



Speed Management Strategies; A Systematic Review

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▶ ABSTRACT

Objective: To systematically identify the various methods of speed management and their effects.

Methods: A systematic search was performed in Science Direct, Ovid Medline, Scopus, PubMed and ProQuest databases from April to June 2015. Hand searching and reference of selected articles were used to improve article identification. Articles published after 1990 which had reported on efficacy/effectiveness of speed management strategies were included. Data were extracted using pre-defined extraction table.

Results: Of the 803 retrieved articles, 22 articles were included in this review. Most of the included articles (63%) had before-after design and were done in European countries. Speed cameras, engineering schemes, intelligent speed adaption (ISA), speed limits and zones, vehicle activated sign and integrated strategies were the most common strategies reported in the literature. Various strategies had different effects on mean speed of the vehicles ranging from 1.6 to 10 km/h. Moreover, 8-65% and 11-71% reduction was reported in person injured accidents and fatal accidents, respectively as a result of employing various strategies.

Conclusion: Literature revealed positive effects of various speed management strategies. Using various strategies was mostly dependent on road characteristics, driver's attitude about the strategy as well as economic and technological capabilities of the country. Political support is considered as a main determinant in selecting speed management strategies.

Keywords: Speed management; Speed reduction; Effectiveness; Traffic.

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Introduction

One of the most important goals for the transportation professionals and policy makers is to prevent and reduce traffic crashes and their severity [1]. Worldwide, traffic accidents have a considerable

difference in the number of causalities [2-4]. As reported in WHO 2015 road safety status report, over 1.25 million people each year die on the world roads [3]. Speed has been declared as the most important determinant of road crashes [5,6]. It affects both the crash rate and injury severity [7]. Previous studies

have reported that lower speed variance is correlated with fewer crashes [8,9]. Also, it was declared that 1 km/h reduction in speed would lead to 3% and 4-5% decrease in accidents with injuries and risk of death in crashes, respectively [10]. So, speed management has been turned into a challenge for countries [11].

Speed management is not only about regulating the speed but also to plan and design appropriate road layout and networks to obtain the proper speed [12]. Various strategies were used for speed management including traditional methods such as advisory speed posting, speed limits and road design as well as modern methods such as intelligent speed adaptation, safety cameras, support via an active accelerator pedal and other strategies [1,2,13]. Studies have demonstrated substantial difference, in traffic accident rate reduction and speed changes, among various approaches [1,14]. It was reported by previous studies that various speed management strategies had an effect of -2.4 to -10 (mph) in mean speed and reduction in person injured accidents (PIAs) ranging from -9% to -58% [14-18]. Elvik (2013) revealed that reducing speed limits had a positive effect on reducing number of crashes [19]. As well as, Ayuso *et al.* concluded that the risk of accident increases with exceeding speed limits [20].

Various speed management strategies with different levels of effect have been used to control vehicles' speed and improve traffic safety. Identifying these methods as well as their effects and implementation characteristics could provide useful information to make decision about using the methods. The aim of this study was to systematically review the various speed management strategies and their effects.

Materials and Methods

Using a systematic method, this review was done by searching the keywords; speed management, speed reduction and combined through strategy, method, policy, plan and program. Literature search was done using Science Direct, Ovid Medline, Scopus, PubMed and ProQuest databases. Manual search of journals were done. Also references of the selected articles were reviewed to increase the chance of articles finding. The inclusion criteria were: publications in a peer reviewed journal, in English and with focus on speed management strategy and its effects. Articles which had measured the effect of speed management strategies on air pollution, driver's perception about speed management strategies as well as conference presentations and qualitative studies were excluded from the review.

Articles were first screened reviewing their titles in order to exclude non-relevant articles. Then the abstract and full texts of the retained articles were reviewed. Endnote X5 software was used for organizing, title and abstract reviewing and also identification of duplications. Extraction table was used to extract the data from the included articles.

Retrieved Content

Totally 793 articles were retrieved through electronic search. Duplicates were excluded and 10 extra articles were added by hand searching and checking the reference of references. Actually 22 articles were included in the study. The article retrieval diagram is reported in Figure 1.

