Installation of Speed Humps

Please refer to this document as follows: **Quigley, C (2017), Installation of Speed Humps, European Road Safety Decision Support System, developed by the H2020 project SafetyCube. Retrieved from www.roadsafety-dss.eu on DD MM YYYY**

Please note: The studies included in this synopsis were selected from those identified by a systematic literature search of specific databases (see supporting document). The main criterion for inclusion of studies in this synopsis and the DSS was that each study provides *a quantitative effect estimate*, preferably on the number or severity of crashes or otherwise on road user behaviour that is known to be related to the occurrence or severity of a crash. Therefore, key studies providing qualitative information might not be included in this synopsis.

1 Summary

Quigley, C., May 2017

1.1 COLOUR CODE: GREEN

Studies on the safety effects of speed hump installation show that accident rates and vehicle speeds are reduced when installed. In half of the analysed studies, the results were significant. In the other half of the studies, no statistical analysis was undertaken, so it is not known whether these results were significant. However, what is clear is that none of the results showed that speed humps resulted in increased speeds or accident rates. Hence, it can be concluded that installing speed humps reduces road safety risk.

1.2 KEYWORDS

Speed hump, speed bump, vertical deflection devices, raised crossing, speed ramp, speed cushion, speed table, speed breaker, road hump, countermeasure, accident rate, vehicle speed

1.3 ABSTRACT

Vertical speed deflection devices (known in general in this study as 'speed humps') aim to reduce vehicle speeds, particularly in urban and residential areas, and to improve the safety not only for vehicles, but also for pedestrians and cyclists using these areas. The effects of the installation of speed humps and other similar devices were investigated in the six studies selected for this synopsis (including one meta-analysis). Studies used either accident rate or vehicle speeds to measure the effectiveness of speed humps. The results found that the installation of speed humps and other similar devices reduces accident rates and vehicle speeds, sometimes significantly. These significant results were found specifically with speed humps and raised crossings, although non-significant decreases were also found with speed bumps and cushions. The topic has been investigated in a relatively wide range of countries and looking at a number of different road user types, but has not considered other condition types (e.g. transport modes…), which limits the transferability potential of the results slightly. However, even when considering this, speed humps appear to be an effective safety measure.

1.4 BACKGROUND

1.4.1 How are speed humps defined?

In this synopsis, speed humps has been used as a general term for any vertical speed deflection devices that aim to reduce the speeds of motor vehicle traffic, particularly in urban and residential areas. It includes road-wide measures such as speed humps, speed bumps (narrower and steeper than humps) and speed tables (flatter and wider than humps); along with speed cushions (allow larger vehicles and cyclists to pass in between the cushions). It also includes raised crossings, which have a dual function of slowing down traffic and allowing pedestrians a safer place to cross.

1.4.2 How can the installation of speed humps affect road safety?

The installation of speed humps and other similar vertical deflection devices can affect safety in a positive way by encouraging motor vehicle drivers to slow so as not damage their vehicles. Slower speeds inherently lead to safer roads as drivers can control their vehicles better at slower speeds and avoid possible collisions. But also in the event of a collision, slower speeds would reduce the likelihood of serious injuries occurring, particularly for pedestrians and cyclists.

1.4.3 Which safety outcomes are affected by the installation of speed humps?

The two main ways safety outcomes are affected by the installation of speed humps are injury accident rates and vehicle speeds. In addition, some literature also considered road user behaviour (e.g. braking distances) and conflicts as potential safety outcomes which could be affected by speed hump installation, but the results in this synopsis have focussed on accidents and speed as the two safety outcomes affected by speed hump installation.

1.4.4 How is the effect of the installation of speed humps studied?

The effect of installation of speed humps is generally studied alongside other speed calming measures, such as chicanes (Agerholm, 2016), safety islands and speed cameras (Jateikiene et al., 2016) and often the study would be focussed on pedestrian crossing areas, with either the speed hump being part of the crossing (i.e. a raised crossing, e.g. Jateikiene et al., 2016), on approach to the crossing (Krudryavtsev et al., 2012) or both (Gitelman et al., 2016). Either accident rates or vehicle speeds are used in a before-after study to investigate whether speeds/ rates are reduced once the speed hump has been introduced at a site. The data is then examined using absolute differences before and after installation, but sometimes statistical analysis on the data is also carried out to find out whether any differences found were significant. The analysis was undertaken using negative binomial and 'zero-inflated negative binomial' regressions ((Krudryavtsev et al., 2012) and ANOVA and Post-hoc (Turkey HSD) tests (Gitelman et al., 2016). The data from the meta-analysis in this study were from the United Kingdom, USA and the Netherlands. The five remaining studies considered in this synopsis were from Russia, Lithuania, Denmark, Israel and Poland.

