Traffic Calming Devices: Challenges for Autonomous Vehicles

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Abstract: Traffic calming aims at improving traffic safety, environmental quality, and the quality of public spaces mainly by decreasing speeds. In residential streets several different technical elements are used for speed reduction. Autonomous vehicles started to appear in relatively simple traffic situations (e.g. on motorways), but they are more and more expected to come in complicated urban settings. The goal of this paper is to give an overview on traffic calming equipment, their impact and their challenges for human drivers and autonomous vehicles. Steps of own future research are also outlined with the goal to identify properly designed and easily recognizable arrangements for autonomous (and traditional) cars and for better traffic safety at locations with traffic calming.

1. INTRODUCTION

Traffic calming is the name for road design strategies to reduce vehicle speeds and volumes. Traffic calming projects can range from a few minor changes to neighbourhood streets to major rebuilding of a street network. Impacts range from moderate speed reductions on residential streets, to arterial design changes, and residential streets with minimal traffic speeds (Litman, 1999).

During the last decade or so the importance and the application of traffic calming have increased as revision and redistribution of transport surfaces have come into the spotlight.

Numerous traffic calming methods and techniques have evolved from point-based to area-wide interventions. 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 (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. (Juhász and Koren, 2016).

Traffic calming goals can be defined on intersection, street or area level. This paper deals mostly with street related measures.

2. STATE OF THE ART

2.1. Types of traffic calming measures

One of the most comprehensive traffic management guidelines classifies traffic calming measures among local area traffic management tools as follows (Austroads, 2020).

Vertical deflection devices

- Road humps (Figure 1)
- Road cushions
- Flat-top road humps
- Wombat crossings
- Raised pavements.

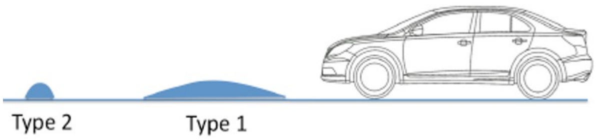

Fig. 1. Two of the many types of road humps

Horizontal deflection devices

- Lane narrowings/kerb extensions
- Slow points
- Centre blister islands
- Driveway links
- Mid-block median treatments
- Roundabouts.

2.2. Impacts of traffic calming measures

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. (Juhász and Koren, 2016).

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). The largest reduction in the number of accidents is found for residential streets (about 25%), a somewhat smaller reduction is found for main roads (about 10%). Similar reductions are found in the number of property damage only accidents.

Another meta-analysis came to a similar conclusion (Bunn et al. 2003). However, as they emphasized, further rigorous evaluations of this intervention are needed, especially in low- and middle-income countries, as the studies included in the meta-analysis came mostly from high-income countries.

An Italian study investigated one road through one small urban community only (Galante et al, 2010). However, it is an important conclusion from this paper, that traffic calming measures are frequently applied in packages, i.e. several measures at one site or close to each other along the same road. This makes impact evaluation more complicated.

Referring to the advice of Bunn et el. (2003), it is interesting to have a look at impact studies from low- and middle-income countries. While the studies cited above from high-income countries concentrated to reduction of speed and accidents, as positive impacts, some studies from less developed countries indicate different priorities.

A paper from Pakistani authors (Ullah et al., 2016) mentions that "Vertical and horizontal calming devices are used globally to decrease speeds at acceptable levels for the execution of laws with ease. Various types of retarders are used to calm the speeds such as speed breakers, which are installed for the safety of users, can impose detrimental effects on vehicles and environment as well. If installed improperly, or the design is ineffective without the use of prior guidelines then they become vehicle breakers actually."

A paper from Nigeria (Akanmu, et el, 2014) describes the locations and designs of speed bumps and other traffic calming devices. The paper considered the effect of road bumps in the society. About 220 units of questionnaires were administered to randomly selected residents. Although the speed bumps improved safety in the areas, yet their perceived adverse effects on the passing vehicles, commuters and residents are enormous. In addition, the substandard and uncontrolled manners in which speed bumps are located and constructed have derogatory implications on their effectiveness. The paper also recommended the redesigning of the existing speed bumps with heights more than 21cm, and sanctions on the arbitrary mounting of speed bumps.

2.3. Recognition of traffic calming measures

The papers cited in this section come mostly from low- and middle-income countries. This is related to the fact described in the previous section, i.e. that the location and design of traffic calming equipment is dangerous.