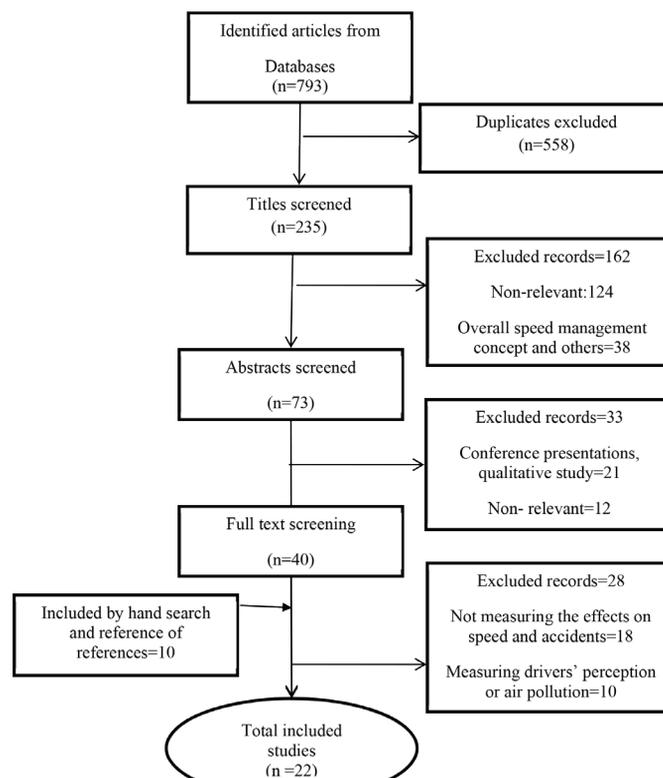


Fig. 1. Article review and retrieval diagram

Most of the included articles (63%) had before-after design and were done in European countries. Speed cameras, engineering schemes, intelligent speed adaptation (ISA), speed limits and zones, vehicle activated sign and integrated strategies were the speed management strategies reported by the literature. The results of included studies are presented in Table 1.

Speed Cameras

One of the most common speed management strategies was the use of speed cameras [14,21]. Studies had reported a reduction in person injured accidents (PIAs) after introduction of speed cameras ranging from 4% in London to 51% in South Wales, UK [15-18,22,23]. Novoa *et al.* had reported 30% and 26% reduction in risk of crashes and people injured in Barcelona, respectively [24]. Similarly, Carnis and Blais (2013) in an assessment of the French speed camera program, revealed reduction in fatal and non-fatal traffic injuries. They had reported 21% reduction in fatality rate per 100000 vehicles [25]. A four year evaluation of speed cameras effectiveness in London showed 5.3 miles/h reduction in average speed for fixed camera sites. This was 1.4 and 1 miles/h for mobile cameras in urban and rural roads, respectively [21].

Most of the studies had reported that speed cameras were effective intervention in reducing vehicles speed, the number of crashes and consequently, the number of traffic injuries or fatalities [21,22,26,27]. Regarding these confounding factors, follow up length had confounding effects on speed cameras' effectiveness measurement [21]. Moreover, type of used metrics and measurement circle range (distance from speed camera) affects effectiveness of the speed cameras [17,25]. Different study parameters had led to heterogeneity in literature and poor methodological rigor was seen in some speed cameras effectiveness studies [21]. Future studies must pay more attention to control the affecting factors.

Engineering Schemes

Engineering schemes or measures includes physically changing the layout of the road to reduce the vehicles speed [28]. Engineering schemes are in two major groups, schemes with vertical deflections and horizontal deflections. Mountain *et al.* (2005) revealed that schemes with vertical deflections had the most reduction in accidents compared with speed cameras and schemes with horizontal deflection. It was reported that vertical deflecting schemes had led to 44% and 35% reduction in PIAs and FSAs, respectively. Moreover, vertical and horizontal deflecting schemes had shown reduction of 8.4 and 3.3 mph in mean speed of vehicles [27]. Literature revealed that horizontal schemes were less effective than vertical ones, however their impact become synergistic when used in combination [14,27,29].

Intelligent Speed Adaptation (ISA)

Intelligent speed adaptation (ISA) refers to any system that did not allow the vehicle to exceed the safe or legally enforced speed. In a speeding situation, the vehicle speed is automatically reduced (active) or the driver could be alerted (passive) [30,31]. ISA helps the drivers to maintain a legal and safe speed along the driving time. Passive methods (such as beeps, buzzers, earcons and visual and auditory messages) had reported with a positive effect on drivers' speed limits compliance [32-36]. However, study results showed that young drivers were not satisfied by visual and auditory messages [33,37].

