The impact of traffic flow distribution over arms at junctions on crash risk

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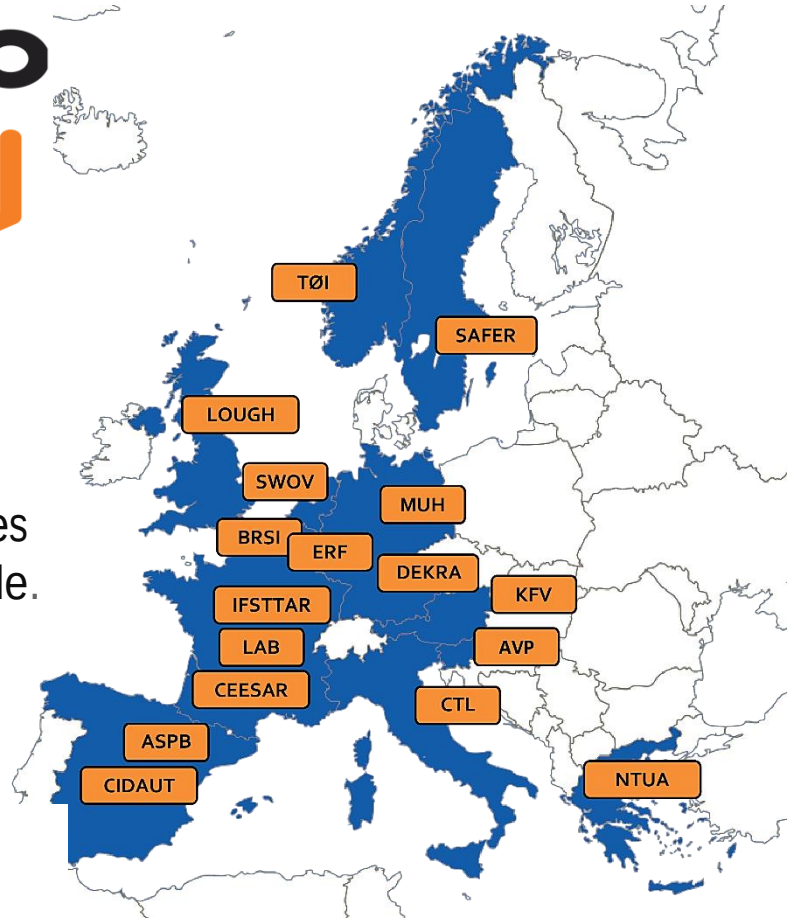
SafetyCube project (Safety CaUsation, Benefits and Efficiency)

the European Road Safety Decision Support System
www.roadsafety-dss.eu

Funded by the European Commission under the Horizon 2020 research framework programme

Coordinator: Pete Thomas, Loughborough University

Objective: DSS that will enable policy-makers and stakeholders to select and implement the most appropriate strategies, measures and cost-effective approaches to reduce casualties of all road user types and all severities in Europe and worldwide.



Start: May 2015

Finish: April 2018

SafetyCube generated new knowledge about accident risk factors & the effectiveness of measures

17 partners from 12 EU countries

Prince Michael INTERNATIONAL ROAD SAFETY AWARD
Recognising achievement and innovations which will improve road safety

HORIZON 2020
The New EU Framework Programme for Research and Innovation
2014-2020

Background

The traffic flow distribution over arms at junctions
the allocation of the traffic across the branches of a junction or the traffic volumes on the major versus the minor road expressed as AADT (Annual Average Daily Traffic)- signalised & non-signalised junctions

According to the literature:

a traffic flow imbalance between the approaches of different roads (particularly when a major and minor road cross), the number of turning lanes, the junction control type (i.e. signalised or non-signalised) and a difference between the major & minor road's traffic volume

A significant change in
crash occurrence & severity
(Abdel-Aty & Nawathe, 2006, Castro et al., 2012, Kulmala, 1996, Ferreira & Couto, 2013).

