607
Crossing	105'155	69'049
Frontal collision	80'046	73'874
Parking	48'622	45'444
Pedestrian	287'057	224'446
Other	101'393	91'684

3.3 Sensitivity analysis

The calculations of cost terms in the previous chapter have shown that, depending on which input cost rates the NSM model is based on, different results can be expected. Extending this approach, the impact of the four NSM model parameters (network length, AADT, ACR and baACR) are examined through a sensitivity analysis. Regarding the connection between different parameters, it shows that, the strongest positive correlation[4] exists between AADT and the number of accidents.

With the help of the model from (Ge & Menendez, 2012) and (Ge & Menendez, 2014), different input data sets are tested. In each step, one of the input parameters is altered so that five series samples are created. By repeating this process for 1000 times, a total of 5'000 combinations of inputs are obtained to calculate the infrastructure potential. Thereby, a maximum range of variation is determined in order to test a relative comparison between the given input factors. Thus, the real data set of the historical number of accidents, which have the strongest relationship with the actual traffic volume, are allocated to the corresponding AADT. By applying these steps to traffic oriented roads, the results are obtained, and an unambiguous dominance of the parameter AADT is shown (see Figure 3).

Figure 3 Impacts of different parameters on the results for traffic oriented roads



Notice that the figure should be interpreted in a qualitative way. Despite the value of the axis, it cannot be said that AADT has for example three times more impact than the other parameters. It stands more for a relative differences of the altered parameters. The units of the axis are dependent on the context of the inputs and have no physical meaning (Ge & Menendez, 2014).

[4] Pearson correlation coefficient r = 0.42

3.4 Overlay with Blacks Spot Management

Traditionally Black Spot Management (BSM) was the common tool to detect hazardous parts of a network. Its main difference to NSM is that BSM tries to identify hazardous locations based on a certain threshold value of accidents within a defined radius. Therefore, hotspots are usually situated more locally. According to (Sørensen & Elvik, 2008), it is highly recommended to combine the results of BSM and NSM because of similar data inputs and a common comparison of a best practice design.

For the city of Zurich, a total of 144 black spots were identified in the period[5] from 2011 till 2013 (Stadt Zürich, 2013). A black spot in an inner urban area is defined as a minimum of five personal accidents[6] within a radius of 50 meters (SNR 641 724, 2014). In order to compare the generated NSM results with BSM, an overlay of the individual locations is made. Thereby, only entities of traffic oriented roads and nodes with a priority of high or medium are taken into account. The overlay resulted in a coverage rate of 61%.

This discrepancy can be explained by the distribution of accidents. As soon as there is a cluster of a certain number of accidents, a black spot is identified. However, NSM normalize accidents according to the length of each network element, so that the effective density of accidents and therefore the ACR can be quite low for NSM. Compared to the expected number of accidents (baAR), it can result in no predicted avAC.

NSM normalizes accidents according to not only the corresponding length but also the given AADT (SNR 641 725, 2013). As a result, roads with high traffic volume have by trend a lower priority. On these sections some of the black spots cannot be discovered by NSM. Examples for this can be found on Mythenquai, Seebahnstrasse and Hardbrücke.

4. Discussion

Regarding the results, it stands out that, compared to their actual traffic volume, traffic oriented roads with a relatively high number of accidents by trend are ranked on top. According to the given formulas of NSM, this results in a high ACD and relatively low baACD (SNR 641 725, 2013). Rear-end collisions are the most recorded accident type among four of these road sections. This indicates that there is often congestion and therefore the inattention of car drivers can lead to a collision with the car in front.

[5] Data input for NSM were the accidents in the period 2009 to 2013

[6] FSI accidents are doubly weighted as MI accidents

For nodes, larger ones usually include more accidents. The calculation steps divide the accident cost to the extent of a node, which is represented by the number of feeding inlets. But this often causes that large nodes have a higher value of avAC per year. Additionally, larger nodes usually exhibit more conflicting points and are used by several modes of transports.

The results for residential zones, which are ranked according to its ACD, give more of an indication where most accidents on residential roads happen. As soon as one accident in a zone is recorded, the zone appears with a potential for improvement. The two old city zones along the river Limmat make up a total of 17% of the entire residential zone’s ACD. The few traffic oriented roads, the density of the public transport system and a high modal split of human powered mobility are, amongst other things, reasons for this.

When analyzing the road safety potential with NSM, it has to be considered that the methodology is based on several assumptions. Apart from the accuracy of input parameters, it is decisive how the basic network is created. Especially the distinction of traffic oriented roads and residential roads and the section creation are crucial factors for the outcome of NSM. Concerning the presented accident cost rates, they are based on the number of involved persons and a cost rate factor per casualty. In order to have more robust key figures and a better classification of the occurring accident cost, more research is recommended.

5. Conclusion

The implemented methodology of NSM for the city of Zurich has shown that, the network elements with a high cost efficiency of infrastructure improvement can be identified. For the analysis, all three categories of accident severity – called fatal or serious injury (FSI), minor injury (MI) and property damage only (PDO) – within the period from 2009 until 2013 are taken into consideration. The highest infrastructure potential for traffic oriented roads can mainly be found at Badenerstrasse, Limmatstrasse and Albisstrasse. The highest infrastructure potential for nodes are at Bellevue, Bucheggplatz and Heimplatz. Due to non-existing basic accident cost rates for minor roads, residential zones are ranked by their specific value of accident cost densities (ACD). The two inner urban zones Bahnhofstrasse/Rennweg and University quarter/Niederdorf are ranked on top. Regarding the results in general, it is conspicuous that on the one hand, network elements with a high AADT tend to have a lower infrastructure potential. On the other hand, when analysing nodes of comparable AADTs, the ones operated by an uncontrolled traffic regime have a distinctly higher value for avAC per year.

The total of more than 13’000 accidents is further examined in order to calculate specific accident cost rates (ACR) and basic accident cost rates (baACR) for the city of Zurich. It resulted in minor differences between the two traffic oriented network elements roads and nodes respectively and the more domestic oriented residential zones. By classifying the accidents according to their accident type, the dissimilarities of cost rates are far more significant.

The work contributes to a comprehensive understanding of NSM model parameters. The main findings of the analyses will be compared with the results of other pilot studies and assist to practise NSM for a broader audience in road safety.

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