Studies reported significant decrease in vehicles speed using active ISAs such as active accelerator pedal (AAP) [13,38,39]. Moreover, drivers thought of AAP as a useful idea [40]. Emeli Adell *et al.* had reported about 4 km/h reduction in mean speed of the vehicles using AAP [13]. Also in Malaysia AAP had led to 1.6 km/h reduction in mean speed and in UK it was the reason of 10% reduction in PIA crashes [41]. Determining the effect of ISA on traffic accidents is difficult. Because the proportion of ISA equipped vehicles in studies were relatively small. Moreover, it is clear that the size of effects depends on ISA type [42].

Speed limits and Zones

Road speed limits are commonly used speed management method in most countries which are set by the legislative bodies and enforced by police. Speed limits are based on road characteristics and surroundings such as road surface, curvature, width and so on [43,44]. Pervious studies had reported that if the speed limit was not compatible with the road characteristics, drivers did not comply with it [45,46]. Jongen *et al.* had reported that setting a lower speed limit could be a useful method for speed reducing but the speed limit signs must repeat more frequently in the zone [43]. In a study by Grundy *et al.* (2009), it was revealed that introducing 32km/h speed limit had led to 41.9% reduction in road casualties [47]. Literature had proved the effect of reducing the speed on reducing crashes and injuries [5,48,49].

Vehicle Activated Sign

Vehicle activated signs (VAS) are a type of traffic signs mainly as speed limit advisory and hazard warning signs. The signs deployed on roadsides alert the drivers about speed limit and danger situations [50-52].

Pervious studies have reported a positive and significant effect of the activated signs on drivers speeding behavior and traffic safety [53]. Winnett MA *et al.* study results illustrated 2.6-7.1% reduction in mean speed of vehicles and 31% decrease in PIAs [54]. In a review by Nygårdhs reduction in mean speed and accidents was reported [55]. However, Tay *et al.* had reported that introducing the activated signs in an inter-city highway, had increased the

Table 1. Exraction table of included studies

N	Author	Date	Country	Study design	Speed management method	Effects on		
						Speed	PIAs ^a	Accidents FSAs ^b
1	L.J. Mountain <i>et al.</i> [27]	2005	UK	Before-after	Safety cameras Engineering schemes incorporating vertical deflections Engineering schemes incorporating horizontal deflections	-4.1(mph) -8.4(mph) -3.3(mph)	-22% -44% -29%	-11% -35% -14%
2	Rinusjaarsma <i>et al.</i> [2]	2011	Netherlands	Controlled study	“low cost designs” in 60 km/h speed limit roads	-	-24%	-27%
3	Md. Tazul Islam <i>et al.</i> [57]	2013	Canada	Controlled experimental study	Integrated speed management strategy (education, enforcement activities, low cost engineering treatment)	-2.94 km/h (5.8%) and -2.26 km/h (4.5%) for the short term and long term, respectively		
4	A. Marinez, D.A. Mantaras, P. Luque [61]	2013	Spain	before-after experimental design	low-cost solutions (Correcting the speed limit, Transversal white lines, Reflecting “cat’s eye” road studs, Linear delineation system for the crash barrier, Reflecting barrier studs, High visibility panels)	7.1% in the average speed and -7.6% in the 85th percentile of the speed immediately after the experiment. ● 6 months after the experiment, the total speed reduction was 31.2% for the average speed and 32.6% for the 85th percentile of the speed.	--	- 25% just after the experiment and -78% 6 months after the experiment
5	Emeli Adell <i>et al.</i> [13]	2008	Spain, Hungary	Field experiment before/during/ after study	ISA (intelligent speed adaptation) (Support via an active accelerator pedal (AAP)and (2) warning via beep signals and a flashing red light when the speed limit was exceeded (BEEP).)	● For 30 km/h streets (2.8 and 3.9 km/h reduction in mean speed) ● 50 km/h streets (Spain)(decreased by between 1.5 and 2.6 km/h) ● 50 km/h streets (Hungary) .7 and 1.1 km/h reduction.	--	---
6	Ahmad Khashairy Makhtar [39]	2012	Malaysia	before-after experimental design	Intelligent Speed Adaptation (ISA)	-1.6 km/h average speed of participants	----	----
7	Andras Varhelyi [41]	2002	Swedes-UK	experimental	In-car devices (in-car feed-back, in-car information, in-car speed supervisor, “intelligent” gas pedal)	----		-10 % with an advisory system -20–40 % with a system that enforces current speed limits
8	Kurt Ron Smith [62]	2011	US	before-after	Various strategies (Speed limits, enforcement, speed enforcement by automation, speed control strategies without enforcement, traffic calming strategies for speed control)	Approximately 55% (106 sites) of the locations assessed had a statistically significant reduction in mean speeds during 2006-2010	---	--
9	Lene Herrstedt [63]	1992	Denmark	An extensive effect evaluation study	Traffic management method called “Environmentally adapted through road.”	8 to 10 km/h reduction in mean speed of the vehicles	--	--
10	Rune Elvik [49]	2001	Meta-analysis	Meta-analysis	Urban traffic calming schemes	----		-15%

