High risk sites treatment

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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.

SUMMARY

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1.1 COLOUR CODE: LIGHT GREEN

On the basis of both study and effect numbers, it can be seen that high risk site treatment measures have a positive effect on road safety. In a minority of cases its impact is unverified or has an isolated negative effect. The coded studies include two meta-analyses, which encompass the findings of several other studies. All of the studies examined have good levels of quality, and are generally consistent in their results. The overall benefits of these measures are not negated and should thus be considered accordingly.

1.2 KEYWORDS

High risk sites; blackspot treatment; network deficiencies

1.3 ABSTRACT

High risk site treatment measures are screening processes, commonly implemented to highlight problematic locations in a road or road network, for further consideration and examination by road safety experts. They enable secondary measures to be determined and applied, and hence improve road safety as a result of their targeted nature. Four high quality studies were coded, including two meta-analyses. The two meta-analyses encompass several effects, and show statistically significant reductions in injury crashes of 28% and 24% to 27%. On the basis of both study and effect numbers, it is evident that high risk site treatment has a positive impact on road safety by reducing crash and injury numbers. The results seem generally transferable with caution.

1.4 BACKGROUND

1.4.1 Definition of high risk site treatment

Road systems are complex environments that serve several simultaneous functions. The aim is to provide road users with safe and accessible facilities for transportation. Nevertheless, crashes do occur, and can often follow patterns and accumulate at specific spots. These spots are frequently termed 'hotspots' or 'blackspots', and are high risk sites that show a disproportionate increase in the number of crashes or other safety-critical events when compared to the rest of the network. Accordingly, several screening processes for the identification of high risk sites have been devised and implemented.

These processes range from simplistic (e.g. crash number comparison) to more complex (crash rate ranking) and sophisticated (statistical distribution modelling such as Poisson distribution or simulation applications). They are conducted by road safety experts for a specific network, either proactively or reactively. Sometimes their undertaking is warranted by the observation of safety problems in specific locations, or for quality control purposes. High risk sites are determined as the end objective, which enables decision making on the quantity and quality of road safety interventions in the form of measures.

1.4.2 How does high risk site treatment affect road safety?

High risk site treatment is the process by which problematic area are highlighted with regard to road safety. This process aids decision making: the implementation of measures follows the information derived as a result of identifying high risk sites.

The measures can be wide-ranging, as different sites typically require different solutions (e.g. signage installation, alignment changes, lighting improvement). Hence, it can be anticipated that conducting high risk site investigation will highlight road safety problems and increase road safety levels.

1.4.3 How is the effect of high risk site treatment studied?

High risk site treatment is sparsely examined in the international literature, primarily because it is used as a preliminary stage for the implementation of secondary measures. Typically, road safety level changes are treated as originating from the secondary measures and are attributed to them. However, there are cases where high risk site treatment is examined as a primary measure.

When a study takes the latter approach, a common practice is to identify a road section or network as a study area. In such cases, before-after measure application approaches are implemented, to capture the effect of high risk site treatment in influencing road safety levels. Benefits are estimated using crash numbers or crash rates, which offer direct insights into road safety levels.

1.5 OVERVIEW OF RESULTS

The effects of high risk site treatment on road safety tend to be positive overall. All examined studies show considerable reductions in crash numbers, while one study also shows a reduction in the number of injured road users.

The two meta-analyses encompass several effects, and show statistically significant reductions in injury crashes of 28% and 24% to 27%.

The crash types examined encompass all crash types and solely injury crashes, so uniform crash reduction effects can be assumed. These results are expected and intuitive, since the measures are usually considered after under case-by-case examination and tailored for every high risk site.

Transferability

Coded studies are based on data from Australia, Belgium, France and Norway. Two of the studies are meta-analyses, encompassing additional countries (Canada, Denmark, New Zealand, United Kingdom) in their. While this is a good sample of developed countries, there is scope for representation of other areas of the globe, and a respective gap in knowledge, particularly for less motorized regions. Most studies conducted a uniform examination of all crash types and road users. One meta-analysis separated studies by injury severity, while another considered different road types (urban vs. rural). In conclusion, there appears to be scope for a greater variety of approaches.

