Convert 4-Leg-Junction to Staggered Junction

Please refer to this document as follows: **Soteropoulos, A., Stadlbauer, S. (2017), Convert 4-Leg-Junction to Staggered Junction, 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

Soteropoulos, A., Stadlbauer, S., March 2017

1.1 COLOUR CODE: LIGHT GREEN

The conversion of 4-leg junctions to staggered T-junctions appears to reduce injury crash occurrence, especially when the amount of side road traffic is high. At sites where the latter is low, an increase in crash occurrence is seen. However, although there were different results for different exposures, staggering junctions has mainly positive effects on road safety.

1.2 KEYWORDS

Staggered junction; offset T-intersection; conversion; junction; staggering

1.3 ABSTRACT

From the studies identified in the international literature, it seems that the conversion of 4-leg junctions to staggered T-junctions statistically significantly reduces injury crash occurrence, especially when the amount of side road traffic is relatively high. However, converting 4-leg junctions to staggered T-junctions when the amount of side road traffic is low, appears to significantly increase injury as well as property damage only crash occurrence. Even though positive effects in general are seen for converting crossroads to staggered T-arms, negative estimates might appear when it comes to different road networks, traffic demand or crash types. One European meta-analysis was included, other research was mainly carried out in the United States and Australia. Therefore, the transferability may be questioned because of potential regional characteristics.

1.4 BACKGROUND

1.4.1 What is convert 4-leg-junction to staggered junction

A conversion of a 4-leg-junction to a staggered junction is the conversion of a 4-leg-junction (crossroad) into two 3-leg junctions (T-intersections or T-arms) (Rossow & Fischer 2006). Staggered junctions (or offset T-intersections) can be constructed in two ways: left-right staggering and right-left staggering. This conversion from a cross intersection into a pair of T-intersections is mainly implemented in rural areas (Yannis et al. 2012).

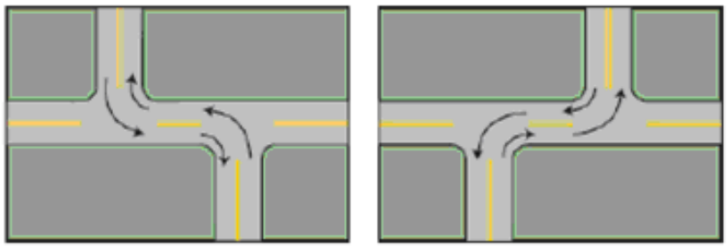

Figure 1. Left-Right and Right-Left Junction staggering (Yannis et al. 2012)

1.4.2 How does convert 4-Leg-junction to Staggered Junction affect road safety?

Staggered junctions aim to reduce the number of conflict points at junctions. This is because in general 4-leg junctions have higher accident rates than 3-leg junctions, since they have more conflict points between the streams of traffic (Yannis et al. 2012). Junctions with four approaches make higher demands on road user alertness and behaviour than junctions with three approaches (Elvik et al. 2009). Converting 4-leg junctions to staggered junctions eliminates crossing manoeuvres and reduces the number of potential conflicts (Bared & Kaisar 2001). They make the task of crossing the junction simpler for road users (Elvik et al. 2009).

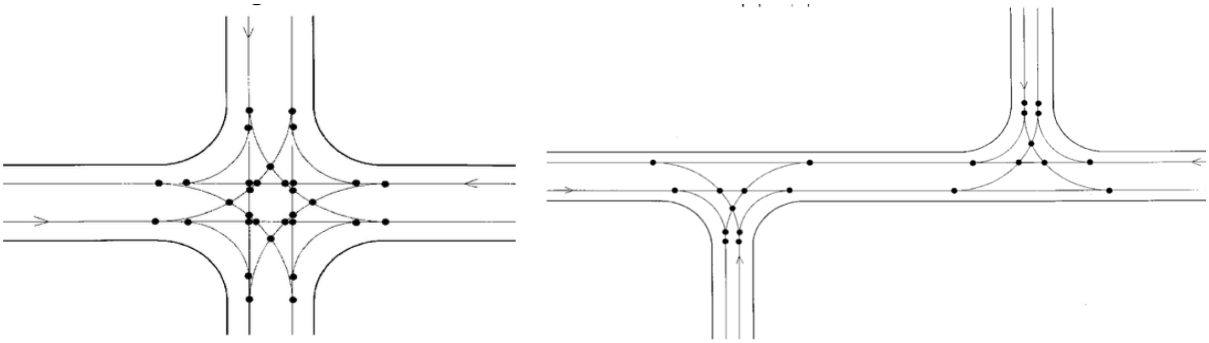

Figure 2. Potential conflict locations at a 4-leg junction (left) and a staggered junction (right) for 2x2-lane junction (Bared & Kaisar 2001)

1.4.3 Which safety outcomes are affected by converting 4-leg-junctions to staggered junctions?

In the international literature, the effect of the conversion of 4-legged-junctions to staggered junctions on road safety has been measured on one basic outcome, namely accident frequency (number of crashes occurred). Different crash types were investigated, whereas no distinction regarding road user types was made.