	R. Ando [64]	2014	Japan	Experimental-simulator	Intelligent Speed Adaptation (ISA)	
11	R. Ando [64]	2014	Japan	Experimental-simulator	Intelligent Speed Adaptation (ISA)	-----
12	Ellen De Pauw et al. [22]	2013	Belgium	Before-After evaluation	Fixed speed cameras	-8% -29%
13	Chris Grundy [47]	2009	UK	Observational study	20 mph (32 km an hour) traffic speed zones	----- -41.9%
14	Paul Pilkington [23]	2005	--	Systematic review	Speed cameras	12% to 65% reduction -17% to -71%
15	L.J Mountain et al. [16]	2004	UK	Before-After	Speed cameras	-4.4 -26% -34%
16	West London report [65]	1997	UK	Before-After	Speed cameras	-8.1% -55.7%
17	Stephane Hess [66]	2004	UK		Speed limit enforcement cameras (SLECs)	-45.74% in the immediate vicinity of the camera sites -
18	Rune Elvik [18]		Norway	before-and-after study	Automatic speed enforcement by means of photo radar	-20% -
19	Richard Allsop [21]	2010	--	review	Speed Cameras	Fixed urban sites= 29% Fixed rural sites= 15% Mobile urban sites= 7% Mobile rural sites= 4% Fixed urban sites= 41% Fixed rural sites= 22% Mobile urban sites= 10% Mobile rural sites= 6%
20	Adrian Gains et al. [67]	2005	UK	Before-fter	Speed and red-light cameras (safety cameras)	6% reduction, -2.3mph in average speed -22% -42_
21	M.A Winnett [54]	2002	UK	Before-After with control	Vehicle-activated signing (Speed limit roundel (just inside the speed limit terminal signs) - mainly village sites. Bend warning. Junction warning. Safety camera repeater sign (displaying camera logo).)	-4mph in mean speed (reduction in the mean speed of between 2.6 and 7.1mph) -31%
22	S M Christie et al. [17]	2003	UK	Controlled before and after study	Mobile speed cameras	-51% -

^aPerson Injured Accidents (PIAs); ^bfatal and serious accidents (FSAs)

likelihood of speed limit obedience in a small group of the drivers [56].

Integrated Strategies

Introducing speed management integrated strategies in roads would benefit the advantage of each strategy. Islam *et al.* had implemented an integrated speed management plan including educational activities, dynamic message sign as well as enforcement and low cost engineering schemes. They had reported 5.8% and 4.5% reduction in mean speed, in short term and long term, respectively [57]. However, some studies had illustrated differing and time contradictory results for effectiveness of delineation methods combination [58,59]. Yannis *et al.* had concluded that an integrated speed management plan, to be effective and successful, depends not only on systematic monitoring of plan implementation and road safety but also needs strong political support of the local governments [60].

Conclusion

Most of the studies had reported positive effects of various speed management strategies on drivers speeding behavior and road safety. Selecting an appropriate speed management strategy depends directly not only on the road characteristics but

also on the political support and community capacity (such as economical, technological, information management power, road safety related organizations ability as well as drivers attitude) about the specific strategy. Retrieved studies showed that developed countries had good experiences of speed management as a national and international priority. Their experiences illustrated that as a controversial issue, speed management needs political support as a driver of the strategies. This issue has more importance in developing countries. Considering variety of factors potentially affecting the effectiveness of speed management strategies, it is highly recommended to conduct national and regional studies on speed management in low and middle income countries. Moreover, developing and implementing a speed management strategy must be based on speed and road safety data to be measurable. However, defining an appropriate combination of effectiveness measures must consider the local circumstances.