1.5 OVERVIEW OF RESULTS

Overall, the results showed that the installation of speed humps and similar devices do reduce accident rates and vehicle speeds. In particular, as shown in some of the studies, the humps were part of a raised crosswalk (non-signalised) or on approach to a crossing/crosswalk, which means that the reduced speeds could be a particular safety benefit to pedestrians crossing the road. The results of the meta-analysis specifically showed a significant reduction in accidents as a whole when speed humps were installed, but not when pedestrian and cyclist crashes were investigated separately, although a non-significant reduction was still seen. Even when the results were not significant, all the results showed a reduction in accident rates and vehicle speeds.

1.6 NOTES OF ANALYSIS METHODS

Most studies used large sample sizes for investigation. For the speed analysis studies, the data samples ranged from 100 recorded speeds per condition/site (Agerholm et al., 2015) to up to 90,000 speeds recorded for one condition (Olszewski et al., 2016). For the accident analysis studies, sample sizes ranged from 10-63 accidents per site/condition (Jateikiene et al., 2016) to samples in the 1000's (Krudryavstev et al., 2012). However, only three studies used statistical analysis on the results.

The topic of "installation of speed humps" has been fairly well studied as a measure, but many studies were excluded because they were not before/after studies. When the topic was analysed, it was often alongside other safety measures (e.g. chicanes, traffic signals…) and sometimes without any statistical analysis being carried out on the results (3 of the 6 studies). The topic has been investigated in a relatively wide range of countries and looking at a number of different road user types (e.g. pedestrians, cyclists), but has not considered other condition types (e.g. rural/urban settings, transport modes…), which limits the transferability potential of the results slightly.

2 Scientific Overview

2.1 LITERATURE REVIEW

2.1.1 DESCRIPTION OF AVAILABLE STUDIES

Six studies were identified for their inclusion in the synopsis of the measure "installation of speed humps". In the six studies, a variety of vertical speed deflection devices was investigated. Three studies looked at speed humps specifically, one study investigated speed cushions, one study investigated a variety of the devices (including humps and raised crossings) and one study looked at both raised crossings and humps together.

One study was a meta-analysis, bringing together the results of four similar studies on speed humps. The meta-analysis, along with two other studies, analysed accident data before and after the speed humps or similar devices were installed. The remaining three studies investigated changes in vehicle speeds before and after installation.

Within the accident analysis studies, pedestrian and cyclist crashes were investigated alongside crashes with all vehicle types, and all three studies looked at injury only accidents, with one specifically looking at fatal and serious injury crashes.

Each study was from a different country (Meta-analysis - UK, USA & Netherlands; plus Russia, Lithuania, Denmark, Israel, Poland) and samples ranged from the 10's into the 1000's.

Studies investigated the effects of installing speed humps and similar devices through mainly before-after accident and speed studies (or quasi-experimental with some before-after study characteristics) based on a number of sites where speed humps or similar had been installed. Results were generally provided as absolute differences in mean speeds or accident rates and where statistical analysis was undertaken, negative binomial regression, ANOVA and Post-hoc (Turkey HSD) tests were used.

Table 1 shows the overview of these coded studies.

Table 1: Descriptions of coded studies on installation of speed humps

Author, Year, Country	Sample, method/design and analysis		Reference group	Additional information on analysis
Høye, A.,2015, UK, USA, Netherlands	Meta-analysis (random effects), which included before-after and case control studies (4 studies total), with all studies included having been controlled for regression to the mean	Percentage change in injury accidents before and after installation of **speed humps**	Percentage of accidents before the installation of speed humps	Percentage change in accident was investigated for all accidents, pedestrian accidents and cyclist accidents
Kudryavtsev et al., 2012, Russia	Quasi-experimental study with some before/after study characteristics, sample of 30 non-signalised crosswalks where speed humps were installed between 2005-2010, with a	Average percentage change in monthly rates of pedestrian-motor vehicle accidents per one unit change in pedestrian safety	Accidents on non-signalised crosswalks before speed humps have been installed	Pedestrian-motor vehicle accidents only