1.4.4 How is the effect of converting 4-leg-junctions to staggered junctions studied?

International literature indicated that the effect of converting 4-leg-junctions to staggered junctions on road safety is often examined by conducting before-after designs. These (quasi-)experimental methods are very suitable regarding crash occurrence. Furthermore, one study used a negative binomial model of crash occurrence.

The studies identified focused both on rural and urban intersections. Most research has been done in the United States but one study from Australia and one Norwegian meta-analysis with international literature were also included.

1.5 OVERVIEW RESULTS

There were four studies coded for the conversion of crossroads to staggered T-arms. Among those, one was a meta-analysis including international studies also focusing on the traffic volume on the side road.

1.5.1 Main results

Even if converting crossroads to staggered T-arms has positive effects in general, negative estimates might appear when it comes to different road networks, traffic demand or crash types.

The meta-analysis shows that when it comes to converting 4-legged junctions to staggered 3-legged junctions in general the measure leads to significant safety improvements as injury accidents were reduced by 20%. The amount of traffic on the side road has a significant impact on the effect of converting crossroads to staggered T-arms. If there is a low amount (<15%) the conversion leads to significantly more crashes (34% more injury crashes and 15% more damage only crashes. If the volume increases, there are significantly less injury accidents occurring (25% to 33% crash reduction).

The main findings of the other included studies are:

- There were differences between left-right offsets and right-left offsets, however in a non-significant way.
- Results of the meta-analysis show a bigger effect when it comes to injury crashes compared to property damage only accidents.

1.5.2 Transferability

Since there is a meta-analysis included, the amount of four coded studies seems to be sufficient. Results were primarily found for motor vehicle crashes. Even though there was one meta-analysis including studies from Europe, research was mainly carried out in the Unites States and Australia. The transferability may be questioned because of potential regional characteristics.

1.6 NOTES ON ANALYSIS METHODS

In general, the coded studies are of sufficient quality and methodologically sound. However, some of the studies used only a small sample for investigation.

2 Scientific overview

2.1 LITERATURE REVIEW

2.1.1 Analysis of study designs and methods

Overall three studies and one meta-analysis on the effect of converting 4-leg-junctions to staggered junctions were selected and coded. All studies focus on accident frequency. The majority of the studies (Rossow & Fischer 2006; Newstead & Corben 2001) used (quasi-)experimental before-after designs. The meta-analysis found (Høye 2014) included studies with random effects. Another study (Bared & Kaisar 2001) deployed negative binomial models (safety performance functions) to analyse the effect of converting crossroads to staggered junctions.

The studies identified focus on urban as well as on suburban and rural intersections. Research was carried out in the United States (2 studies), Norway (meta-analysis) and Australia (1 study). For conducting the meta-analysis besides studies from the United States and Norway, studies from Denmark and Sweden were also used.

Table 1 illustrates an overview of the main features of coded studies (sample, method, etc.).

Table 1 Description of coded studies

Author, Year, Country	Sample, method/design and analysis		Reference group	Additional information on analysis
Bared & Kaisar, 2001, United States	Observational, mainly negative binomial models (Safety Performance Functions)	negative binomial model of crash occurrence	-	urban and rural intersections
Høye 2014; Norway	Meta-analysis including 9 studies with random effects	Meta-analysis with random effects and fixed effects	-	Meta-analysis includes studies from Denmark, Norway, Sweden and the United States
Newstead & Corben, 2001, Australia	Quasi-experimental, before-after analysis of 559 different sites	before-after analysis of crash occurrence	untreated intersections	Focus on hazardous sites throughout Victoria, Australia
Rossow & Fischer, 2006, United States	Quasi-experimental, before-after analysis, including accident data of two intersections from 1990-2004	before-after analysis of crash occurrence	-	-

2.1.2 Study results

From the studies identified in the international literature, it seems that the conversion of 4-leg junctions to staggered T-junctions statistically significantly reduces crash occurrence, especially when the percentage of side road traffic amount is high: in her meta-analysis Høye (2014) indicated that for all junctions the conversion to staggered junctions showed a significant reduction of injury crashes of 20%, whereas property damage only crashes increased in a non-significant way. When there is a low percentage of traffic on the side road (<15%) staggering leads to significantly more

injury crashes (34%) and property damage only crashes (15%). If the percentage of side road traffic increases to 15-30%, injury crashes are significantly reduced by 25%. If the amount of side road traffic is greater than 30%, injury crashes are significantly reduced by 33%.
Results of Newstead & Corben (2001) also indicate a reduction of crash occurrence due to the conversion of 4-leg junctions to staggered T-junctions of 86%, however, in a non-significant way.

