TRAFFIC CALMING AT STATIONARY SHORT-TERM ROADWORK ZONES

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ABSTRACT/RÉSUMÉ: TRAFFIC CALMING AT STATIONARY SHORT-TERM ROADWORK ZONES

High vehicle speeds past roadwork zones put both road workers and road users at risk. In order to gather ideas from employees on how to improve safety at roadworks the Swedish Road Administration organised a ”Hunting for Ideas” campaign. Over 130 proposals were submitted, of which traffic calming and traffic control for two types of stationary work zones were selected for testing. The first involved traffic calming at short-term stationary roadworks zones on roads with one traffic lane in each direction. A reduction in speed was found for all the methods tested. The second proposal involved convoy traffic management where median barriers were being repaired on “alternating 2+1 lane roads”. In connection with a test demonstration, an opinion survey revealed that drivers generally considered the convoy method to be good, with a large percentage indicating a preference for this method. A traffic simulation test showed the maximum traffic volume that could be controlled in this way without causing unreasonably long delays for road users.

1. INTRODUCTION

Roadworks entail a risk and discomfort for road users and road workers alike. Several fatal accidents occur in roadwork zones every year in Sweden. High vehicle speeds past the work zone is recognised as a key risk factor. Several traffic calming methods (such as portable speed bumps) have been available for quite some time, while other new methods are under development.

The intention of the ”Hunting for Ideas” campaign, run in 2002-2004 by the Swedish Road Administration, was to gather ideas from employees on how to improve safety at roadworks. This resulted in over 130 proposals being submitted, the best of which were amalgamated into a few studies within the “Safer Road Works” project [1]. This was financed by the Swedish Road Administration and carried out by Vägverket Produktion in cooperation with the largest Swedish trade union organisations (SACO, SEKO and TCO). Furthermore, the project had a steering group comprising key persons and a reference group consisting of road safety experts.

The objective of one of these was to “demonstrate the effectiveness of various traffic calming methods at small stationary roadwork zones where the temporary speed limit was 30 km/h”. Based on the ideas proposed, traffic calming for two types of roadwork zones were selected for testing: 1) traffic calming at an ordinary short-term stationary roadwork zone on roads with one traffic lane in each direction, 2) convoy traffic management where median barriers were being repaired on roads with alternating two traffic lanes in one direction and one in the other (designated “2 + 1 lane roads”).

2. TRAFFIC CALMING AT STATIONARY SHORT-TERM ROADWORK ZONES

Many serious accidents occur in stationary roadwork zones every year in Sweden. High vehicle speeds past the work zone is recognised as a key risk factor [2].

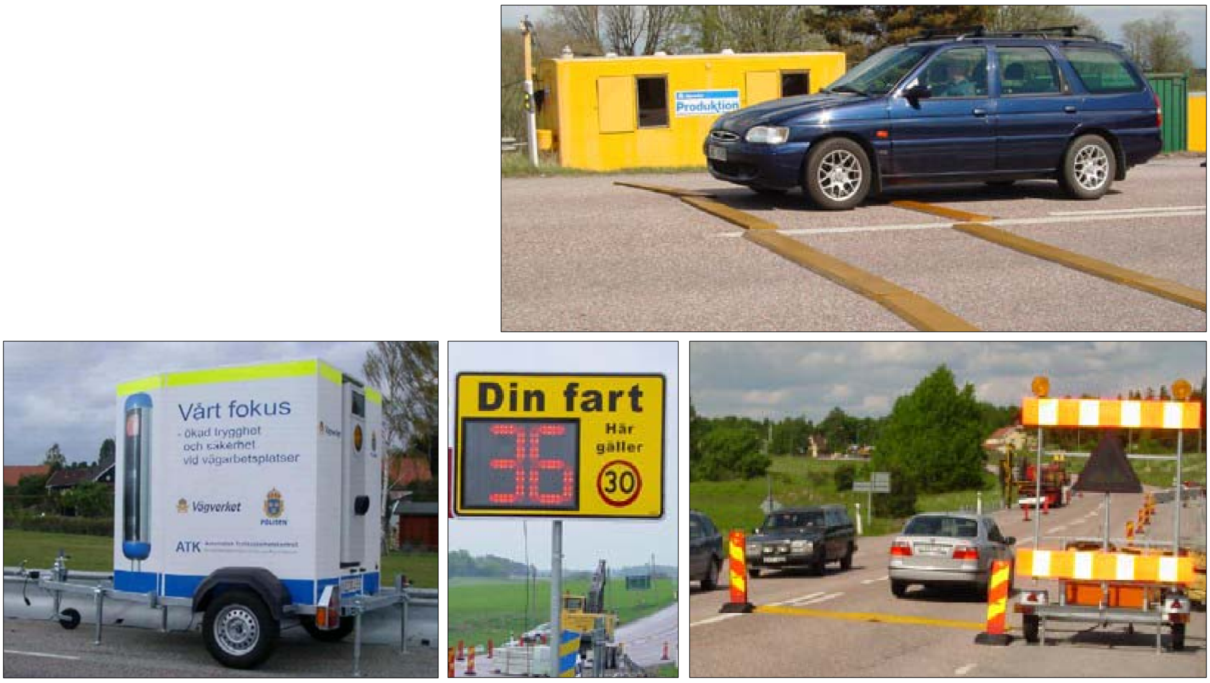

Figure 1 - Tested products. Mini speed bump (top right), mobile police speed surveillance camera (bottom left), speed display (bottom centre) and active mini-bump (bottom right without flashing lights).