Author, Year, Country	Sample, method/design and analysis		Reference group	Additional information on analysis
	total of 2363 pedestrian-motor vehicle accidents occurring during that time	measures (i.e. installation of **speed humps**)		
Jateikiene et al., 2016, Lithuania	Quasi-experimental study with some before/after study characteristics, sample of 53 sites where vertical traffic calming measures were installed prior to 2011 (169 accidents recorded in total).	Changes in the number of fatal and injury accidents before and after installation of the vertical speed deflection devices were analysed in the study.	Accidents at sites before vertical traffic calming devices were installed	Vertical speed deflection device types investigated: **"Speed humps of trapeze shape"** **"Raised pedestrian crossings"** **"Speed bumps"** **"Speed humps at the junctions"**
Agerholm et al., 2015, Denmark	Before-after study, with speed measurements from 3216 trips on a 1400m stretch of road (2605 trips before the 3 speed humps were installed (Dec 2012-July 2013) and 611 after they were installed (Dec 2013 – Mar 2014)).	Difference in mean speed of vehicles after the implementation of **speed humps** within a distance of 75m & 125m	Speeds recorded before the speed humps were installed	
Gitelman et al., 2016, Israel	Before-after study, with speed measurements recorded from 8 sites (100 at each site in each direction) where raised crosswalks with preceding speed humps were installed	Differences in mean speeds (km/h) and numbers of pedestrian-vehicle conflicts before and 2 months after the **raised crosswalks and preceding speed humps** were installed	Speeds and pedestrian-vehicle conflicts recorded before the raised crosswalk and preceding speed humps were installed	Pedestrian-motor vehicle conflicts only
Olszewski et al., 2016, Poland	Quasi-experimental study with some before/after study characteristics, with speed measurements taken at one site on both lane 1 and 2, before and after speed cushions were installed on approach to a pedestrian crossing.	Differences in mean speeds (km/h) up to 12 days before and 11 days after **the speed cushions** were installed (resulting in 1000's of speed measurements both before and after installation)	Mean speeds recorded before the speed cushions were installed	

2.1.2 Study Results

Overall, the results across all six studies, including the meta-analysis, showed that the installation of speed humps or similar devices resulted in reduced accident rates and vehicle speeds. Where statistical analysis was carried out, significant results were found when accidents involving all road user types were included (i.e. when including all road user types, accident rates reduced when speed humps were installed) and when only pedestrian-vehicle accidents were considered. Speeds were found to be significantly lower when raised crosswalks were installed along with preceding speed humps.

Høye (2015) undertook a meta-analysis of four studies investigating the safety effects of installing speed humps and found a significant decrease in the percentage of all accidents when speed humps were installed (17%), but although a decrease was also found when looking specifically at pedestrian accidents and cyclist accidents (1% and 16% respectively), it was found not to be statistically significant.

Kudryavstev et al. (2012) investigated the effect of the installation of speed humps on accident rates at non-signalised crossings and found a significant decrease in the rate of pedestrian-vehicle injury accident rates near the crosswalk (2.7% average monthly reduction), when the pedestrian is presumed at fault. When the driver is presumed at fault in accidents involving pedestrians on the crosswalk, a decrease in accidents was also seen, but it was not significant.

Jateikiene et al. (2016) looked at a number of vertical speed deflection devices, including speed humps, humps at junctions, raised pedestrian crossings and speed bumps and their effect on accident rates when installed. While some large accident rate reductions were seen (29-100%), as no statistical tests were undertaken in this part of the study, it is not known whether these reductions are statistically significant.

The effect on mean vehicle speeds when speed humps were installed was investigated by Agerholm et al. (2015). Although no statistical analysis was carried out, reductions in mean speeds were recorded at both 75m and 125m from the speed humps.

When investigating the effects of installing raised pedestrian crosswalks combined with preceding speed humps, Gitelman et al. (2016) found mean speeds were significantly reduced after installation at all eight sites where speed measurements were recorded, with speeds being reduced by between 10-28%.

Olszewski et al. (2016) investigated the effect of installing speed cushions at one site (in 2 lanes) on vehicle speeds. Over a number of months, many 1000's of vehicle speeds were recorded before and after installation and speed reductions of 8.5 to 12.2% was found across the two lanes. However, statistical analysis on this data was not undertaken and therefore it is not known whether these reductions were significant.

Table 5 in the supporting document presents an overview of the information on the main outcome of coded studies on the installation of speed humps.

2.1.3 meta analysis of data for installation of speed humps

Table 2 outlines the main results of the existing meta-analysis of the four speed humps studies undertaken by Høye (2015).

Table 2 Random effects meta-analysis for speed hump effects on percentage accident occurrence (Høye, 2015)

Variable	Estimate	95% CI	Statistically significant?
Speed humps (all accidents)	-17%	(-25%, -8%)	Y
Speed humps (pedestrian accidents)	1%	(-19%, 26%)	N
Speed humps (cyclist accidents)	16%	(-17%, 62%)	N

2.2 DESCRIPTION OF ANALYSIS CARRIED OUT

In addition to the existing meta-analysis and due to variance between individual reported effects in the papers and differences in the types of vertical deflection devices investigated in the study, it was decided the best way to evaluate the remaining five papers would be through a vote count. The overall results of the meta-analysis would also be included in this vote count.

Table 3 shows the results of the vote count analysis for the five studies and additional meta-analysis. Care was taken not to ensure that data was counted twice from the same study. For example, for the meta-analysis, only the overall ('all accidents') results were included and not the results for the pedestrian and cyclist accidents, as this data would already be included in the 'all accidents' results. The table shows that 50% of the studies (n=3) conclude overall reduced risk (and therefore increased safety) when safety humps and similar devices were installed, whereas no significant outcome was concluded for the other 50% (n=3), although from the results it can be seen that it was a non-significant decrease in accidents/vehicle speed in all three of these studies.