Results of Bared & Kaisar (2001) indicate that for rural 2x2-lane two-way stop control intersections on an aggregate level, the converting of a crossroad to an offset T-arm reduces total crash occurrence as well as injury crash occurrence. A reduction of crash occurrence through the conversion of a crossroad to a staggered intersection is also described for 2x4-lane two-way stop control intersections, for divided four-lane highways with design speeds greater than 80 km/h and for urban 2x2-lane signalized intersections (at higher ADTs). However, results were non-significant. Furthermore, Rossow & Fischer (2006) indicate that converting crossroads to left-right or right-left staggered intersections leads to a reduction of total crash occurrence, however, no test for statistical significance is mentioned and the analysis was done at two sites only.

1.3.1 Description of analysis carried out

2.1.2.1 Review-type analysis

Considering the number of studies with the relevant estimates is was decided that neither a meta-analysis nor a vote-count analysis can be conducted. Hence, to find an overall estimate of the absence of access control a review-type analysis was chosen.

The only significant results were presented in the Norwegian meta-analysis. The effects of staggering 4-legged junctions was neither limited to different road user groups nor to different road networks. However, as presented above, there are mixed results when it comes to different traffic amounts on the side road.
It can be summarised that staggering crossroads leads to both significant positive as well as negative effects on road safety.

Hence, on the basis of both study and effect numbers, it can be argued that staggering crossroads has a positive effect on road safety. However, there were also significant negative estimates presented for intersections with a low traffic amount on the minor road. As mentioned before, the chosen studies are of sufficient quality. In short, results show that staggering 4-legged junctions to T-arms decreases road safety risk. Since there were also negative results, a light green colour code was assigned.

2.2 CONCLUSION

Studies on the effect of converting crossroads to staggered T-arms identified in the international literature focused on accident frequency as an outcome.

Regarding the conversion, in general studies present (non-)significant positive effects on road safety. But when traffic volume on the side road was taken into consideration, significant negative estimates were also presented. If there is a low amount (<15%) the number of crashes increases, while injury crashes decrease with higher traffic demand. Injury accidents are clearly affected more than property damage only crashes.

Since there were different results for different conditions a specific conclusion can hardly be made. Still, it was shown that staggering junctions has mainly positive effects on road safety. This is also shown by the qualitative review-type analysis.

3 Supporting document

3.1 METHODOLOGY

3.1.1 Literature Search strategy

The literature search was conducted in November and December 2016. It was carried out in four databases with similar search strategies. The following databases were browsed through during the literature search: 'Scopus', 'Science Direct', 'TRID' and 'Taylor and Francis Online'. Detailed search terms, as well as their linkage with logical operators and combined queries are shown in the following tables. The study scope did not exclude countries or source types like "Journal" or "Project". In some of the searches remaining studies were limited to subject areas (e.g. "Engineering"). Out of the overall 278 potentially eligible studies, after screening the abstracts of these 278 studies the full-text was obtained from only 5, but none of these studies was coded and included in the synopsis. Other already known or during the literature search occasionally (e.g. via Google) found studies, as well as studies found in the literature search for other topics and including effects for converting 4-legged junction to staggered junction were added as additional studies (4). The reference lists of the studies were only partly checked.

Table 3 Literature search strategy, database: Scopus

search no.	search terms / operators / combined queries	hits
#1	TITLE-ABS-KEY ("junction" OR "intersection" OR "crossroad" AND "staggering" OR "staggered") AND PUBYEAR > 1989	**256**
#2	TITLE-ABS-KEY ("junction" OR "intersection" OR "crossroad" AND "staggering" OR "staggered") AND PUBYEAR > 1989 AND (LIMIT-TO (SUBJAREA , "ENGI"))	**87**

Table 4 Literature search strategy, database: ScienceDirect

search no.	search terms / operators / combined queries	hits
#1	pub-date > 1989 and (intersection OR junction OR crossroad) and (staggering OR staggered)	**8,128**
#2	pub-date > 1989 and TITLE-ABSTR-KEY(intersection OR junction OR crossroad) and TITLE-ABSTR-KEY(staggering OR staggered)	**61**
#3	pub-date > 1989 and ("junction" OR "intersection" AND "convert" OR "conversion" AND "staggered" OR "offset" AND "measure" OR "treatment" AND "safety") and TITLE-ABSTR-KEY("staggered" OR "offset" OR "junction" OR "intersection")[All Sources(Engineering)].	**92**