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References

1. Kweon Y-J, Oh C. Identifying promising highway segments for safety improvement through speed management. *Transportation Research Record: Journal of the Transportation Research Board*. 2011;(2213):46-52.
2. Jaarsma R, Louwse R, Dijkstra A, de Vries J, Spaas J-P. Making minor rural road networks safer: The effects of 60km/h-zones. *Accid Anal Prev*. 2011;43(4):1508-15.
3. Toroyan T. Global status report on road safety 2015. Supporting a decade of action. Geneva: World Health Organization, Department of Violence and Injury Prevention and Disability. 2013.
4. Aarts L, Van Schagen I. Driving speed and the risk of road crashes: A review. *Accid Anal Prev*. 2006;38(2):215-24.
5. Cascetta E, Punzo V, Montanino M. Empirical analysis of effects of automated section speed enforcement system on traffic flow at freeway bottlenecks. *Transportation Research Record: Journal of the Transportation Research Board*. 2011;2260:83-93.
6. Mohan D. Road traffic injury prevention training manual: World Health Organization; 2006.
7. Elvik R, Vaa T, Erke A, Sorensen M. The handbook of road safety measures: Emerald Group Publishing; 2009.
8. Warner HW, Åberg L. Drivers' beliefs about exceeding the speed limits. *Transportation Research Part F: Traffic Psychology and Behaviour*. 2008;11(5):376-89.
9. Ghadiri S, Prasertijo J, Sadullah A, Hoseinpour M, Sahranavard S. Intelligent speed adaptation: Preliminary results of on-road study in Penang, Malaysia. *IATSS research*. 2013;36(2):106-14.
10. Kanitpong K, Jiwattanakupaisarn P, Yaktawong W. Speed management strategies and drivers' attitudes in Thailand. *IATSS research*. 2013;37(1):39-48.
11. Greibe P, Nilsson PK, Herrstedt L. Speed Management in Urban Areas: A framework for the planning and evaluation proces. The Danish Road Directorate, Traffic Safety and Environment Division; 1999.
12. Adell E, Vårhelyi A, Hjälm Dahl M. Auditory and haptic systems for in-car speed management—A comparative real life study. *Transportation research part F: traffic psychology and behaviour*. 2008;11(6):445-58.
13. Hirst WM, Mountain LJ, Maher MJ. Are speed enforcement cameras more effective than other speed management measures? An evaluation of the relationship between speed and accident reductions. *Accid Anal Prev*. 2005;37(4):731-41.
14. Gains A, Heydecker B, Shrewsbury J, Robertson S. The national safety camera programme: Three-year evaluation report. 2004.
15. Mountain LJ, Hirst WM, Maher MJ. Costing lives or saving lives: a detailed evaluation of the impact of speed cameras. *Traffic, Engineering and Control*. 2004;45(8):280-7.
16. Christie S M, Lyons R A, Dunstan F D, Jones S J. Are mobile speed cameras effective? A controlled before and after study. *Inj Prev*. 2003;9(4):302-6.
17. Elvik R. Effects on accidents of automatic speed enforcement in Norway. *Transportation Research Record: Journal of the Transportation Research Board*. 1997;(1595):14-9.
18. Elvik R. A re-parameterisation of the Power Model of the relationship between the speed of traffic and the number of accidents and accident victims. *Accid Anal Prev*.