Table 3: Vote count result of comparing "installation of speed hump" studies in terms of accident rate and vehicle speed

Outcome definition	Tested in no. of studies	Result (no. of studies)			Result (% of studies)			Result (no. of effects)			Result (% of effects)		
		↑	-	↓	↑	-	↓	↑	-	↓	↑	-	↓
Accident rate	3	-	1	2	-	33%	67%	-	5	2	-	71%	29%
Vehicle speed	3	-	2	1	-	67%	33%	-	4	8	-	33%	67%
Total	6	-	3	3	-	50%	50%	-	9	10	-	47%	53%

When analysing the number of effects, the results indicate that 53% (n=10) of the reported effects led to a significant decrease in accident rate, with none showing a significant increase. The table also appears to show that vehicle speeds are affected more positively by the introduction of speed humps and similar devices than accident rates. This result is mainly an effect of one study which undertook a before-after study at eight separate sites and analysed the results at these eight sites separately, which all came back significant for reducing speeds at each site.

By displaying the results using the outcome of accident rate and vehicle speed, it is not possible to see whether specific vertical speed deflection devices are linked to a greater or reduced road accident rate and/or vehicle speeds. Therefore, Table 4 shows the vote count results for the various vertical speed deflection devices looked at in the selected studies.

Table 4: Vote count result of comparing studies in terms of the vertical speed deflection device investigated in the studies

Vertical speed deflection type	Included in number of studies	Result (number of studies)			Result (% of studies)			Result (number of effects)			Result (% of effects)		
		↑	-	↓	↑	-	↓	↑	-	↓	↑	-	↓
Speed humps*	4	-	2	2	-	50%	50%	-	4	11	-	27%	73%
Speed cushions	1	-	1	-	-	100%	-	-	2	-	-	100%	-
Speed bumps	1	-	1	-	-	100%	-	-	1	-	-	100%	-
Raised crossings**	2	-	1	1	-	50%	50%	-	1	8	-	11%	89%

** Speed humps – includes 'speed humps', 'speed humps at non-signalised crossings', speed humps of trapeze shape', 'speed humps at the junctions' and 'raised pedestrian crosswalks combined with preceding speed humps'*
*** Raised crossings – includes 'raised pedestrian crossings' and 'raised pedestrian crosswalks combined with preceding speed humps'*

The results in Table 4 show that only significantly positive results were found for studies which investigated the installation of speed humps and raised crossings, so it appears that installing speed humps and raised crossings can help to reduce vehicle speeds and accident occurrence, but it is not so clear for speed bumps and speed cushions.

2.3 CONCLUSION

Overall, it was found that the installation of speed humps and similar devices do not appear to affect safety in a negative way, and in the majority of studies, lead to reduced accident rates and vehicle speeds, although not always significantly.

The significant results were found to be in studies where speed humps and raised crossings were the vertical speed deflection devices being investigated. Although reductions in accident rates and vehicle speeds were found in the studies investigating speed bumps and speed cushions, it was not known whether the results were significant, as the studies investigating these devices did not undertake statistical analysis on the results.

Overall, these results would generally be expected as the main aim of a vertical speed deflection device is to reduce the speed of the vehicle travelling over it. A direct influence of this would be reduced accidents, particularly serious accidents, and there is plenty of existing evidence which highlights this, particularly in urban areas (e.g. Taylor et al., 2000).

Many of these studies, however, only consider absolute differences in vehicle speeds and accident numbers, and do not make it clear how much other external factors have been taken into account that may affect how much the reduction in speed/accident rates is actually down to the installation of the speed hump or similar device, or other factors (e.g. weather, time of day…).

3 Supporting Documents

3.1 DESCRIPTION OF THE STUDIES IDENTIFIED FOR INCLUSION IN SYNOPSIS

In total, six studies were identified as being the most relevant for this synopsis on installation of road humps and other similar devices.

Høye (2015) undertook a literature review and meta-analysis of the effect on accidents of installing speed humps. All included studies controlled for regression to the mean and installing speed humps reduced the total number of accidents by 17%. The results from single studies varied greatly, so generalizing the result was found to be problematic. No effect was found for pedestrian accidents. The result for bicycle accidents indicate increased risk, but was not statistically significant.

The study by Kudryavtsev et al. (2012) attempted to explain the reduction of pedestrian-motor vehicle accidents in Arkhangelsk, Russia during the period 2005-2010. Using a retrospective ecological design (quasi-experimental) the authors utilized data from pedestrian-motor vehicle crashes, traffic violations and total number of vehicles along with changes in legislation and infrastructure. With regard to speed humps the paper looks at pedestrian crossings which are "black spotted" and had three or more traffic crashes during a year. Using negative binomial regression the authors found an inverse association with the implementation of speed humps. More specifically for accidents where pedestrians were at fault for the accident, the estimate of average rates at crossing with speed humps dropped by 2.7 while for accidents were the drivers were at fault, the rates dropped by 0.4. Hence, it can be concluded that the installation of speed humps was associated with a negative effect on road safety.