2.1. Background

Several traffic calming methods (such as portable speed bumps) have been available for quite some time, while other new methods are under development. Many studies have been conducted on the effect of traffic calming methods in general (outside schools, on city streets, etc) and several are applicable at smaller roadwork zones [3-15]. However, there is a definite lack of studies that compare the various types of different speed reduction equipment [16].

Based on the ideas proposed, four types of equipment were selected for testing:

1. A "your speed" road sign mounted on a mobile trailer to display both the temporary speed limit and the individual driver's actual speed.
2. A portable version of traditional speed bumps, not intended for permanent installation.
3. An "active" speed bump, the size of which depended on the speed of the passing vehicle. The control and power unit were mounted on a mobile trailer and a flexible "bump hose" was placed temporarily across the road.
4. Speed surveillance camera, mounted in a cabinet on a mobile trailer.

Although several different brands of each type of equipment are available on the market, it was decided that the specific product tested would be representative of its type. Figure 1 shows those used in the test: 1) Dynamic Speed Display Sign "GR 42"; 2) "Wake up" bump; 3) Active Safety Roads "Diamond" Flexible Sign Trailer; and 4) Police speed surveillance camera, UniTraffic.

2.2. The traffic calming method at stationary roadwork zones

Different traffic calming methods were tested at three locations in Sweden during 2005 and 2006: at Fjärdhundra, 70 km north-west of Stockholm, Fagersta 180 km north-west of Stockholm and at Katrineholm 100 km south-west of Stockholm. The same roadwork zones without speed calming equipment were used as references.

Radar equipment of type Sierzega SR3+ was used to measure such variables as speed, type of vehicle, length, time, etc. All survey points were located in the work zone where the maximum posted speed limit was 30 km/h: the first about 100 m ahead of the actual roadworks on the bridge, the second at the worksite and the third 100 m past the site. All the data compared was collected on Mondays to Fridays during working hours.

To ensure high quality data, each traffic survey method was tested for at least four hours, and preferably for two days. Since the tests were conducted at small, short-term roadworks sites, it was difficult to apply and compare all the methods under the same conditions at one specific site.

2.3. Results

The results from Fjärdhundra (Figure 2a) show that all the tested methods had a traffic calming effect: the mean speeds as well as the variances decreased in comparison to the reference (i.e., there were fewer vehicles driving at extremely high speeds). The decrease in speed is most obvious at the actual roadworks where there were passive bumps, which is the only survey point where the mean value is below the 30 km/h posted speed limit. The results obtained at Fjärdhundra can be compared to those obtained at Katrineholm (Figures 2b and 3) and Fagersta (Figure 4), where the mean speed was generally lower without any method being tested (reference).

A traffic calming effect was observed in connection with all the methods tested: speed display, speed surveillance cameras, active speed bumps and passive mini-speed bumps, (even though data is not presented in the diagram for the last method). This was also the case at Katrineholm, although the difference there was considerably less than at Fjärdhundra.

