

Assessing Traffic Calming Measures for Safe and Accessible Emergency Routes in Norrköping City in Sweden

Ghazwan Al-Haji

Abstract—Most accidents occur in urban areas, and the most related casualties are vulnerable road users (pedestrians and cyclists). The traffic calming measures (TCMs) are widely used and considered to be successful in reducing speed and traffic volume. However, TCMs create unwanted effects include: noise, emissions, energy consumption, vehicle delays and emergency response time (ERT). Different vertical and horizontal TCMs have been already applied nationally (Sweden) and internationally with different impacts. It is a big challenge among traffic engineers, planners, and policy-makers to choose and priorities the best TCMs to be implemented. This study will assess the existing guidelines for TCMs in relation to safety and ERT with focus on data from Norrköping city in Sweden. The expected results will save lives, time, and money on particularly Swedish Roads. The study will also review newly technologies and how they can improve safety and reduce ERT.

Keywords—Traffic safety, traffic calming measures, speeding, emergency response time.

I. INTRODUCTION

THE main purpose of transport is to move persons and goods from place to another in a quick, convenient and safe modes/routes. However, there are many challenges that need to be tackled for sustainable transport systems including: congestion, emissions, accidents, energy consumption, costs, ERT, etc.

The ERT of ambulance, rescue, fire vehicles to the incident is the most critical as it is a matter of life or death. In Ireland, there are 700 fatalities annually as a result of inadequate ambulance response [1].

Most road traffic accidents happen in urban roads, while most serious casualties occur in rural roads or in urban roads with higher speed limits. Pedestrians and cyclists are the most vulnerable road users in urban roads. As a result, many cities implement TCMs on urban streets for reducing speed, overtaking, and adjust driver behavior.

TCMs can be divided mainly into horizontal and vertical measures. The horizontal measures make the driver slow down because of curves or narrowing width in the street for instance chicanes, chokers, traffic circles, roundabouts, etc. The vertical measures are differences in height for instance humps, speed tables, raised crosswalks/intersections, etc. Both types of horizontal and vertical measures can be applied together at the same site of road.

TCMs have different impacts on accidents, mobility,

accessibility, cost, emissions, noise, and delay travel time of emergency vehicles (ERT). As a result, it is a major challenge for traffic engineers and planners to choose the optimal TCMs for a specific location. A number of guidelines and handbooks have been developed worldwide with the aim of assisting practitioners and planners in order to choose and implement the most suitable TCMs in a city. These guidelines and handbooks define, among other things, short-medium-long term implementation of TCMs according to standards, local needs and costs/benefits.

The aims of this paper are to formulate the problem and provide literature review. Further, an evaluation of TCMs on both ERT and accessibility for emergency vehicles will be given. A field observation will investigate the primary emergency network in Norrköping city in Sweden, with respect to the relation between TCMs and ERT.

II. THEORETICAL BACKGROUND

There are advantages and disadvantages of using TCMs. TCMs can improve safety for pedestrians and bicycles to cross by decreasing the average speed. The reduction of road accidents can be estimated by 50-70% [2]. Even if TCMs are considered to be a successful, and are therefore widely used, there are also unwanted negative side effects. TCMs can increase noise, air pollution, and energy consumption [3], [4]. The reduction of road capacity can increase vehicle delays. They may eliminate some on-street parking. TCMs can cause a "rough ride" for drivers, and passengers include patients with certain disabilities.

With quicker ERT the number of road accidents and fatalities can be lowered and prevented. Based on a Swedish study, about 12% of those who were killed in road accidents could have survived if they had been transported faster to a hospital and further 32% could have survived if they had been transported more quickly to an advanced trauma center. This shows the importance of planning the infrastructure in a way that helps emergency vehicles to reach their destination in a short amount of time [2]. The main results from this study are shown in Fig. 1, which basically shows that the number of people killed in traffic accidents increases with increasing ERT. The actual response time is defined from when one calls an ambulance until the time that it arrives [2].