- 2013;**50**:854-60.
19. Ayuso M, Guillén M, Pérez-Marín AM. Time and distance to first accident and driving patterns of young drivers with pay-as-you-drive insurance. *Accid Anal Prev*. 2014;**73**:125-31.
 20. Allsop R. The effectiveness of speed cameras: a review of evidence. London: Royal Automobile Club Foundation for Motoring; 2010.
 21. De Pauw E, Daniels S, Brijs T, Hermans E, Wets G. An evaluation of the traffic safety effect of fixed speed cameras. *Safety science*. 2014;**62**:168-74.
 22. Pilkington P, Kinra S. Effectiveness of speed cameras in preventing road traffic collisions and related casualties: systematic review. *BMJ*. 2005;**330**(7487):331-4.
 23. Novoa AM, Perez K, Santamarina-Rubio E, Mari-Dell'Olmo M, Tobias A. Effectiveness of speed enforcement through fixed speed cameras: a time series study. *Inj Prev*. 2010;**16**(1):12-6.
 24. Carnis L, Blais E. An assessment of the safety effects of the French speed camera program. *Accid Anal Prev*. 2013;**51**:301-9.
 25. Perez K, Mari-Dell'Olmo M, Tobias A, Borrell C. Reducing road traffic injuries: effectiveness of speed cameras in an urban setting. *Am J Public Health*. 2007;**97**(9):1632-7.
 26. Mountain LJ, Hirst WM, Maher MJ. Are speed enforcement cameras more effective than other speed management measures? The impact of speed management schemes on 30 mph roads. *Accid Anal Prev*. 2005;**37**(4):742-54.
 27. Bellefleur O, Gagnon F. Urban Traffic Calming and Health. Literature Review. Quebec, Canada: National Collaborating Centre for Healthy Public Policy; 2011.
 28. Harvey T. A review of current traffic calming techniques. Leeds, UK: Institute for Transport Studies, University of Leeds; 1992.
 29. Broekx S, Vlassenroot S, De Mol J, Int Panis L. The European PROSPER-project: Final results of the trial on Intelligent Speed Adaptation (ISA) in Belgium. 2006.
 30. In: Wikipedia. Intelligent speed adaptation, 2015 [cited 20.11.2015]. Available from: https://en.wikipedia.org/wiki/Intelligent_speed_adaptation.
 31. Lahrman H, Madsen J, Boroch T, editors. Intelligent Speed Adaptation: development of GPS based System and Field operational test of the System with 24 test Drivers. Proceedings of the 8th World Congress on Intelligent Transport Systems, Sidney, Australia; 2001.
 32. Brookhuis K, de Waard D. Limiting speed, towards an intelligent speed adapter (ISA). *Transportation Research Part F: Traffic Psychology and Behaviour*. 1999;**2**(2):81-90.
 33. Stephan K, Young K, Newstead S, Lenné M, Cavallo A, Duck N, et al., editors. The effectiveness of an advisory Intelligent Speed Adaptation (ISA) system for Victorian repeat speeders. 2014 Australasian Road Safety Research, Policing & Education Conference (Transport Accident Commission); 2014: Australasian College of Road Safety.
 34. Lai F, Carsten O. What benefit does Intelligent Speed Adaptation deliver: a close examination of its effect on vehicle speeds. *Accid Anal Prev*. 2012;**48**:4-9.
 35. Van der Pas J, Kessels J, Vlassenroot S, van Wee B. The pros and cons of Intelligent Speed Adaptation as a restrictive measure for serious speed offenders. *Transportation Research Part A: Policy and Practice*. 2014;**67**:158-74.
 36. de Waard D, van der Hulst M, Brookhuis KA. Elderly and young driver's reaction to an in-car enforcement and tutoring system. *Appl Ergon*. 1999;**30**(2):147-57.
 37. Várhelyi A, Hjalmdahl M, Hyden C, Draskoczy M. Effects of an active accelerator pedal on driver behaviour and traffic safety after long-term use in urban areas. *Accid Anal Prev*. 2004;**36**(5):729-37.
 38. Makhtar AK, Ismail MS, Patar MNAA. A study on the effect of intelligent speed adaptation to bus drivers. *Procedia engineering*. 2012;**41**:1426-31.
 39. Adell E, Várhelyi A. Drivers' acceptance of the Active Accelerator Pedal. *Transportation Research Part F: Traffic Psychology and Behaviour*. 2008;**11**(1):37-51.
 40. Várhelyi A. Speed management via in-car devices: effects, implications, perspectives. *Transportation*. 2002;**29**(3):237-52.
 41. In: SWOV Institute for Road Safety Research. SWOV Fact sheet: Intelligent Speed Assistance (ISA). The Netherlands: SWOV, Leidschendam; 2015. Available from: http://www.swov.nl/rapport/Factsheets/UK/FS_ISA_UK.pdf.
 42. Jongen EM, Brijs K, Mollu K, Brijs T, Wets G. 70 km/h speed limits on former 90 km/h roads: effects of sign repetition and distraction on speed. *Hum Factors*. 2011;**53**(6):771-85.
 43. Edquist J, Rudin-Brown C, Lenne MG. Road design factors and their interactions with speed and speed limits. Monash University Accident Research Centre. 2009:30.
 44. Van Nes N, Houtenbos M, Van Schagen I. Improving speed behaviour: the potential of in-car speed assistance and speed limit credibility. *Intelligent Transport Systems, IET*. 2008;**2**(4):323-30.
 45. Van Schagen IN LG, Wegman FC M, Roszbach R. Safe and credible speed limits: A strategical exploration (R 2004-12). The Netherlands: SWOV Institute for Road Safety Research, Leidschendam; 2004.
 46. Grundy C, Steinbach R, Edwards P, Green J, Armstrong B, Wilkinson P. Effect of 20 mph traffic speed zones on road injuries in London, 1986-2006: controlled interrupted time series analysis. *BMJ*. 2009;**339**:b4469.
 47. Bunn F, Collier T, Frost C, Ker K, Roberts I, Wentz R. Area-wide traffic calming for preventing traffic related injuries. *Cochrane Database Syst Rev*. 2003;(1):CD003110.
 48. Elvik R. Area-wide urban traffic calming schemes: a meta-analysis of safety effects. *Accid Anal Prev*. 2001;**33**(3):327-36.
 49. Jomaa D, Dougherty M, Yella S, Edvardsson K. Effectiveness of trigger speed of vehicle-activated signs on mean and standard deviation of speed. *Journal of Transportation Safety & Security*. 2016:1-17.
 50. Makwasha T, Turner B, editors. Evaluating vehicle activated signs on rural roads. ARRB Conference, 26th, 2014, Sydney, New South Wales, Australia; 2014.
 51. In: Wikipedia. Vehicle-activated sign, 2015 [cited 2015]. Available from: https://en.wikipedia.org/wiki/Vehicle-activated_sign.
 52. Davoodi SR, Hossayni SM. Role of Motorcycle Running Lights in Reducing Motorcycle Crashes during Daytime; A Review of the Current Literature. *Bull Emerg Trauma*. 2015;**3**(3):73-78.
 53. Winnett M, Wheeler A. Vehicle-activated signs: a large scale evaluation. Road Safety Division, Department for Transport; 2002.
 54. Nygårdhs S. Literature review on variable message signs (VMS) 2006-2009. Linköping; 2011.
 55. Richard T, De Barros A. Effectiveness of Road Safety Messages on Variable Message Signs. *Journal of Transportation Systems Engineering and Information Technology*. 2010;**10**(3):18-23.
 56. Islam MT, El-Basyouny K. An integrated speed management plan