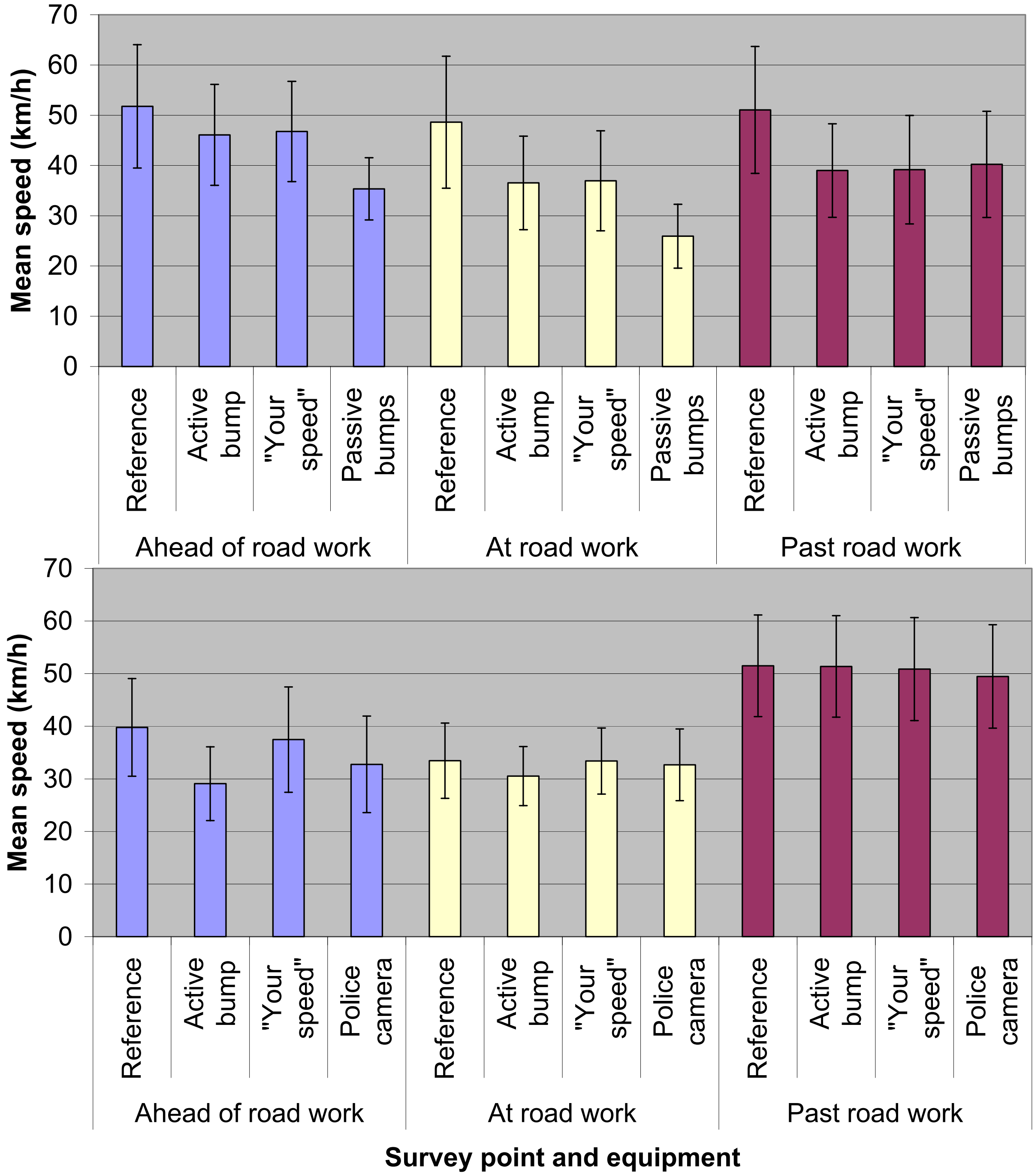

Figure 2 - Speed of vehicles passing a stationary roadworks site at Fjärdhundra (a) and Katrineholm (b, below). The figures show the mean speeds (km/h) ± S.E. of vehicles driving past different survey points found through using different types of speed calming equipment. All data was collected on Mondays to Fridays, 7 am to 3.30 pm, and most survey points were located within an area with a 30 km/h speed limit. An exception was the 50 km/h “Past road work” point in Katrineholm. Police speed surveillance cameras were used only at Katrineholm and data obtained from passive speed bumps is only presented for Fjärdhundra (passive speed bumps were tested under other conditions at Katrineholm). Observe that the mean speed where no method was tested (reference) is higher through the roadwork sites at Fjärdhundra, which resulted in a greater speed reduction effect for all the methods tested.

The conditions were changed at Katrineholm during the course of the field trial. The passive mini-speed bump was tested under other conditions and is presented separately (Figure 3). At Katrineholm it served to reduce speeds substantially, both at the worksite as well as ahead of and past it. The active speed bump reduced the speed of vehicles ahead of and at the worksite. The “your speed” sign and the speed surveillance cameras reduced the speed ahead of the worksite, but had no clear effect at or past the site at Katrineholm.

A clear reduction in speed was also observed at Fagersta (Figure 2) in connection with the ”your speed” sign and the passive mini-speed bump. Although the narrow passage at the worksite meant relatively low speeds, even without any traffic calming equipment, the reference speed was nevertheless above the speed limit. The mean traffic speed during the reference survey was 36 km/h. The mini-speed bump served to reduce the mean speed by 7 km/h and the ”your speed” sign by 4 km/h in relation to the reference speed.

2.4. Discussion

The comparison of a few methods to reduce the speed of vehicles passing three stationary roadworks sites shows the effect of all four types of equipment used: passive, mobile speed bumps; digital road sign displaying the speed of passing vehicles (“your speed”); and an ”active speed bump”. The results indicate that relatively inexpensive methods (passive, mobile speed bumps) can be equally as good as more expensive ones.

The on-site road work crew stated that they found the “your speed” sign to demand less handling efforts than all other tested traffic calming equipment.