Table 5 Literature search strategy, database: TRID

search no.	search terms / operators / combined queries	hits
#1	Keywords (intersection OR junction AND staggering OR staggered) in: Passenger Transportation, Pedestrians and Bicyclists, Public Transportation, Safety and Human Factors, Transportation (General)	**5,048**
#2	Keywords (junction AND staggering OR staggered) in: Passenger Transportation, Pedestrians and Bicyclists, Public Transportation, Safety and Human Factors, Transportation (General)	**89**

Table 6 Literature search strategy, database: Taylor & Francis Online

search no.	search terms / operators / combined queries	hits
#1	Search Abstract (junction AND staggering OR staggered AND effect AND safety)	**10**

Table 7 Results Literature Search

Database	Hits
Scopus (remaining papers after several limitations/exclusions)	87
Science Direct	92
TRID	89
Taylor & Francis Online	10
Total number of studies to screen title/ abstract	**278**

The final 4 studies included in the synopsis indicate that the topic has been investigated to a sufficient extent. The prioritising criteria for coding were the following, however all studies codable and suitable for the topic, were coded.

- Prioritizing Step A (e.g. meta-analysis first)
- Prioritizing Step B (most recent studies)
- Prioritizing Step C (Journals over conferences and reports)
- Prioritizing Step D (Prestigious journals over other journals and conference papers)

One meta-analysis was found.

3.1.2 Exploratory analysis of results

Table 8 presents information on the main outcomes of coded studies on converting 4-leg-junction to staggered junctions.

Table 8 Main outcomes of coded studies on Convert 4-Leg-Junction to Staggered Junction

Author, Year, Country	Exposure variable	Outcome variable / Outcome type	Effects		Main outcome description
Bared & Kaisar, 2001, United States	Conversion of cross intersection to offset t-intersection (2x2-lane two-way stop control, rural intersection)	Crash count / All	–	percent accident reduction=20-30%	Non-significant reduction of crash occurrence due to conversion of crossroad to offset t-intersection (2x2-lane two-way stop control, rural intersection)
	Conversion of cross intersection to offset t-intersection (2x2-lane two-way stop control, rural intersection)	crash count / fatal/injury crashes	–	percent accident reduction= approx. 40%	Non-significant reduction of injury crash occurrence due to conversion of crossroad to offset t-intersection (2x2-lane two-way stop control, rural intersection)
	Conversion of cross intersection to offset t-intersection (2x4-lane two-way stop control, rural intersection)	Crash count / All	–	percent accident reduction=40-60%	Non-significant reduction on crash occurrence due to conversion of crossroad to offset t-intersection (2x4-lane two-way stop control, rural intersection)

Author, Year, Country	Exposure variable	Outcome variable / Outcome type	Effects		Main outcome description
	Conversion of cross intersection to offset t-intersection (2x2-lane signalised, urban intersection	Crash count / All	–	percent accident reduction=20% (expected)	Non-significant reduction of crash occurrence due to conversion of crossroad to offset t-intersection (2x2-lane signalised, urban intersection)
Høye 2014; Norway	Conversion of 4-leg-junction to staggered junction (all junctions)	Crash count / injury accidents	↘	Percent change in accident number=-20%	Significant reduction of injury crash occurrence due to the conversion of 4-leg-junctions to staggered junctions
		Crash count / property damage only	–	Percent change in accident number=3%	Non-significant increase of damage property only crash occurrence due to the conversion of 4-leg-junctions to staggered junctions
	Conversion of 4-leg-junction to staggered junction (side road traffic amount <15%)	Crash count / injury accidents	↗	Percent change in accident number=34%	Significant increase of injury crash occurrence due to the conversion of 4-leg-junctions with side road traffic amount <15% to staggered junctions
		Crash count / property damage only	↗	Percent change in accident number=15%	Significant increase of damage property only crash occurrence due to the conversion of 4-leg-junctions with side road traffic amount <15% to staggered junctions
	Conversion of 4-leg-junction to staggered junction (side road traffic amount 15-30%)	Crash count / injury accidents	↘	Percent change in accident number=-25%	Significant reduction of injury crash occurrence due to the conversion of 4-leg-junctions with side road traffic amount 15-30% to staggered junctions
		Crash count / property damage only	–	Percent change in accident number=0%	Non-significant effect on damage property only crash occurrence due to the conversion of 4-leg-junctions with side road traffic amount 15-30% to staggered junctions
	Conversion of 4-leg-junction to staggered junction (side road traffic amount >30%)	Crash count / injury accidents	↘	Percent change in accident number=-33%	Significant reduction of injury crash occurrence due to the conversion of 4-leg-junctions with side road traffic amount >30% to staggered junctions
		Crash count / property damage only	–	Percent change in accident number=-10%	Non-significant reduction of damage property only crash occurrence due to the conversion of 4-leg-junctions with side road traffic amount >30% to staggered junctions
Newstead & Corben, 2001, Australia	Conversion of 4-leg junction to staggered T-junctions	Crash count / All	–	Percent accident reduction=86%, p=0,0615	Significant reduction of crash occurrence due to the conversion of 4-leg junctions to staggered T-junctions
Rossow & Fischer, 2006, United States	Conversion of 4-leg junction to offset T-intersection (staggered junction)	Crash count / All (left-right offset T-intersection)	–	percent accident reduction=29,4%	Non-significant reduction of crash occurrence due to conversion of 4-leg junction to offset (left-right) offset T-intersection
		Crash count / All (right-left offset T-intersection)	–	percent accident reduction=53,2%	Non-significant reduction of crash occurrence due to conversion of 4-leg junction to offset (right-left) offset T-intersection