1.6 NOTES ON ANALYSIS METHODS

While the methods for capturing the impact of high risk site treatment are similar (before-after measure application approaches), the outputs are interpreted in differing ways. Sometimes, raw crash numbers or descriptive statistics are provided, whilst other studies

use significance testing to determine the level of statistical significance of each parameter. No considerable potential biases were identified in the before-after studies examined. In one case, several measures are investigated together (labelled as hotspot treatment): intersections treatments or replacements, speed calming, parallel service roads and others. This leads to an unclear outcome for the effectiveness of the measure. There is scope for investigating different road user categories and/or other geographical regions. The aforementioned factors make the findings for high risk site treatment transferable with caution.

Scientific overview

2.1 ANALYSIS OF STUDY DESIGNS AND METHODS

After appropriate use of search tools and databases, four (4) high quality studies were selected and coded for the measures of high risk site treatment. The primary parameter investigated was crash numbers, either collectively as in Meuleners et al. (2008) and Moisan et al. (2014) or via injury crash numbers, as in Elvik (2016). Similarly, the number of injured road users was examined in conjunction with CMFs (De Pauw et al., 2014).

The number of crashes and injured users provides a very direct method for investigating effects on road safety. Whilst this is direct and comprehensible it is also fairly simplistic, and often ignores network particularities best captured via crash rates (e.g. taking into account vehicle-kilometers). However, the data would be more complex in nature and harder to work with.

To examine the relationship between the effects of high risk site treatment, the studies utilised either significance testing (e.g. confidence interval calculation or standard error provision) or conducted basic descriptive statistical analysis as a minimum.

It should be noted that studies relevant to this topic are particularly scarce in the literature, and there is a significant knowledge gap in this area. It is noteworthy that many of the studies consider road safety improvements as the consequence of implementing specific measures (i.e. as a result of high risk site treatment), not the beneficial impact of the screening processes themselves. The screening processes are often mentioned as an introductory process.

Whilst the interpretation of this interrelation depends primarily on the view of the researcher, there is value in summarizing the direct numerical impacts of high risk site treatment for the benefit of road safety researchers and stakeholders.

2.2 LITERATURE REVIEW

All reviewed studies reported crash reductions after implementing high risk site treatment procedures, both overall and at a macroscopic level. For all results from Moisan et al. (2014) and for some descriptive statistics from De Pauw et al. (2014) no statistical significance testing was conducted or presented, and thus the findings are interpreted with caution.

As previously stated, in several cases high risk site treatment proved to be highly effective at reducing the number of crashes and injured road users. De Pauw et al. (2014) found an isolated case of a small increase in the number of injured road users, but the respective study clearly reports overall positive effects for high risk site treatment with meta-analysing techniques. The study reports a statistically significant decrease in injurious crashes of 24 to 27%.

Additionally, the CMF calculated by this study ranges from 0.430 to 0.760, again indicating considerable crash reductions. It should be noted that the other meta-analysis included (Elvik, 2016) reports similar reductions for injurious crash numbers of 28%. The other two studies report a reduction in overall crash percentages (15%) or absolute numbers

(reduction from 16 crashes to no crashes after implementing high risk site treatment (Meuleners et al., 2008 and Moisan et al., 2014. These results are statistically significant importance and support the overall conclusions.

The overall positive results are intuitive considering the nature of the measure. Road safety environments are complex and dynamic: specialized, dedicated processes are required to locate potential problematic areas and determine their nature. Consequently, when such blackspots are identified and treated with measures that target their shortcomings, road safety levels increase.

An overview of the main features of the coded studies (sample, method, outcome and results) is presented in Table 1.