Background

Forms in which distribution of flow is examined

- natural logarithm of AADT on the major road (Haleem & Abdel-Aty, 2010)
- ratio of major road AADT to minor road AADT (Agbelie & Roshandeh, 2015)
- flows on the approach streets of an intersection (Guo et al., 2010)
- ratio of the minor approach traffic volume to the major approach traffic volume (Ferreira & Couto, 2013)
- incoming motor vehicle traffic from the primary and secondary direction (Greibe, 2003)
- percentage of minor road traffic (Kulmala, 1996) &
- minor approach right-turn lanes traffic volume (Pulugurtha & Nujjetty, 2011)

Junction Control type

Signalised vs non-signalised

Approaches

the split of traffic volumes ⇄ number of crashes

Poisson and negative binomial models (e.g. Greibe, 2003, Kulmala, 1996, Castro et al., 2012)

whereas

Crash severity → a binary probit framework (Haleem & Abdel-Aty, 2010) .

Methodology

Literature review-Selection and Coding of Studies

Study search in key databases
(Scopus, TRID)
Study selection and prioritization criteria

- Studies with quantitative results
- Meta-analyses, or other high-quality studies (peer-reviewed)
- Recent studies
- European studies

Study selection and prioritization criteria

- Study design & methodology
- Results & their confidence intervals
- Study limitations

Methodology

Meta-analysis

a statistical analysis of a set of numerical research results of studies aiming :

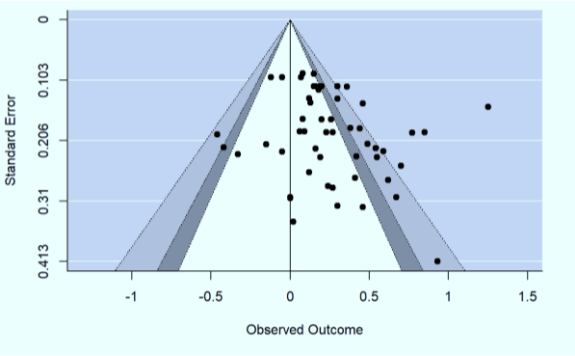
- to develop a single weighted overall mean result &
- identify sources of systematic variation in individual results.

☞ under comparable conditions & a similar framework.

Meta-regression

systematically compares input study characteristics and explains any heterogeneity in present effects by the significance of each study characteristic (e.g. study year, area, unit of analysis etc.).

❖ Funnel plots can be used to visualize the presence of heterogeneity and publication bias by contrasting the input estimates by their respective standard errors



Methodology

➢ The minor road's traffic for 3-arm and 4-arm junctions was examined for this study in 2 separate meta-analyses.

- ✓ A minimum required number of effects for each type of junction is achieved (3).
- ✓ The studies have used the same model specifications (Poisson distribution)
- ✓ The sampling frames were similar
- ✓ The measure of effect was the same (elasticity)

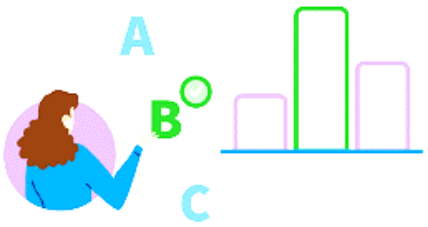
Analysis & Results

Literature search strategy

- 224 research studies initially identified
- 8 studies were selected as being specifically relevant to the topic and presenting findings to a level of detail necessary for meta-analysis.

Meta-analysis & meta-regression methods

- The results of the meta-analysis suggest a significant negative effect of secondary road traffic at junctions on road safety (both for 3-and 4-arm junctions) at the 95% confidence level→ an increase of secondary road traffic at junctions is translated to an increase on crash numbers.



Qualitative analysis

- no fixed variable used
- studies that referred to the imbalance of traffic flows between the branches of a junction or the primary or secondary road traffic

*All the studies use regional data and most of them are from U.S.A.

*Urban environment only and not different road users into account.

Table 1: Description of considered studies

Author & Year	Country	Risk factor	Method	Measure of effect
Greibe [15]	Denmark	Traffic flow on primary and secondary road	Generalized linear model-Poisson distribution	Elasticity
Kulmala [20]	Finland	Percentage of minor road traffic and overall traffic flow	Generalized linear model-Poisson (and negative binomial distribution)	Elasticity
Castro et al. [3]	USA (Texas)	Flows on the approach streets for each intersection	Generalized ordered-response model	Elasticity
Pulugurtha & Nujjetty [24]	USA (North Carolina)	Minor approach right-turn lanes	Generalized linear model-Negative binomial distribution	Correlation coefficient & Slope
Guo et al. [16]	USA (Florida)	ADT of each intersection approach (major/minor roads) [Signalised junctions]	Bayesian models (Poisson CAR model)	Slope
Ferreira & Couto [11]	Brazil	Ratio of the minor/major approach traffic volumes [Signalised junctions]	Random-effect Poisson model	Slope
Agbelie & Roshandeh, [1]	USA (Illinois)	Ratio of major road AADT to minor road AADT [Signalised junctions]	Random-parameters negative binomial model	Marginal effect
Haleem & Abdel-Aty, [17]	USA (Florida)	AADT on the major road [Unsignalised junctions]	Binary probit model	Marginal effect & difference (%)

Qualitative analysis

*Road Safety Impacts are considered to be negative if the risk factor increases either crash occurrence and/or crash severity and positive in the opposite case.