Jateikiene et al. (2016) investigated the effect of vertical traffic calming measures (i.e. speed bumps, speed humps and raised crosswalks), safety islands and speed cameras on the safety of Lithuanian roads. More specifically the authors analysed fatal and injury accident data on the national road network of Lithuania. The considered types of speed humps are speed humps of trapeze shape, raised pedestrian crossings, speed bumps and speed humps at junctions. The absolute numbers of fatal and injury accidents were compared before and after the installation of the speed measures and the relevant percent changes were reported as effects. In all the effects a decrease in the percent was obvious after the installation of speed humps. It should be noted here, however, that no statistical test was used and the reported results are the absolute percent of the fatal and injury accidents before and after the installation of speed humps.

Agerholm et al. (2015) discusses the effects of chicanes and speed humps on drivers' speed when they travel on urban roads in minor towns in Denmark. The study design is a naive before-after study. More specifically a minor distributor road in Skorping was chosen as the study location and the data used in the study were obtained through floating car data of position and speed. As the authors aim was to detect speeding behaviour, this was considered as an outcome variable. Mean speed and standard deviation of speed were considered as effects as these are reported in the paper. Regarding mean speed this was documented at two spatial thresholds; within 75m from the speed calming measure and within 125m from the measure. The standard deviation was logged for all locations. Finally the highest registered speed was also documented and was included in the effects. For all the effects a reduction was observed after the installation of the speed humps. However, because no specific statistics were given the effect on traffic safety was coded as not significant because of the lack of in-depth statistical details.

In Gitelman (2016), the author discusses the behavioural changes that followed the installation of two types of raised pedestrian crosswalks in eight sites in Israel. The two types of speed humps are: a 15cm high trapezoidal hump combined with 8-10cm high circular humps and a 10-12cm high trapezoidal hump combined with 6-8cm high circular humps. The behaviours studied included the vehicle travel speeds while approaching a crosswalk, the number of vehicles which yield to pedestrians, the conflict occurrences between pedestrians and vehicles in the crosswalk area, the number of pedestrians crossing in the designated area and the accordance to safe crossing rules by pedestrians before a crossing. For every site along with the before period (i.e. before the installation of speed humps) two temporal periods were taken into account (i.e. shortly after the installation (1-2 weeks after) and (2 months after)). Eight sites were used for the study, each containing two pedestrian crosswalk on different travel directions. For each of the site all the above mentioned behaviours were quantified and detailed results were described for site1. Due to the large number of variables included (8 sites x 2 directions x 9 behavioural variables) it was decided to only look at the summary tables (i.e. Tables 5 & 6) which include the results for all the sites and specifically code the speed reduction changes and the percent change of traffic conflicts between pedestrians and vehicles as these were considered to be more important for pedestrian safety. All the coded results considered the comparison between the before period and the period two months after the installation of speed humps. The results for the outcome variables (mean speed and speed distribution & %-change of conflicts) after the installation of the exposure variable (installation of speed humps) showed that at the majority of the sites pedestrian safety increased regarding the reduction of the speed of vehicles. On the other hand, at most sites the difference in the number of conflicts before and after was not significant.

The study by Olszewki et al. (2016) investigated pedestrian-vehicle safety measures through the use of video cameras to extract vehicle and pedestrian trajectories. They developed surrogate safety indicators for pedestrian-vehicle encounters and proposed classification techniques based on the characteristics of those encounters. Regarding speed humps the authors looked at how the speed measurement was affected at a pedestrian crossing where speed cushions were installed. The measured outcome was the mean and standard deviation of vehicle speeds at the crossing and these were coded. They also investigated the mean volume of vehicles but the coder chose not to code it because the speed measurement was the effect that the authors identified. It was found that the mean and standard deviation of speed were lower where speed cushions were installed, thus pedestrian-vehicle safety was increased. However, the authors did not distinguish between vehicles which encountered pedestrians and did not investigate the fact that the volume of vehicles might influence the speed of vehicles.

Table 5 illustrates an overview of the main features and outcomes of the six the coded studies.

Table 5: Main outcomes of coded studies on installation of speed humps

Author, Year, Country	Exposure variable	Outcome variable / Outcome type	Effects		Main outcome -description
Høye, A.,2015, UK, USA, Netherlands (meta-analysis)	Installation of speed humps	Percent change in all accidents, from random effects meta-analysis	↘	17% reduction 95% CI	Significant decrease in percentage of accidents when speed humps were installed
		Percent change in pedestrian accidents, from random effects meta-analysis	-	1% reduction 95% CI	There is a decrease in risk of pedestrian accidents when speed humps were installed, but it is not statistically significant.