According to Mohit et al (2012) there is evidence to support the claim that speed breakers can cause accidents and injury. Speed-breakers are inconspicuous in low visibility conditions, like at night, or when there is fog, rain or snow. This problem is particularly acute in developing countries where speed-breakers don't always accompany warning signs. They propose an early warning system that uses a smartphone-based application to alert the driver in advance when the vehicle is approaching a speed breaker. The algorithm was evaluated using 678 Km of drive data, which involved 22 different drivers, 5 different types of vehicles (bus, auto rickshaw, cycle rickshaw, motorcycle, and car), and 4 smartphones.

Another paper from India (Umakirthika, 2018) describes Obstacle Detection and Alert System (ODAS) both incorporated as a single system for the obstacles such as speed breakers, barricades on the road using Internet of Things. Obstacle detection system uses in-built algorithm to detect an obstacle on the road using minimal vehicle parameters such as vehicle speed, steering angle. Obstacles locations thus marked by the detection system are stored locally and uploaded to cloud from time-to-time. Cloud server processes data from different vehicles and finalizes that there is a real obstacle at the particular location based on its own algorithm. Obstacles locations thus confirmed by the cloud server are downloaded to obstacle alert system from time-to-time, which alerts the driver about the obstacle on the road when the driver is nearing the location of the obstacle.

ODAS provides audible alert to the user by means of buzzer connected to ODAS. Buzzer frequency depends upon the current speed of the vehicle above the threshold limit on nearing the obstacle location. ODAS provides visual alert to the user by means blinking LED lights. Similar to audible alert, the frequency of blinking depends upon vehicle speed above threshold limit.

Some papers combine the recognition of speed-breakers and potholes. According to Monica S. et al (2018) identification of pavement distress such as potholes and humps not only helps drivers to avoid accidents or vehicle damages but also helps authorities to maintain roads. The proposed system that have been developed and proposed a cost effective solution to identify potholes and humps on roads and provide timely alerts to drivers to avoid accidents or vehicle damages.IR sensor is used to detect the obstacles and hence avoid the accidents. Ultrasonic sensors are used to identify potholes and humps and also to measure their depth and height respectively. The system captures the geographical location coordinates of potholes and humps using GPS receiver. The sensed data includes pothole depth, height of hump and geographical location. This serves as a valuable source of information to the Government authorities and to vehicle drivers. An android application is used to alert drivers so that precautionary measures can be taken to evade accidents. Alerts are given in the from a flash message with an audio beep.

Rishival and Khan (2016) present a vibration-based approach for automatic detection of potholes and speed breakers along with their co-ordinates. In this approach, a database is maintained for each road, which is made available to the public with the help of global database or through a portal. Potholes and speed breakers are detected along with their severity using android's built-in accelerometer. The results of the proposed approach are tested over a 4 km flat road and compared to manual inspection of pothole and speed breakers on the same considered road. The accuracy of the proposed approach came out to be 93.75% for detection of potholes and speed breakers. This approach is cost efficient and very effective for road surface monitoring.

2.4. Yielding behaviour

Frequent elements of traffic calming measures are narrowings of the traveled way, or Pinch-Points (Figure 2).

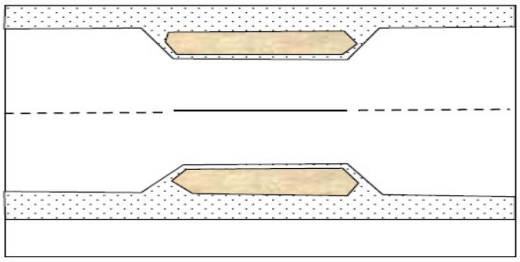

Fig. 2. Plan view of a typical narrowing

Research investigated the effect of roadway widths for street narrowings or "pinch-points" in Christchurch (Chai et al. 2011), with a particular focus on speed and yielding behaviour. A 6m wide 2-way pinch-point was found to be not effective in slowing most private vehicles down. Drivers travelled at a similar speed whether they were crossing the pinch-point by themselves or with opposing traffic approaching.

Approximately 40% of drivers reduced their vehicle speed when negotiating a 5m wide 2-way pinch-point. Around 20% of drivers avoided traversing with oncoming traffic and opted to wait until it was clear before proceeding. Male drivers also tended to travel faster through the narrowing when compared to female drivers. For a 4.5m wide 1-way pinch-point where motor vehicles and cyclists approached them simultaneously, one of them gave way and waited nearly 60% of the time. Around 35% of the time cyclists and motorists shared the narrowing and 8% of the cyclists (mostly younger children) avoided the narrowing, using a bypass instead.