Table 2: Main outcomes of considered studies

Author & Year	Outcome variable	Road Safety Impacts	Main outcome description
Greibe [15]	Crash frequency	Negative	Models that relate crash occurrence with traffic flow and road design (95% CI).
Kulmala [20]	Crash frequency	Negative	As minor road traffic portion increases, crash rate increases (95% CI).
Castro et al. [3]	Crash frequency /year/intersection	Positive	Lower crash propensity associated with higher flow imbalance (No CI).
Pulugurtha & Nujjetty [24]	Crash frequency	Negative	The number of turn lanes generally tend to increase crashes at an intersection (95% CI).
Guo et al. [16]	Crash frequency	Positive, Negative, Negative,	(95% CI): (i) For one standardized unit of increase in major through-traffic expected crash rate will drop by a multiplicative factor (ii) For one unit increase the crash rate will increase by a multiplicative factor (iii) For one unit increase for through-traffic per lane on minor roads, the crash rate will increase by a multiplicative factor.
Ferreira & Couto [11]	Crash frequency	Negative	When the difference between major and minor traffic volume increases or decreases, the crash risk is expected to change significantly; when the proportion approaches zero the crash risk is high.
Agbelie & Roshandeh [11]	Crash frequency	Negative	For most of the intersections, increasing the ratio of traffic volume on the major road to this on the minor road will increase accident frequency. A unit increase in this ratio would increase crash frequency by a multiplicative factor (No CI).
Haleem & Abdel-Aty [17]	Crash severity	Positive	As the natural logarithm of AADT on the major road increases, the severe injury probability reduces (90% CI).

Analysis & Results

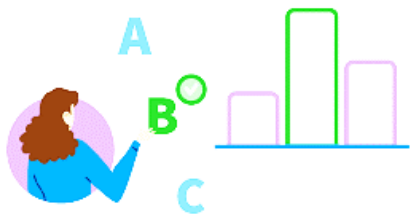


Table 3: Random effects meta-analysis on crash frequency for secondary road traffic flow at 3-arm junctions.

Variable	Unit	Estimate	Std. Error	p-value	95% CI
Secondary road traffic flow	ADT	0.396	0.1114	<0.001	(0.1775, 0.6142)