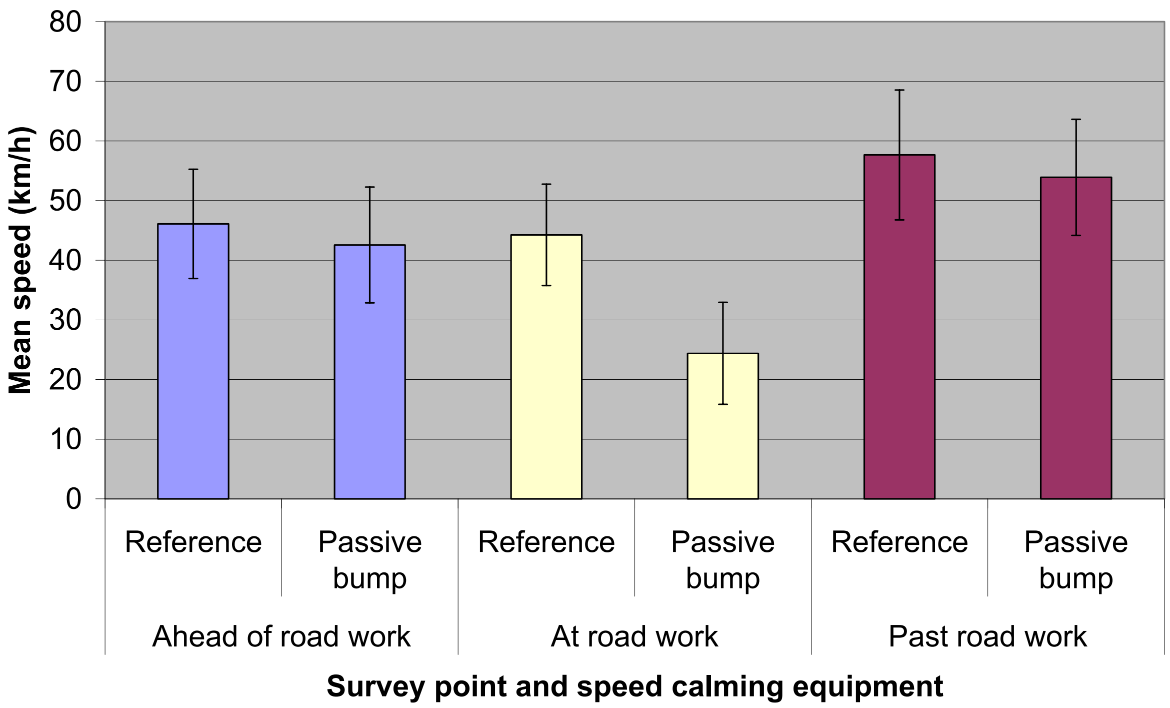

Figure 3 - Speed of vehicles passing a stationary roadwork site at Katrineholm with and without passive speed bumps. Although the roadworks site is the same as in Figure 1b, the conditions were not the same, and consequently the reference was different.

As mentioned, several previous studies have tried to analyse the effect of speed calming equipment. For example, Ullman & Rose (2005) [17] evaluated the effect of dynamic speed design during different times at seven permanent locations of particular interest; e.g., schoolyards in Texas, and Fontaine & Carlson (2001) [18] evaluated the effect of speed displays and rumble strips at rural maintenance work zones. The study at hand is, however, one of the first to compare a few different commercial products. It should be observed that the "active speed bump" (size depending on the speed of the passing vehicle) was more or less a prototype and, according to the manufacturer, has been further developed since the test.