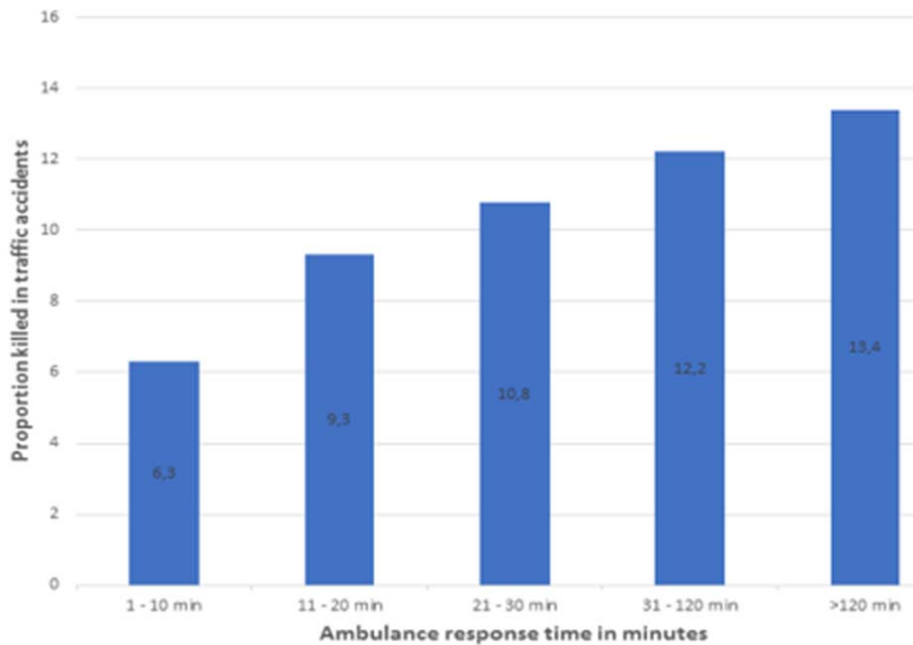


Fig. 1 The relationship between ambulance response times for traffic accidents and the proportion killed in accidents [2]

TCMs have different impacts on ERT. In a previous pre-study, the summary of these impacts [13] include:

- Studies shows that fire trucks can experience delay of ERT to 10.7 seconds per TCM [5]. Similarly, ambulances can experience delay of ERT as high as 9.6 seconds. In addition, ambulance vehicles can take longer alternative routes with up to 1 km, or 40 seconds, in order to avoid congestion or TCMs constructed on the road [6].
- TCMs can create damages to the emergency vehicle mainly over speed humps and bumps. For instance, the fire department in Linköping city confirms the damage of vehicles due to TCMs [7].
- TCMs with significant effect on ERT are: traffic circles, speed humps, raised crosswalks, raised intersections, and street closures [8].
- Policy makers must consider carefully less or no TCMs on the primary and secondary emergency routes that are used by emergency, fire and rescue vehicles in a city.

One of the improvements for ERT due to TCMs is the replacement of the speed humps to the speed cushions. The speed cushions are designed as the separated parts, not as the only one element like the speed humps. Due to the created gap, the bigger vehicles, such as the emergency services or busses, can pass without the increase of the travel time, because they have a wider wheelbase, thus they are not affected.

Another TCM that may affect ERT is the poorly designed roundabouts, which do not allow large emergency vehicles to drive around or straight through. The geometry design in terms of the size of the roundabout, radius, entry and exit points all play role in the delay of ERT.

In Sweden, safety and ERT are considered in the geometric design and infrastructure standards include TCMs.

Trafikverket (The Swedish Transport Administration) develops the guidelines and standards for implementation of TCMs. The most commonly used TCMs in Sweden are: circles, roundabouts, humps, refuge-island and chokers [9]. According to TRAST (Traffic for an Attractive City), which is a project that help municipalities in Sweden to create local traffic infrastructure include TCMs, the accessibility of emergency vehicles is affected by the availability of TCMs on primary emergency routes, in which TCMs need to be mapped out in the routes [10].