Installation of Speed Humps

Author, Year, Country	Exposure variable	Outcome variable / Outcome type	Effects		Main outcome -description
		Percent change in cyclist accidents, from random effects meta-analysis	-	16% reduction 95% CI	There is a decrease in risk of cyclist accidents when speed humps were installed, but it is not statistically significant.
Kudryavtsev et al., 2012, Russia	Installation of speed humps at non-signalised crossings	Pedestrian-vehicle injury accident rate in accidents near the crosswalk where pedestrian is presumed at fault	↘	2.7% average monthly reduction p=<0.05, 95% CI	Significant decrease in risk of pedestrian-vehicle injury accidents where pedestrian is at fault when speed humps were installed
		Pedestrian-vehicle injury accident rate in accidents on the crosswalk where driver is presumed at fault	-	0.4% average monthly reduction p=<0.05, 95% CI	There is a decrease in risk of pedestrian-vehicle injury accidents where the driver is at fault when speed humps were installed, but it is not statistically significant.
Jateikiene et al., 2016, Lithuania	Speed humps of trapeze shape	Percent change in number of fatal and injury accidents	-	36% reduction	There was a decrease in percentage of fatal & injury accidents, but as no statistical analysis was undertaken, it was not significant.
		Percent change in number of people killed	-	100% reduction	There was a decrease in the percentage of fatalities, but as no statistical analysis was undertaken, it was not significant.
		Percent change in number of people injured	-	45% reduction	There was a decrease in the percentage of seriously injured casualties, but as no statistical analysis was undertaken, it was not significant.
	Raised pedestrian crossings	Percent change in number of fatal and injury accidents	-	65% reduction	There was a decrease in percentage of fatal & injury accidents, but as no statistical analysis was undertaken, it was not significant.
		Percent change in number of people killed	-	83% reduction	There was a decrease in the percentage of fatalities, but as no statistical analysis was undertaken, it was not significant.
		Percent change in number of people injured	-	68% reduction	There was a decrease in the percentage of seriously injured casualties, but as no statistical analysis was undertaken, it was not significant.
	Speed bumps	Percent change in number of fatal and injury accidents	-	73% reduction	There was a decrease in percentage of fatal & injury accidents, but as no statistical analysis was undertaken, it was not significant.
		Percent change in number of people killed	-	73% reduction	There was a decrease in the percentage of fatalities, but as no statistical analysis was undertaken, it was not significant.
		Percent change in number of people injured	-	77% reduction	There was a decrease in the percentage of seriously injured casualties, but as no statistical analysis was undertaken, it was not significant.

Author, Year, Country	Exposure variable	Outcome variable / Outcome type	Effects		Main outcome -description
	Speed humps at the junctions	Percent change in number of fatal and injury accidents	-	44% reduction	There was a decrease in percentage of fatal & injury accidents, but as no statistical analysis was undertaken, it was not significant.
		Percent change in number of people killed	-	75% reduction	There was a decrease in the percentage of fatalities, but as no statistical analysis was undertaken, it was not significant.
		Percent change in number of people injured	-	29% reduction	There was a decrease in the percentage of seriously injured casualties, but as no statistical analysis was undertaken, it was not significant.
Agerholm et al., 2015, Denmark	Speed hump	Difference in mean speed of vehicles after the implementation of speed humps within a distance of 125m	-	Mean speed reduction of 4.4km/h	There was a decrease in the mean speed of vehicles after the implementation of speed humps, but as no statistical analysis was undertaken, it was not significant.
		Difference in mean speed of vehicles after the implementation of speed humps within a distance of 75m	-	Mean speed reduction of 5km/h	There was a decrease in the mean speed of vehicles after the implementation of speed humps, but as no statistical analysis was undertaken, it was not significant.
Gitelman et al., 2016, Israel	Raised pedestrian crosswalks combined with preceding speed humps	Difference in mean speed of vehicles at site 1 (average over both directions)	↘	Mean speed reduction of 22.5% $p=<0.05$, 95% CI	Significant decrease in the mean speed of vehicles after the raised crosswalk with preceding speed humps were installed
		Difference in mean speed of vehicles at site 2 (average over both directions)	↘	Mean speed reduction of 20.5% $p=<0.05$, 95% CI	Significant decrease in the mean speed of vehicles after the raised crosswalk with preceding speed humps were installed
		Difference in mean speed of vehicles at site 3 (average over both directions)	↘	Mean speed reduction of 28.5% $p=<0.05$, 95% CI	Significant decrease in the mean speed of vehicles after the raised crosswalk with preceding speed humps were installed
		Difference in mean speed of vehicles at site 4 (average over both directions)	↘	Mean speed reduction of 22.5% $p=<0.05$, 95% CI	Significant decrease in the mean speed of vehicles after the raised crosswalk with preceding speed humps were installed
		Difference in mean speed of vehicles at site 5 (average over both directions)	↘	Mean speed reduction of 11% $p=<0.05$, 95% CI	Significant decrease in the mean speed of vehicles after the raised crosswalk with preceding speed humps were installed
		Difference in mean speed of vehicles at site 6 (average over both directions)	↘	Mean speed reduction of 10.5% $p=<0.05$, 95% CI	Significant decrease in the mean speed of vehicles after the raised crosswalk with preceding speed humps were installed
		Difference in mean speed of vehicles at site 7 (average over both directions)	↘	Mean speed reduction of 15% $p=<0.05$, 95% CI	Significant decrease in the mean speed of vehicles after the raised crosswalk with preceding speed humps were installed