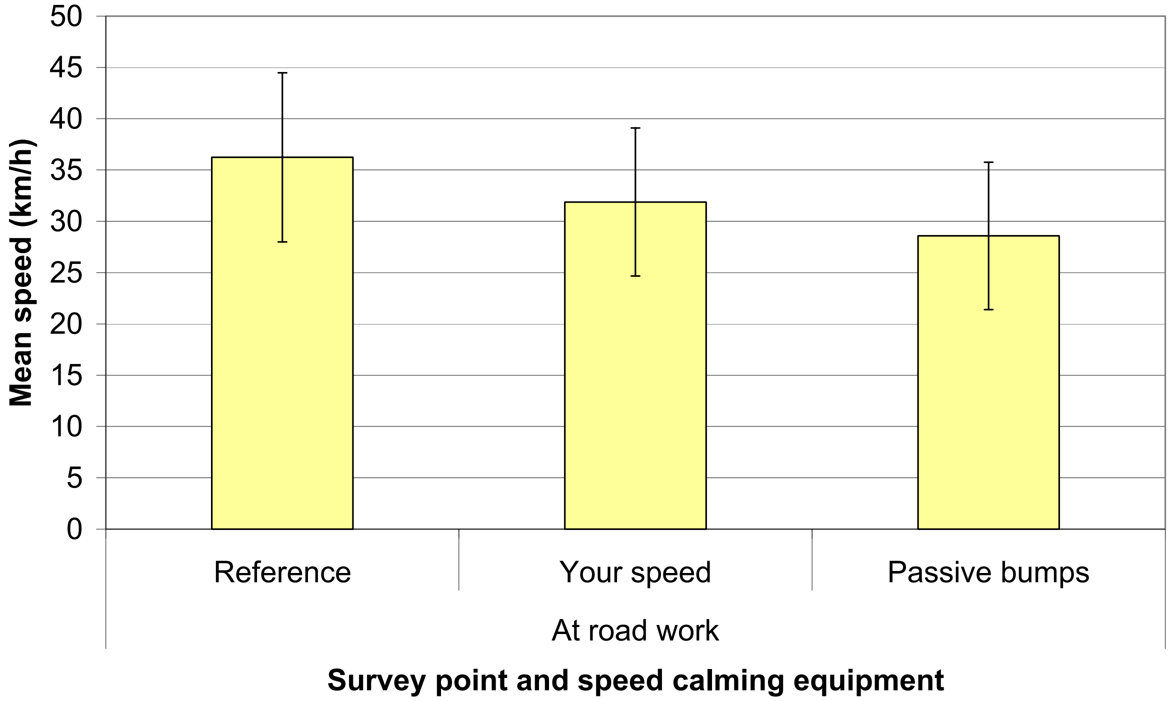

Figure 4 - Speed of vehicles passing a stationary roadworks site at Fagersta. The figure shows the mean speed (km/h) mean±S.E. of vehicles driving past different survey points using different speed calming equipment. All data was collected on Mondays to Fridays from 7 am to 3.30 pm and all the survey points were located within the area where the speed limit was 30 km/h.

It is not possible, based on the current findings, to recommend any specific method or equipment, as they all appeared to have a traffic calming effect. The choice of method should be based on the type of works, traffic and economic circumstances. It might just be conceivable that excessive use of a certain method could, in fact, diminish its traffic calming effect [19]; e.g., too many "your speed" signs or "dummy" cameras could serve to blunt driver awareness. There might be the risk that extensive use of equipment at places where speeds are low could weaken their effect at roadwork sites where speeds are unfortunately high. However, more research is needed to be able to verify this.

Comparisons between the different test sites showed varying results. The effect of the traffic calming equipment was best at the worksite where speeds were high without any traffic calming method (Fjärdhundra). Based on this, it would seem reasonable to assume that the greatest effect is obtained at those sites where traffic speeds are highest, and consequently where the need is greatest. One suggestion is then to prioritise the use of traffic calming equipment at worksites considered to be particularly subjected to high speeds as early as at the planning stage.

3. TRAFFIC CALMING WHEN REPAIRING MEDIAN BARRIERS

3.1. “2 + 1 Lane Road” as a ROAD safety measure in Sweden

Most of Sweden’s older high traffic volume roads are 13 m wide, with one lane in each direction and wide shoulders. 1998 saw the first in a massive wave of revolutionary cost effective measures whereby these road sections were redesigned with alternating two traffic lanes in one direction and one in the other (designated “2+1 lane roads”) in combination with a median barrier [20]. This separates the flow of traffic and makes overtaking possible on up to half the road length (which is actually more than on normal high traffic volume roads) while at the same time improving road safety dramatically. These road sections are without shoulders. Today, over 1 400 km of road have been redesigned in this way.

However, this road type does pose new problems in connection with road worker safety at maintenance works. Due to the fact that the median barriers are frequently damaged, there is a regular need for repairs in situations where road workers are exposed to dangerous situations. One way to reduce the accident risk in such situations is to stop traffic and use a pilot escort (on a four-wheel motorcycle) to escort a convoy of vehicles at very low speeds past the roadworks zone.

Head-on collisions often result in serious or even fatal injuries. This is most evident in side impact accidents as a result of skidding on icy roads in the winter. In these cases, the most effective deformation zone of the vehicle (at the front) is unable to provide protection for occupants in the skidding car, which results in even worse injuries. Irrespective of climate conditions, head-on collisions can be prevented by installing median barriers to separate opposing lanes of traffic.

The aim of this study was to evaluate the effect of convoy traffic management. A demonstration test was conducted in August 2005 as well as a traffic simulation test to find out the maximum traffic volume that can be controlled in this way without causing unreasonably long delays for road users.

3.2. Background

The Swedish Work Environment Authority [21] has set 30 km/h as the ”maximum actual speed” (note the wording) for vehicles driving past building and civil engineering works where there are unprotected road workers if the lateral distance is less than 2.5 metres. Lateral distance refers to the distance between workers and the edge of the closest traffic lane. The repair of median barriers on a “2+1 lane road” is a good example of such an unprotected situation. In the same publication it is stated that 50 km/h applies where this distance is more than 2.5 metres. 70 km/h applies at works where there are safety protection barriers, provided that these barriers meet the class T2 (SS-EN 1317-1 and 2) specifications. These limits represent the Swedish Work Environment Authority’s interpretation of its own code of statutes for building and civil engineering works (AFS 1999:3) [22].

It could be worth mentioning that interpretations vary from country to country and that Sweden has chosen to apply a relatively strict interpretation. Nonetheless, it is very difficult to be able to control speeds past roadworks on a “2+1 lane road” through using a speed limit of 30 km/h without taking special measures, such as using a pilot escort.