*Significant effects on road safety are coded as: positive (↘), negative (↗) or non-significant (–)

3.2 FULL LIST OF STUDIES

1.3.2 Meta-analyses

Høye A. (2014). Staggered junctions (reconfiguring crossroads to two T-junctions. The Handbook of Road Safety Measures, Norwegian (online) version.

Following studies were concluded in the Meta-analysis:

Brüde, U. & Larsson, J. (1981). Vägkorsningar på landsbygd inom huvudvägnätet. Olycks-analys. VTI-rapport 233. Linköping, Statens väg- och trafikinstitut (VTI).

Brüde, U. & Larsson, J. (1987). Före-efter studier avseende olyckor i landsbygdskorsningar ingående i "Korsningsinventering 1983". VTI-meddelande 545. Statens väg- och trafikinstitut (VTI), Linköping

Cedersund, H-Å. (1983). Olyckor i tätortskorsningar. VTI-meddelande 362. Statens väg- och trafikinstitut (VTI), Linköping

Hanna, J. T., Flynn, T. E. & Tyler, W. E. (1976). Characteristics of Intersection Accidents in Rural Municipalities. Transportation Research Record, 601, 79-82

Johannessen, S. & Heir, J. (1974). Trafikksikkerhet i vegkryss. En analyse av ulykkesforholdene i 187 vegkryss i perioden 1968-72. Oppdragsrapport 4. Norges Tekniske Høgskole, Forskningsgruppen, Institutt for samferdselsteknikk, Trondheim.

Lyager, P. & Løschenkohl, C. (1972). Uheldsmønstre i kanaliserede landevejskryds. Sammenfatning. RfT-rapport 14. Rådet for Trafiksikkerhedsforskning (RfT), København.

Montgomery, R. E. & Carstens, R. L. (1987). Uncontrolled T Intersections: Who Should Yield? Journal of Transportation Engineering, 113, 299-314.

Vaa, T. & Johannessen, S. (1978). Ulykkesfrekvenser i kryss. En landsomfattende undersøkelse av ulykkesforholdene i 803 kryss i perioden januar 1970 - juni 1976. Oppdragsrapport 22. Norges Tekniske Høgskole, Forskningsgruppen, Institutt for samferdselsteknikk, Trondheim.

Vodahl, S. B. & Giæver, T. (1986). Risiko i vegkryss. Dokumentasjonsrapport. Rapport STF63 A86011. SINTEF Samferdselsteknikk, Trondheim.

3.2.1 Original studies

Bared J.G. & Kaisar E.I. (2001). Advantages of Offset T-Intersections with Guidelines. International Conference: Traffic Safety on Three Continents.

Newstead S. & Corben B. (2001). Evaluation of the 1992-1996 Transport Accident Commission Funded Accident Blackspot Treatment Program in Victoria. Monash University Accident Research Center.

Rossow E. & Fischer E.L. (2006). "Offset T-Intersections". Unknown source.

3.2.2 References on further background information

Elvik, R. / Høye, A. / Vaa, T. / Sørensen, M. (2009). The Handbook of Road Safety Measures. Second edition. Emerald Group. Bingley

Yannis, G. / Papadimitriou, E. / Evgenikos, P. (2011). Effectiveness of Road Safety Measures at Junctions. 1st International Conference on Access Management. Athens.