We can see recent trends of information technology solutions that can improve availability for emergency services, communication with other vehicles V2V and infrastructure V2I, besides reducing the travel time. For instance, speed bumps use some form of smart detection system (loop or radar) to identify the speed of the approaching vehicle, besides detection of the type of approaching vehicle. There are also possibilities to modify vehicles, for example emergency vehicles or buses, to not be affected by these types of calming measures. The Acti Bump [11], developed in Linköping City in Sweden, is a smart TCM which can be activated when a speeding driver is detected. The Acti Bump can also be set up in an inactive format when the emergency vehicles approach the location. Other IT solutions can be integrated for TCMs and ERT are Intelligent Speed Sdaption (ISA) and Variable Speed Signs. A study at the Royal Institute of Technology (KTH) in Stockholm has developed a communication system called the EVAM system. The purpose with the system is to make drivers pay attention to approaching emergency vehicles, which will improve the traffic for ambulance, police and fire trucks. The EVAM system uses existing sound systems together with a Radio Data System and requires therefore no new installations [12].

III. METHODOLOGY

The GIS tool ArcMap is used in order to analyze the availability for emergency vehicles in Norrköping city in Sweden. A map over the primary emergency network in the city were provided on the municipality's website and implemented as a dataset in GIS. Locations of the emergency services were found on the website for the emergency service of the region. The Swedish national traffic accident data (STRADA) were firstly imported to ArcMap. A base map from *OpenStreetMap* were added for visualization. A road network for Norrköping was added to enable measurement on links. The field observations were imported with GPS coordinates.

IV. DATA

The input data used for this work are mainly transport network model for Norrköping city, the Swedish Traffic Accident Data Acquisition (STRADA) database and TCM locations, primary emergency network and emergency service locations.

The Norrköping city in Sweden has about 120,000 inhabitants. The TCM location data were constructed based on data from Norrköping municipality and field observations on main streets (e.g. Promernaderna and Kungsgatan streets).

V. RESULTS AND DISCUSSION

To calculate the impact of the delay caused by a TCM, an

average delay over all available TCMs was calculated. For example, traffic circle and roundabouts can potentially cause the highest delay rate with maximum delay of 11 seconds, while gateways have no or minimal effect on the vehicles travel time. Therefore, depending on the number of available TCMs and their average delay rate, speed an overall average delay rate for TCMs is calculated.

Fig. 2 illustrates a heatmap over the emergency network and TCM locations in Norrköping. The heatmap consists of different colors depending on the intensity of TCMs. The green areas on the map show locations with none or very few TCMs. Yellow and red colors correspond to areas with a higher number of TCMs. Therefore, these areas are considered to have worse accessibility for EV than the green areas. Overall, it is the roads around the city center that has the lowest accessibility because of the number of TCMs. The high amount of TCMs on these streets is negative for ERTs, since they are the easiest way to travel around the city. Both the police and the fire departments are affected since they are located near the city center and need to use roads that are not green. The fire department has good accessibility to the south part of the city but worse to the north side, as illustrated with yellow and red colored links.

It is worth mentioning that the heatmap color areas are based on the amount of TCMs in relation to the size of the area, which means that the green areas might have TCMs, but not as many as the yellow or red areas.