Swedish Road Administration regulations concerning convoys cover less than one page without any supplementary manuals or recommendations [23]. In Great Britain, for example, the method is described in detail by the Department for Transport/Highways Agency et. al. [24, 25] as follows: *“In this method, traffic is brought to a halt in advance of roadworks and is then led slowly in single file through the site past the works by an appropriately signed works vehicle”* and continues: *“convoy traffic management may be used “where normal traffic management arrangements are not feasible because of restricted highway width, and diversion is impracticable...”.*

3.3. Demonstration test

A demonstration test was conducted in Nora, 300 km west of Stockholm in August 2005 (Figure 5). The objective was to evaluate the effect of the convoy method to control traffic when repairing median barriers on “2+1 lane roads”.

The convoy was directed by a flagman and a pilot escort on a four-wheel motorcycle. During the test a questionnaire was distributed to drivers waiting in the queue.

The pilot collected the vehicles and drove at a speed just over 20 km/h, directed by the flagman via radio contact. After a few cars had been waved through to follow the pilot, the flagman stopped traffic. The pilot then led the convoy past the worksite, stopped and turned after the last vehicle had driven past. The route back and forth took about 3 minutes at a traffic volume of between 300 and 400 vehicles per hour. Occasionally, traffic was also permitted to drive past unaccompanied for a few minutes while the pilot waited beyond the roadworks site. The queue was interrupted when the flagman thought that traffic had started to drive too fast (above 30 km/h) past the roadworks site. Traffic was considered to flow more smoothly at these times than when the flagman stopped the queue without assessing the speed of traffic past the worksite.

The method was considered to be suitable at sites with a traffic volume up to at least 500 vehicles per hour. An opinion survey showed that road users generally considered the pilot vehicle method to be good (26%) or very good (58%). A large percentage (68%) preferred this method, compared to up to a 21% preference found for other methods. The opinion survey also revealed a general understanding for the need to improve road worker safety.

Unfortunately the response frequency was low, with only 34 of 150 drivers having completed the questionnaire. However, the unambiguous results indicated that the conclusions drawn were reasonably safe.

3.4. Simulation test

In order to examine how well the pilot escort method works at higher traffic volumes, a model of a “2+1 lane road” was run in the VISSIM 4.10 simulation program. The intention was to check the capacity of this method. Experience from the demonstration test indicated that traffic volume and the length of a worksite are factors that considerably affect queue times.

The simulation model was used to determine the traffic volumes that the method could manage. Traffic volumes from 500 to 900 vehicles per hour were studied in the model for one-hour periods. The roadwork zones studied were either 200 or 400 metres long. An average queue time of 2-3 minutes, with a 4 minute maximum was considered to be acceptable in this test.

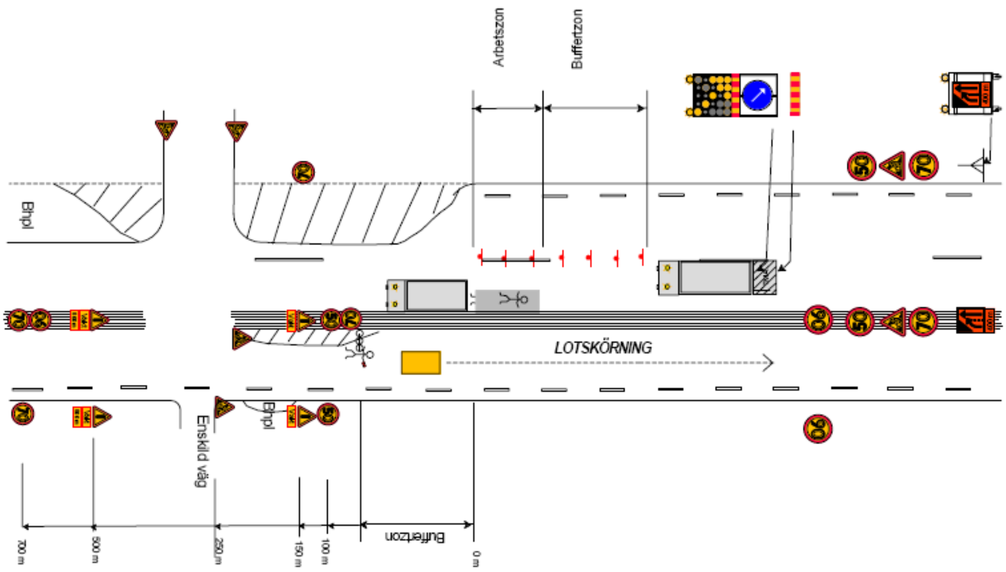

Figure 5 - Convoy for work sites on a road with a median barrier and alternating two traffic lanes in one direction and one in the other. The layout shows the demonstration test in Sweden with safety zones, work zones, flagman and convoy.