Author, Year, Country	Exposure variable	Outcome variable / Outcome type	Effects		Main outcome -description
		Difference in mean speed of vehicles at site 8 (average over both directions)	↘	Mean speed reduction of 23.5% p=<0.05, 95% CI	Significant decrease in the mean speed of vehicles after the raised crosswalk with preceding speed humps were installed
Olszewski et al., 2016, Poland	Speed cushions	Difference in mean speed of vehicles in Lane 1	-	Mean speed reduction of 12.2%	There was a decrease in the mean speed of vehicles after the implementation of speed cushions, but as no statistical analysis was undertaken, it was not significant.
		Difference in mean speed of vehicles in Lane 2	-	Mean speed reduction of 8.5%	There was a decrease in the mean speed of vehicles after the implementation of speed cushions, but as no statistical analysis was undertaken, it was not significant.

↗ = *Significantly greater accident rates/vehicle speeds when speed humps or similar vertical deflection devices are installed.*

↘ = *Significantly less risk of accident rates/vehicle speeds when speed humps or similar vertical deflection devices are installed.*

\- = *Differences in accident rates/vehicle speeds may have been found, but not statistically significant or not known (i.e. statistical analysis not carried out).*

3.2 METHODOLOGY

This section describes the search terms, screening and eligibility selection processes that were used to identify relevant papers for investigating the safety effectiveness of speed humps and similar devices.

3.2.1 Literature Search Strategy

A systematic literature search was conducted in January 2017. It was carried out in two databases with broadly similar search strategies. The databases 'Scopus' and 'TRID' were used to identify papers that examined the effectiveness of installing speed humps and similar devices in improving road safety.

Detailed search terms, as well as their linkage with logical operators and combined queries are shown in Tables 6 and 7.

Table 6: Scopus search terms and results

Database: Scopus **Date:** 17 Jan 2017

search no.	search terms / operators / combined queries	hits
#1	"speed hump*" OR "speed bump*" OR "speed ramp*" OR "speed cushion*" OR "speed table" OR "speed tables" OR "speed breaker*" OR "road hump*" OR "road bump*" OR "road ramp*" OR "road cushion*" OR "sleeping policeman" OR "raised crossing*"	849
#2	"safe*" OR "countermeasure*" OR "crash*" OR "accident*" OR "incident*" OR "collision*" OR "risk*" OR "impact*" OR "severity"	7647928
#3	#1 and #2	323

Table 7: TRID search terms and results

Database: TRID **Date:** 17 Jan 2017

search no.	search terms / operators / combined queries	hits
#1	"speed hump*" OR "speed bump*" OR "speed ramp*" OR "speed cushion*" OR "speed table"	629
#2	"speed tables" OR "speed breaker*" OR "road hump*"	542
#3	"road bump*"	13
#4	"road ramp*"	26
#5	"road cushion*"	1
#6	"sleeping policeman"	242
#7	"raised crossing*"	2
#8	#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7	697
#9	"safe*" OR "countermeasure*" OR "crash*" OR "accident*" OR "incident*" OR "collision*" OR "risk*" OR "impact*" OR "severity"	15000
#8 AND #9		31

A number of limitations and exclusions were applied on the 354 papers initially found using the search terms listed in Tables 6 and 7, which were as follows:

- Search field: TITLE-ABS-KEY
- published: year > 1990
- Document Type: "All"
- Source Type "Journals" or "Conference Proceedings"
- Subject area: "Engineering", "Social Sciences", "Psychology", "Undefined" or "Multi-disciplinary"
- Language: "English"

Table 8 shows the number of remaining papers after the limitations and exclusions were applied.

Table 8: Papers still remaining after applying limitations/exclusions

Database	Hits
Scopus	184
TRID	31
Total number of studies to screen title/ abstract	**215**

3.2.2 Results of literature search, screening and prioritizing

As shown in Table 9, the titles and abstracts of the 215 papers remaining after the initial searches and exclusions were screened for their relevance to the countermeasure 'installation of speed humps'. From this screening, 48 were found to still have possible relevance to this factor.