- to reduce vehicle speeds in residential areas: implementation and evaluation of the Silverberry Action Plan. *J Safety Res.* 2013;**45**:85-93.
57. Bahar GB. Safety evaluation of permanent raised pavement markers: Transportation Research Board; 2004.
58. Donnell ET, Gemar MD, Cruzado I. Operational effects of wide edge lines applied to horizontal curves on two-lane rural highways. 2006.
59. Yannis G, Mavromatis S, Laiou A. Integrated speed management strategies in local communities in south east Europe. 10th International Conference on Road Safety In Local Community; Serbia, Kragujevac, Hotel Kragujevac; 2015.
60. Matirnez A, Mántaras D, Luque P. Reducing posted speed and perceptual countermeasures to improve safety in road stretches with a high concentration of accidents. *Safety science.* 2013;**60**:160-8.
61. Smith KR. Using Four-Year Speed Inventories to Measure the Impact of Urban Speed Management Programs in Washington, DC: Howard University; 2011.
62. Herrstedt L. Traffic calming design--a speed management method. Danish experiences on environmentally adapted through roads. *Accid Anal Prev.* 1992;**24**(1):3-16.
63. Ando R, Ono T, Obayashi F, Mimura Y, Kozuka K, Ozawa S. Effect Analysis of Intelligent Speed Adaptation (ISA) in Advisory Mode on Community Roads. *Procedia Computer Science.* 2014;**32**:277-84.
64. West London speed camera demonstration project. London: Department for Transport; 1997. p. 1-47.
65. Hess S. Analysis of the effects of speed limit enforcement cameras: Differentiation by road type and catchment area. *Transportation Research Record: Journal of the Transportation Research Board.* 2004;(1865):28-34.
66. Gains A, Nordstrom M, Heydecker BG, Shrewsbury J. The national safety camera programme: Four-year evaluation report. London: PA Consulting Group; 2005.