The simulation was modelled on the conditions in the demonstration: a “2+1 lane road” with one eastbound traffic lane and two westbound lanes, one of which was closed to traffic. Repair works on the cable-fence (median barrier) were simulated, with roadworks vehicles and road workers placed in the lane that had been closed to traffic. Initially the “flagman” waved through traffic behind the pilot vehicle travelling in an easterly direction. When the convoy had passed the roadworks site, the pilot pulled over to the side and allowed traffic to continue on past and then returned to the flagman to collect the next convoy.

In the model, a traffic light was used to represent the flagman, which stopped traffic when the headway was more than six seconds. This was due to the fact that a longer time gap would mean that the pilot/escort’s effect on traffic would be limited – which in turn could result in higher speeds past the worksite. Driver behaviour for the different vehicles was chosen at random in VISSIM. The pilot/escort was represented by a vehicle that maintained an even speed randomly distributed between 25 and 30 km/h. The rest of traffic moved at a desirable speed randomly distributed between 40 and 45 km/h past the roadworks, and forced to keep the same speed as the pilot when passing the roadworks.

A speed detector was used in the model at the end of the roadworks (i.e., the pilot) that displayed red at the traffic signal (flagman) west of the roadworks. This occurred in the simulation when the speed exceeded 35 km/h. Seven simulations were conducted for each traffic volume studied and the results are presented as a mean value for every simulation. Driver behaviour and the desired acceleration in the model varied with the speed according to the standard program settings in VISSIM 4.10, which in turn is based on Wiedemann, 1974 [26] and “multiple field measurements” [27]. The behaviour of traffic apart from the mean speed was thus not calibrated with local conditions. Vehicles in the model were counted as a queue if their speed slowed down below 5 km/h. They continued to be considered a queue until they reached a speed that exceeded 10 km/h or if the distance to the vehicle ahead was longer than 20 metres.

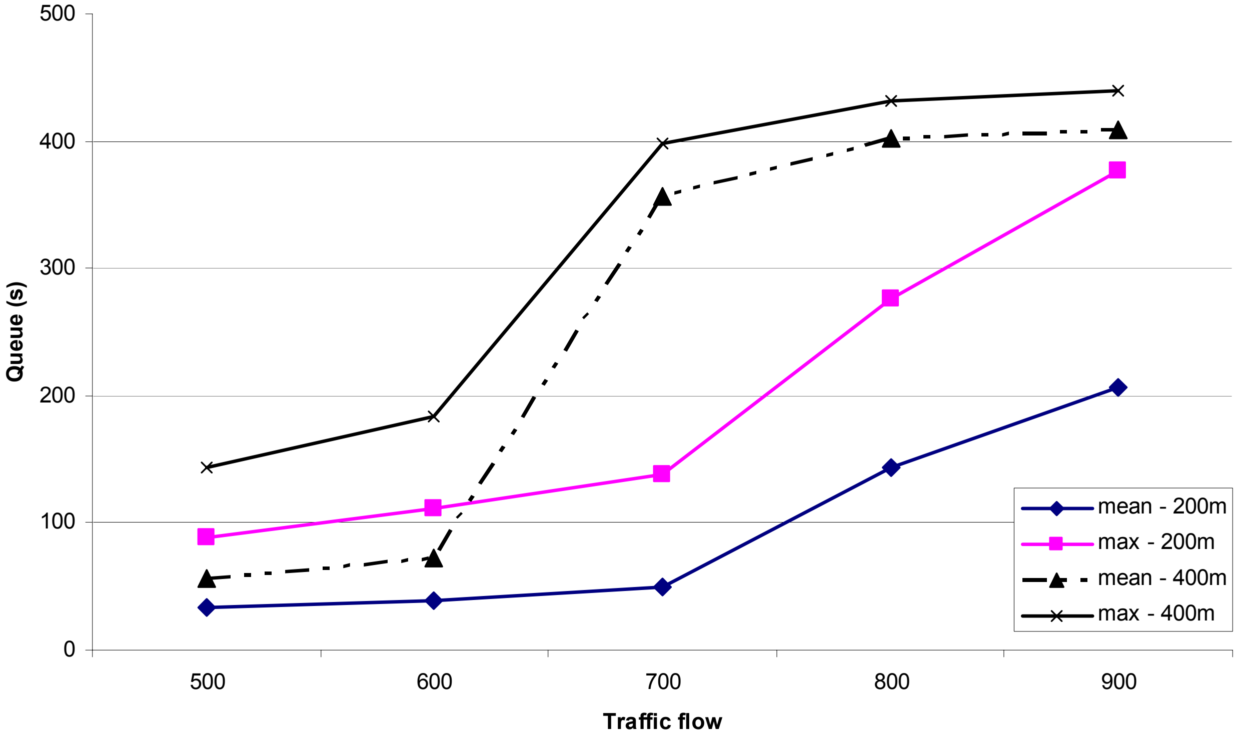

Figure 6 - Average length of queue in seconds as a function of traffic volume. The results are based on a simulation of a pilot/escort as a means of controlling the flow of traffic when repairing a median barrier on a “2+1 lane road”.