Number	Author(s); Year; Country;	Sampling frame for risk site treatment studies	Method for risk site treatment impact investigation	Outcome indicator	Main Result
1	Elvik, R.; 2016; Norway	Existing literature review and meta-analysis of relevant studies.	Literature review and meta-analysis on the effect of treatment of high-risk sites or road sections on accidents.	Injury accident numbers [Absolute difference]	Improvement of high-risk sites and sections reduce the number of injury accidents by 28 %. The effect is somewhat larger for high-risk sites than for high-risk road sections.
2	De Pauw, E., Daniels, S., Brims, T., Hermans, E., & Wets, G; 2014; Belgium	A black spot programme with 800 black spots, from which 134 locations, redesigned between 2004 and 2007, were included.	Empirical Bayes before-and after study that accounts for effects of general trends and for the stochastic nature of crashes, including regression to the mean	Crash numbers [CMF] & Injured road users [Relative difference]	The analyses showed a decrease in the number of injury crashes of 24–27%, significant at the 1%-level.
3	Meuleners, L. B., Hendrie, D., Lee, A. H., & Legge, M.; 2008; Australia	This study evaluates the effectiveness of the Black Spot Programs in Western Australia.	Poisson regression based on generalized estimating equations for before-and-after comparison of crashes.	Crash numbers [Percentage difference]	The results showed that the programs have been effective overall, reducing all reported crash rates by 15%.
4	Moisan, O., Subirats, P., Bisson, O., Cheinisse, D., Chauvin, P., & Violette, E.; 2014; France	The Yvetot – La Mailleraye development project monitoring process. A multidisciplinary method was devised in order to trial safer projects that include road safety considerations at the design stage.	Crash comparison	Crash numbers [Absolute difference]	Accidents were found to be reduced to zero from the implementation of various improvements in high risk sites.

Table 1: Description of coded studies

A few limitations can be arguably found in the current literature for the effects of high risk site treatment on road safety. Firstly, there are very few studies: this appears to be an under-researched topic. This shortcoming may indicate that there is a lack of interest in implementing the measures, or in devising new methods to monitor their benefits, despite the clearly significant results presented in this synopsis. Research findings often demonstrate that the exact measures in a case-by-case approach are considered to be direct causes for road safety improvements, rather than the initiative of high risk location screening (to identify high risk areas and the corresponding measures).

Secondly, all included studies originate from developed and highly motorized countries, known to possess and apply high road design standards. Hence, this sample is not particularly representative of the worldwide impact of high risk site treatment measures (similar to road safety audits and inspections) and as such any results and conclusions drawn from this synopsis are transferrable with caution.

2.3 RESULTS FOR HIGH RISK SITES TREATMENT

The effects of high risk sites treatment can be summarized as follows:

- 3 studies with a significant decrease in road crashes, 1 of which reports a significant decrease in injured road users
- 1 study with an unverified decrease in road crashes

Table 2 is included in the supporting document, and presents the quantitative results of the coded studies together with their general effects on road safety.

After collectively reviewing the results, the following points were observed:

a) There is an adequate number of studies. However,
b) The studies have used different methods for analysis.
c) There are similar indicators but at times expressed differently
d) The sampling frames were different, and there was a lack of statistical verification
e) Two meta-analyses are already included in the studies examined

2.4 DESCRIPTION OF ANALYSIS CARRIED OUT

2.4.1 Review type analysis

After considering the previous points, it was decided that a meta-analysis should not be carried out. Review type analysis was selected. The effect of the high risk site treatment measures is given via qualitative analysis.

The findings show that the positive effects of high risk site treatment measures are: injury crash reductions apply across all segment types, both to road isolated sites and road sections. Similarly, the Crash Modification Factors (CMF) are positive when examining injury crashes or severe injury only crashes. The number of injured road users appears to be reduced uniformly for all road user groups, with one exception: a very small increase in the number of injured cyclists for a control group (blackspots treated later than the main test area). This can be attributed to study particularities. Furthermore, crash percentage numbers were found to be reduced for both urban and rural areas after implementing high risk site treatment measures, once again indicating their effectiveness.

2.4.2 Overall estimate for road safety

On the basis of both study and effect numbers, it can be argued that high risk site treatment measures have a positive effect on road safety. In a minority of cases its impact is unverified, or shows an isolated negative effect. The particular coded studies include two meta-analyses that encompass the benefit of several other studies. All studies have good levels of quality, and are generally consistent in their results. The overall benefits of these measures are not negated and should thus be considered accordingly. Results consistently show that the examined measure reduces road safety risk. This leads to the assignment of the light green colour code for high risk site treatment.

2.5 CONCLUSION

The review-type qualitative analysis carried out showed that high risk site treatment has a positive impact on road safety, reducing the number of crashes and the number of injured road users.