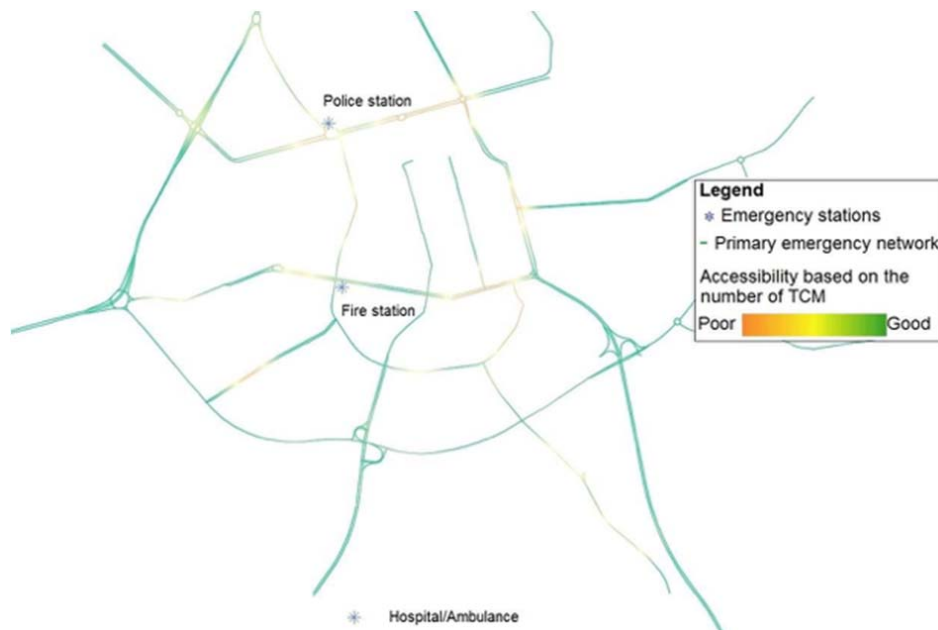


Fig. 1 Heatmap over Norrköping based on number of TCMs

There are 74 TCMs in total in the emergency network shown in the above map.

Fig. 3 presented below is illustrating the constructed accessibility map for emergency vehicles. This figure is created based on the combination of maximum speed limits on

the links together with the number of TCMs on each link. The colors on each link represent the accessibility on the link based on the speed limit and the potential delay due to TCMs.

Table I presents the classification of good and bad links and what the different colors represents.

TABLE I
QUALITY OF THE EMERGENCY NETWORK IN NORRKÖPING BASED ON SPEED
AND NUMBER OF TCMs

Classification of the emergency network			
Speed (km/h)	< 30	30 – 50	> 50
Color	Red	Yellow	Green
Accessibility	Poor	Acceptable	Good

As can be seen in the map, there are not many links in the network that are considered to be poor emergency routes even though a total of 74 TCMs are included in the primary emergency network. There are some of the yellow links that are close to be marked as red after the calculations with the TCM delay. When coloring the links according to the

classification in Table I, the speed has to be strictly below 30 km/h to be marked as red and therefore be considered as poor emergency routes.

Some of the TCM locations obtained from Norrköping municipality are temporary and will be removed during the cold season. This can potentially affect the GIS map and the obtained results regarding the TCMs impact on ERT. TCMs that are located with reasonable distances after each other might have higher effects on speed reduction. In this work, each TCM is considered to have an isolated effect on ERT. In this work, it is assumed that all TCMs are located on both directions.