Figure 6 presents queue times at the flagman. Where the roadwork zone is 200 metres long, there is a sharp rise in queue times when the traffic volume increases from 700 to 800 vehicles per hour. Where the traffic volume is 700 vehicles per hour the average queue time is about 50 seconds, while the corresponding figure for a traffic volume of 800 vehicles per hour is almost 150 seconds. When the length of the roadwork zone increases, so do queue times. At a traffic volume of 600 vehicles per hour, queuing times are 70 seconds, and subsequently increase to over 350 seconds when the traffic volume is 700 vehicles an hour. Observe that the model is misleading for queue times above 300 seconds, since the maximum length of a queue presented in this VISSIM version was 510 metres.

Consequently, the simulation shows that the pilot escort method works at roadwork zones up to 200 metres long where the traffic volume reaches up to 700 vehicles per hour. When this increases to 800 vehicles an hour, there is a noticeable increase in both queuing times and the length of the queue. The average queuing time where the traffic volume is 700 vehicles per hour is about 50 seconds and the average queue is then about 100 metres long. This can be compared to 150 seconds and over 300 metres where the traffic volume is 800 vehicles an hour.

The capacity of the pilot escort method decreases when the length of the roadworks zone increases from 200 to 400 metres. The method works at traffic volumes up to 600 vehicles per hour when the zone is 400 metres long, when the model shows an average queuing time of about 70 seconds. This subsequently increases to over 350 seconds when the traffic volume increases to 700 vehicles per hour.

Speeds past roadworks are not affected by the different traffic volumes to any great extent. A certain increase in speed occurs with an increase in the traffic volume at short roadwork zones (200 m). This is probably due to the fact that the length of the convoy increases where there is more traffic, and then the effect of the pilot vehicle on the last vehicles in the convoy is less.

3.5. Convoy for controlling traffic: discussion and general conclusions

The results from the test demonstration showed that the pilot escort method provides a good alternative for achieving a low, even speed of traffic past median barrier repair works on a “2+1 lane road” (Figure 7). However, the suitability of the method depends on local conditions, such as the traffic volume. The test demonstration showed that, at least in normal cases, a pilot escort is sufficient and that radio contact is a good way to facilitate communication between the flagman and the pilot.

The opinion survey indicated a general acceptance of this method. One problem in connection with the evaluation of the questionnaire was the low response frequency (23 per cent), but the unambiguous results suggest that the conclusions could be considered quite reliable.

Figure 7 - Evaluation of a method to escort traffic through a work zone. This work zone is located on a road with a median barrier and alternating two traffic lanes in one direction and one in the other.

The results provided by the simulation test give an idea on the traffic volumes that can be handled by means of a pilot escort. About 700 vehicles an hour can be escorted past a 200 metre long roadworks site without the average queuing times exceeding a minute. However, when the traffic volume approaches some 800 vehicles an hour, problems start to arise, but it is difficult to exactly say when the limit has been reached.

In any event, a traffic volume of 700 vehicles per hour is quite high for a “2+1 lane road” in Sweden, particularly if it is possible to avoid carrying out roadworks during rush hours. On Highway 222 at Mölnvik, where the average weekday traffic volume is some 10 000 vehicles (ADT around 22 000) in each direction, simulation test results show that it would be possible to use the pilot escort method in the direction towards Stockholm any time except between 6 and 9.30 a.m. and around 4 p.m. In the direction from Stockholm the method could be used around the clock except between 2 and 7 p.m.

The maximum traffic volume in the model can be compared to the estimated traffic volumes and capacity in Great Britain [28]. The estimates presented in these manuals originally came from Advice Note (TA63/97) [29] (Paul Goward, by letter). The figures given, for example, for the traffic volumes at which the convoy method can be used are based on experience from when the method was being developed more than 10 years ago, and there are no reports of this work available.

4. CONCLUSIONS: TRAFFIC CALMING AT STATIONARY SHORT-TERM ROADWORK ZONES

Comparison of traffic calming measures at short-term stationary roadwork sites:

- The results showed considerably lower average traffic speeds past roadwork sites for all the four methods tested: active mini-speed bump, ”your speed” signs, passive mini-speed bump and police speed surveillance cameras.
- The difference when using signs was particularly obvious in the case of vehicles that drove the fastest.
- The results also indicated a greater effect at roadworks where there is a higher frequency of speeding offences.

Pilot escort for regulating traffic on “2+1 lane roads”.

- A test demonstration showed that a pilot escort to control traffic on ”2+1 lane roads” functions at shorter roadworks zones (200-400 metres long). The method can handle traffic volumes (700 - 800 vehicles per hour) under conditions existing in Sweden, with a possible exception of ”2+1 lane roads” in the vicinity of Stockholm during rush hours.

5. CLOSING WORDS

Some of the results have been presented in the Swedish entry to the PIARC PRIZE 2007 for Road Safety.

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