Supporting document

3.1 SUPPORTING QUANTITATIVE TABLE

Table 2 is shown below, and includes all quantitative effects from the coded studies for the measures of high risk site treatment.

Number	Author(s); Year; Country	Measure Exposure	Outcome indicator	Quantitative Estimate	Effect on road safety
1	Elvik, R.; 2016; Norway	High risk site treatment [meta-analysis]	Injury crash numbers [Relative difference]	Treatment of high risk sites/sections: Percent accident change = -28%, CI [95%] = (-32%, -23%)	↑
				Treatment of high risk road sections: Percent accident change = -27%, CI [95%] = (-36%, -16%)	↑
				Treatment of high risk sites: Percent accident change = -31%, CI [95%] = (-39%, -23%)	↑
2	De Pauw, E., Daniels, S., Brijs, T., Hermans, E., & Wets, G; 2014; Belgium	High risk site treatment [meta-analysis]	Crash numbers [CMF]	Injury Accidents Group 1 (black spots treated after 2008): CMF = 0.760, p=0.010 CI [99%] = (0.660, 0.870)	↑
				Severe Injury Accidents Group 1 (black spots treated after 2008): CMF = 0.540, p=0.010 CI [99%] = (0.360, 0.810)	↑
				Injury Accidents Group 2 (all injury crashes in Flanders): CMF = 0.730, p=0.010 CI [99%] = (0.640, 0.840)	↑
				Severe Injury Accidents Group 2 (all injury crashes in Flanders): CMF = 0.430, p=0.010 CI [99%] = (0.280, 0.640)	↑
			Injured road users [Relative difference]	Injury Accidents Group 2 (all injury crashes in Flanders): CMF = 0.730, p=0.010 CI [99%] = (0.640, 0.840)	↑*
				All Accidents - Car occupants: Group 2 (all injury crashes in Flanders): Percentile difference of injured users = -50.90 %	↑*
				All Accidents - Car occupants: Group 1 (black spots treated after 2008): Percentile difference of injured users = -18.55 %	↑*
				All Accidents - Moped riders: Group 2 (all injury crashes in Flanders): Percentile difference of injured users = -36.43 %	↑*
				All Accidents - Moped riders: Group 1 (black spots treated after 2008): Percentile difference of injured users = -26.71 %	↑*
				All Accidents - Cyclists: Group 2 (all injury crashes in Flanders): Percentile difference of injured users = -29.59 %	↑*
				All Accidents - Cyclists: Group 1 (black spots treated after 2008): Percentile difference of injured users = 2.16 %	↓*
				All Accidents - Motorcyclists: Group 2 (all injury crashes in Flanders): Percentile difference of injured users = -39.55 %	↑*
				All Accidents - Motorcyclists: Group 1 (black spots treated after 2008):	↑*

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Number	Author(s); Year; Country	Measure Exposure	Outcome indicator	Quantitative Estimate	Effect on road safety
				Percentile difference of injured users = -10.64 %	
				All Accidents - Pedestrians: Group 2 (all injury crashes in Flanders): Percentile difference of injured users = -27.20 %	↑*
				All Accidents - Pedestrians: Group 1 (black spots treated after 2008): Percentile difference of injured users = -18.44 %	↑*
				All Accidents - Truck drivers: Group 2 (all injury crashes in Flanders): Percentile difference of injured users = -77.63 %	↑*
				All Accidents - Truck drivers: Group 1 (black spots treated after 2008): Percentile difference of injured users = -21.33 %	↑*
3	Meuleners, L. B., Hendrie, D., Lee, A. H., & Legge, M.; 2008; Australia	High risk site treatment	Crash numbers [Percentage difference]	All roads - Whole program: Percent accident change = -14.60%, s.e.=0.0170, p = 0.0010	↑
				Urban roads - Whole program: Percent accident change = -15.70%, s.e.=0.0210, p = 0.0010	↑
				Rural roads - Whole program: Percent accident change = -13.60%, s.e.=0.0310, p = 0.0010	↑
				All roads - Intersection treatments: Percent accident change = -16.30%, s.e.=0.0200, p = 0.0010	↑
				Urban roads - Intersection treatments: Percent accident change = -15.90%, s.e.=0.0220, p = 0.0010	↑
				Rural roads - Intersection treatments: Percent accident change = -18.20%, s.e.=0.0510, p = 0.0010	↑
				All roads - Road section and non-intersection treatments: Percent accident change = -9.90%, s.e.=0.0380, p = 0.0060	↑
				Urban roads - Road section and non-intersection treatments: Percent accident change = -10.00%, s.e.=0.1140, p = 0.3560	-
				Rural roads - Road section and non-intersection treatments: Percent accident change = -11.10%, s.e.=0.0360, p = 0.0010	↑
4	Moisan, O., Subirats, P., Bisson, O., Cheinisse, D., Chauvin, P., & Violette, E.; 2014; France	High risk site treatment	Crash numbers [Percentage difference]	Absolute accident change = - 16	↑
↑	denotes positive road safety effects		-	denotes unclear or marginal road safety effects	
↓	denotes negative road safety effects		* denotes that no statistical analysis was conducted for the significance of the effects		