The authors recommended that further research be conducted:
1. at more sites with different road widths and environment;
2. with heavy vehicle movements on these pinch-points;
3. to understand whether a longer pinch-point will alter driver behavior.

3. RESEARCH PROBLEMS AND GOALS

In this research the following problems and questions will be addressed:

- Although there is a huge amount of information in the international literature about general impact of traffic calming measures, the behavior of drivers (speed choice, lateral position, willingness to yield) in a wide variety of different traffic calming designs is not known under local circumstances.
- As a consequence of the previous statement, road engineers cannot give advices for self-driving vehicles concerning optimal (safe) behavior when approaching to traffic calming equipment.
- Is the observed behavior of different human drivers transferable to recommend strategies for autonomous vehicles? If yes, how?

Goals of research:

- Learn how drivers behave in different traffic-calming design situations.
- Define the behavior to be followed by self-driving vehicles in different traffic-calming situations (speed choice, lateral position, priority behavior)
- Prepare a design-guide for traffic-calming tools suitable for AV's and humans at the same time.

4. STUDY OF DRIVER BEHAVIOUR

To reach the above goals, several field studies are planned concerning speed choice, lateral position, and willingness to yield.

4.1. Speed choice

This part of the study will measure passing speeds of vehicles on speed-humps according to geometry and color. Speeds before and after the speed humps will be measured, speed profiles will be set up. Equipment required: video camera, analyzer program (Fig. 3).

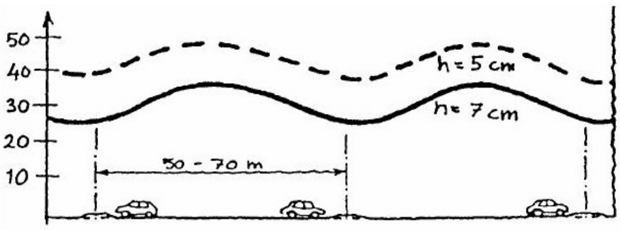

Fig. 3. Speed profile around traffic calming

Speed choice is also influenced by perceptibility of speed humps. The latter is depending among others on the color of the speed hump. Perceptibility can be derived from speed profiles measured, but a questionary survey is planned in addition.

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4.2. Lateral position of vehicles

Lateral position of vehicles and horizontal traffic calming equipment may depend on several variables. The most common influencing factors are curbs. Here, driver behavior, especially lateral position at different curb types (normal, dropped, and low-angled curbs) will be investigated.

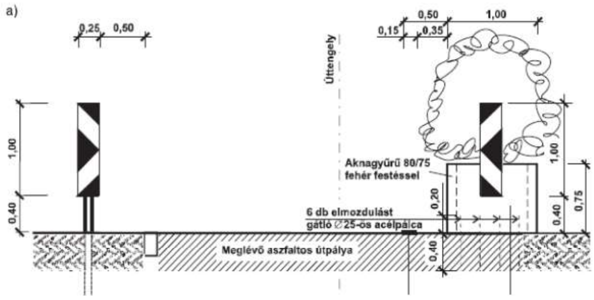

Fig. 4. Side obstacles at traffic calming (MAÚT, 2017)

Various obstacles are frequently used on either one or both sides of traffic calming sites (Fig. 4). Impacts of obstacles will be studied depending on their

- lateral position
- height
- form and
- color.

4.3. Yielding behaviour

Referring to the paper by Chai et al (2011) cited above, it is intended to study the yielding behavior of vehicles at several locations under Hungarian conditions, as yielding behavior might be quite different from country to country.

5. INFORMATION FOR AUTONOMOUS VEHICLES

Although sensors of autonomous vehicles are developing constantly, there are a lot of data which is difficult to catch by sensors with a reasonable accuracy. For example. location of traffic calming equipment is hard to recognize if the height is small and the colour is not different from that of the pavement. A warning in these cases is useful.

The horizontal and vertical layout of these installations is also difficult to recognize, even if they are mostly in areas with public lighting. Even more complicated is to choose speeds necessary to pass these sites safely. Excess vertical acceleration can cause comfort but also safety problems. If drivers do not choose proper speeds, traffic calming will have an adverse impact on safety.

All geometric data could be stored in high-resolution map servers. However, it might be difficult to process these data each time by each vehicle passing the traffic calming site. Therefore, the research described above can give useful pre-set advices for both autonomous vehicles and human drivers to choose optimal speeds, trajectories and yielding behaviour at these critical sites.

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