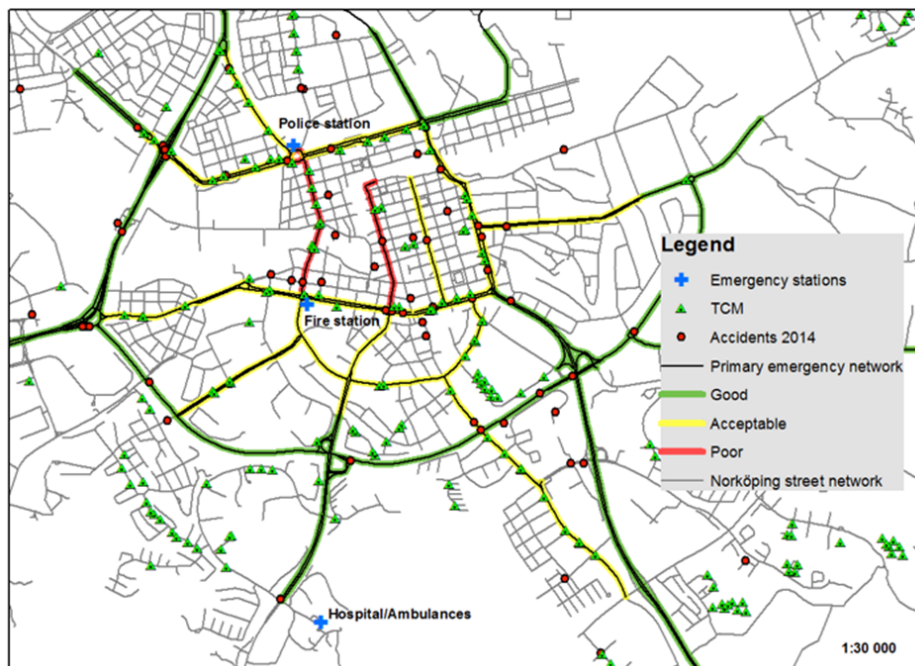


Fig. 2 Accessibility map over Norrköping

The different types of TCMs have various effects for ERT, where some of them have no effect and others have high effect. Because the TCMs tend to reduce the speed and/or the volume of the road, they might make it harder for the emergency vehicles to reach their destination in time. Based on the different TCMs that the study has decided to investigate, speed humps and traffic circles both have significant effect on ERT, which means that emergency vehicles need to slow down a lot in order to pass these types of TCMs. Chicanes has moderate effect, which means that emergency vehicles have to adapt and lower their speed to pass a chicane. Chockers and speed cushions have a minimal or no effect on emergency vehicles, which makes them ideal as TCMs in order to minimize the effect on ERT.

VI. RECOMMENDATION AND CONCLUSIONS

This section includes the conclusions drawn from the process of completing this work, the results and the future

work in this field.

Different types of TCMs affect ERT on different levels in terms of delay and speed. The main aim of TCMs is to decrease speeds, which leads to longer ERT. Vertical TCMs have the largest impact on ERT and accessibility by lowering speed significantly, which results in higher delays. Furthermore, different vertical TCMs affect ERT differently. For example, there are speed cushions on which vehicles with wider wheelbase can pass with no delay. The delay caused by a TCM increases if there are several TCMs in a row, since the vehicles never obtains their original speed between the TCMs.

Several kinds of guidelines for implementation of TCMs exist, both nationally and internationally. However, there is a demand for developing specific guidelines with focus on the impact of TCMs on ERT.

Policy makers must consider carefully less or no TCMs on the primary and secondary emergency routes that are used by emergency, fire and rescue vehicles in a city.

We can see recent trends of IT solutions that can improve ERT and accessibility, via communication with other vehicles and infrastructure.

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Ghazwan. Al-Haji, Associate Professor at Linköping University in Sweden, is a qualified Transport Engineering, Traffic Safety, Road User Behaviour and Intelligent Transport System (ITS) expert with research, teaching and work experience. These qualifications included quantitative and qualitative assessment of traffic safety and ITS development at micro and macro level, transport benchmarking,

development of national traffic safety action plans and evaluation of their effects, distribution of responsibilities among the key professionals and agencies that are responsible for transport and traffic safety in a country, capacity building, and development of networking at national, regional and international level for sharing the good practices and know-how in transport, traffic safety and ITS. Dr. Al-Haji has engaged in a considerable number of research and overseas consulting activities in Southeast Asia, South African countries, Middle East, and Russia. Has worked closely with international bodies such as the Asian Development Bank and the European Commission.

Ghazwan has a good standing experience regarding international cooperation and coordination in higher education e.g. curriculum, accreditation and institutional development. He participated in different

international conferences and workshops. Has taught two master courses in Road Traffic Safety at the department of science and technology, Linköping University for several years. His PhD research "RSDI" is the first approach worldwide to measure road safety achievements in a country or big city in a simple quantitative value, which was acknowledged internationally.