Table 2: Quantitative results of coded studies and impacts on road safety.

3.2 METHODOLOGY

Literature search strategy

The literature search undertaken was for the two measures of high risk site treatment, as was examined in this synopsis. The results are summarized in the relevant tables. To locate all relevant scientific publications, several databases were searched. As with the standards specified for the SafetyCube project, journal or conference papers published after 1990 were prioritized ahead of reports.

Identifying relevant studies for high risk site treatment

Database: Scopus **Date:** 20th of December 2016

search no.	search terms / operators / combined queries	hits
#1	"road" AND "safety"	
#2	AND ("risk site" OR "risk location" OR "hotspot" OR "blackspot")	473
#3	AND ("identification" OR "location")	452
	All years	462

Database: TRID (trid.trb.org) **Date:** 20th of December 2016

search no.	search terms / operators / combined queries	hits
#1	Risk site OR hot spot OR black spot identification effect	13
	All years	18

Database: Science Direct **Date:** 20th of December 2016

search no.	search terms / operators / combined queries	hits
#1	"road" AND "safety" AND " risk site*" OR "hotspot" OR "blackspot"	39370
#2	AND "identification" AND "effect"; Filter: safety	278

Limitations/ Exclusions:

- Search field: TITLE-ABS-KEY
- Published: 1990 to current
- Document Type: "Review" and "Article"
- Language: "English"
- Source Type: "Journal"
- Only Transport Journals were considered
- Subject Area: "Engineering"

Results of Literature Search

Database	Hits
Scopus (remaining papers after several limitations/exclusions)	462
TRID	18
Science Direct	278
Total number of studies to screen title/abstract	758

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Screening

Total number of studies to screen title/ abstract	758
-De-duplication	0
-exclusion criteria A (not related to the topic/not relevant risk factor)	737
-exclusion criteria B (part of meta-analysis)	0
Remaining studies	21
Not clear (full-text is needed)	21
Studies to obtain full-texts	21

Eligibility

Total number of studies to screen full-text	21
Full-text could be obtained	9
Reference list examined Y/N	Yes (+0 papers)
Eligible papers prioritized	4

Prioritizing coding

- Prioritizing Step A (accidents over other performance indicators)
- Prioritizing Step B (Journals over conferences and reports)
- Prioritizing Step C (journal quality)
- Prioritizing Step D (more recent studies)

No meta-analyses were found.

3.3 LIST OF CODED STUDIES FOR HIGH RISK SITE TREATMENT

1. De Pauw, E., Daniels, S., Brijs, T., Hermans, E., & Wets, G. (2014). Safety effects of an extensive black spot treatment programme in Flanders-Belgium. Accident Analysis & Prevention, 66, 72-79.
2. Elvik, R., Høye, A., Vaa, T., & Sørensen, M. (Eds.). (2009). The handbook of road safety measures. Emerald Group Publishing Limited.
3. Meuleners, L. B., Hendrie, D., Lee, A. H., & Legge, M. (2008). Effectiveness of the black spot programs in Western Australia. Accident Analysis & Prevention, 40(3), 1211-1216.
4. Moisan, O., Subirats, P., Bisson, O., Cheinisse, D., Chauvin, P., & Violette, E. (2014, April). A safer road with no accidents: a case study. In Transport Research Arena (TRA) 5th Conference: Transport Solutions from Research to Deployment.