Table 9: Screening process of the 215 studies identified from the initial literature search

Total number of studies to screen title/ abstract	215
-De-duplication	1 from Scopus & 2 from TRID
-Not relevant studies excluded	150 from Scopus & 14 from TRID
-Studies with no risk estimates excluded	0
Studies not clearly relevant to the topic (full-text screening later)	0
Remaining studies	48
Studies to obtain full-texts	48

A search for all of the full-texts of these 48 studies was undertaken so that the whole paper could be screened to determine their eligibility for analysing the countermeasure "installation of speed humps".

Table 10 shows the number of papers which were eligible for analysing the safety effectiveness of speed humps and similar devices. In addition to the 48 studies identified from the literature search for full-text screening, a further 1 was added which was a meta-analysis first published in the most recent version of The Handbook of Road Safety Measures (Elvik, 2009) and updated to include more recent papers (Høye, 2015). As the full-text of 10 studies could not be obtained, a total of 38 papers had their full-text screened for eligibility for analysing the safety effectiveness of speed humps and similar devices. Apart from the updated meta-analysis from Høye (2015), no other meta-analyses were found in the remaining studies.

Table 10: Eligibility of papers selected for full-text screening

Total number of studies to screen full-text	48
Full-text could be obtained	38
Additional relevant studies identified from reference lists/other sources	1
Exclude: included in meta-analysis	2
Exclude: not relevant	27
Total number of eligible papers	**10**

As can be seen from Table 10, ten of the papers obtained for full-text screening were found to be relevant for analysing the safety effectiveness of speed humps and similar devices.

3.2.3 Prioritisation

Once ten of the full-text papers had been evaluated as eligible, they were assessed as to their suitability to be included in this synopsis based on the following prioritisation criteria:

- Prioritizing Step A: Meta-analysis;
- Prioritizing Step B: studies dedicated on this countermeasure over studies with multiple measures;
- Prioritizing Step C: journal papers first;
- Prioritizing Step D: studies published more recently
- Prioritizing Step E: studies from Europe

Using the prioritisation criteria, six papers were identified as the most suitable for coding and therefore inclusion in this synopsis, which included the meta-analysis.

3.3 REFERENCES

Coded studies

Kudryavtsev, A. V., Nilssen, O., Lund, J., Grjibovski, A. M., & Ytterstad, B. (2012). Explaining reduction of pedestrian-motor vehicle crashes in arkhangelsk, russia, in 2005-2010. International Journal of Circumpolar Health, 71(1) doi:10.3402/ijch.v71i0.19107

Jateikiene, L., Andriejauskas, T., Lingyte, I., & Jasiuniene, V. (2016). Impact assessment of speed calming measures on road safety. Paper presented at the Transportation Research Procedia, , 14 4228-4236. doi:10.1016/j.trpro.2016.05.394

Agerholm, N., Knudsen, D., & Variyeswaran, K. (2015). Speed-calming measures and their effect on driving speed - test of a new technique measuring speeds based on GNSS data. Transportation Research Part F: Traffic Psychology and Behaviour, doi:10.1016/j.trf.2016.06.022

Gitelman, V., Carmel, R., Pesahov, F., & Chen, S. (2015). Changes in road-user behaviors following the installation of raised pedestrian crosswalks combined with preceding speed humps, on urban arterials. Transportation Research Part F: Traffic Psychology and Behaviour, doi:10.1016/j.trf.2016.07.007

Olszewski, Piotr; Buttler, Ilona; Czajewski, Witold; Dabkowski, Pawel; Kraskiewicz, Cezary; Szagala, Piotr; Zielinska, Anna. (2016). Pedestrian Safety Assessment with Video Analysis. Transportation Research Procedia, Volume 14, 2016, pp 2044-2053 http://trid.trb.org/view/1414066

Høye, A. (2015). Physical measures for speed regulation. The Handbook of Road Safety Measures, Norwegian (online) version. http://tsh.toi.no/index.html?22167

References from Høye (2015):

Chen, L., Chen, C., Ewing, R., McKnight, C. E., Srinivasan, R., & Roe, M. (2013). Safety countermeasures and crash reduction in New York City — Experience and lessons learned. Accident Analysis & Prevention, 50, 312-322

Ewing, R., Chen, L., & Chen, C. (2013). Quasi-Experimental Study of Traffic Calming Measures in New York City. Transportation Research Record: Journal of the Transportation Research Board, 2364, 29-35.

Mountain, L. J., Hirst, W. M., & Maher, M. J. (2005). Are speed enforcement cameras more effective than other speed management measures?: The impact of speed management schemes on 30mph roads. Accident Analysis & Prevention, 37(4), 742-754.

Schepers, J. P., Kroeze, P. A., Sweers, W., & Wüst, J. C. (2011). Road factors and bicycle–motor vehicle crashes at unsignalized priority intersections. Accident Analysis & Prevention, 43, 853-861.

Other references

Taylor, M. C., Lynam, D. C. & Baruya, A. (2000). The effects of drivers' speed on the frequency of road accidents. Transport Research Laboratory. TRL421. https://trid.trb.org/view.aspx?id=651648