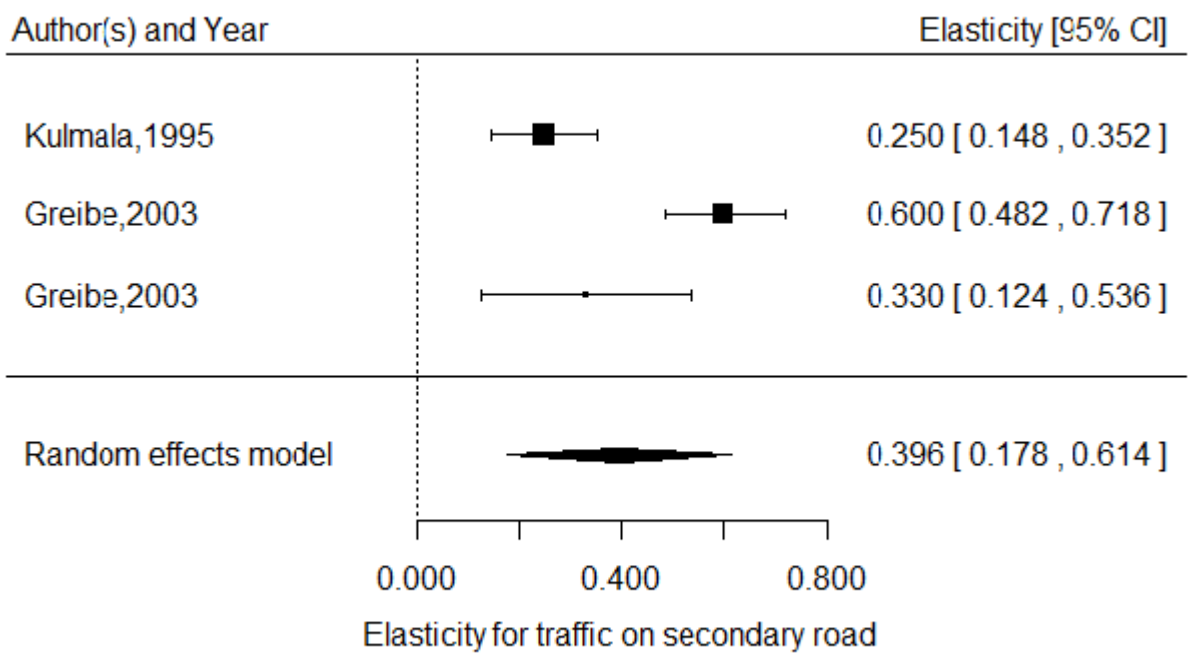


Figure 1: Forest plot for 3-arm junctions

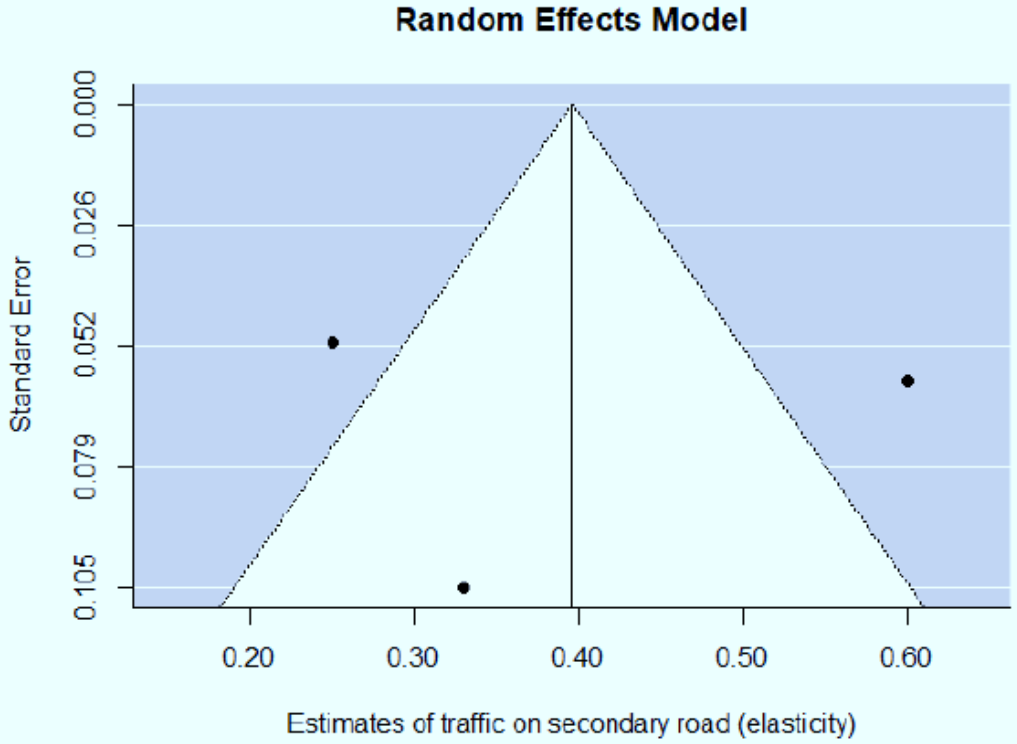


Figure 3: Funnel Plot for crash frequency (effect of secondary road traffic at 3-arm junctions).

Analysis & Results

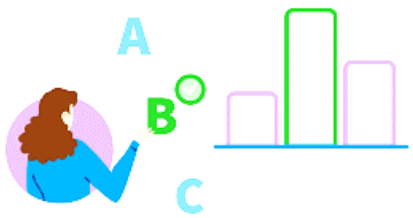


Table 4: Fixed effects meta-analysis on crash frequency for secondary road traffic flow at 4-arm junctions.

Variable	Unit	Estimate	Std. Error	p-value	95% CI
Secondary road traffic flow	ADT	0.480	0.0301	<0.0001	(0.4212, 0.5390)

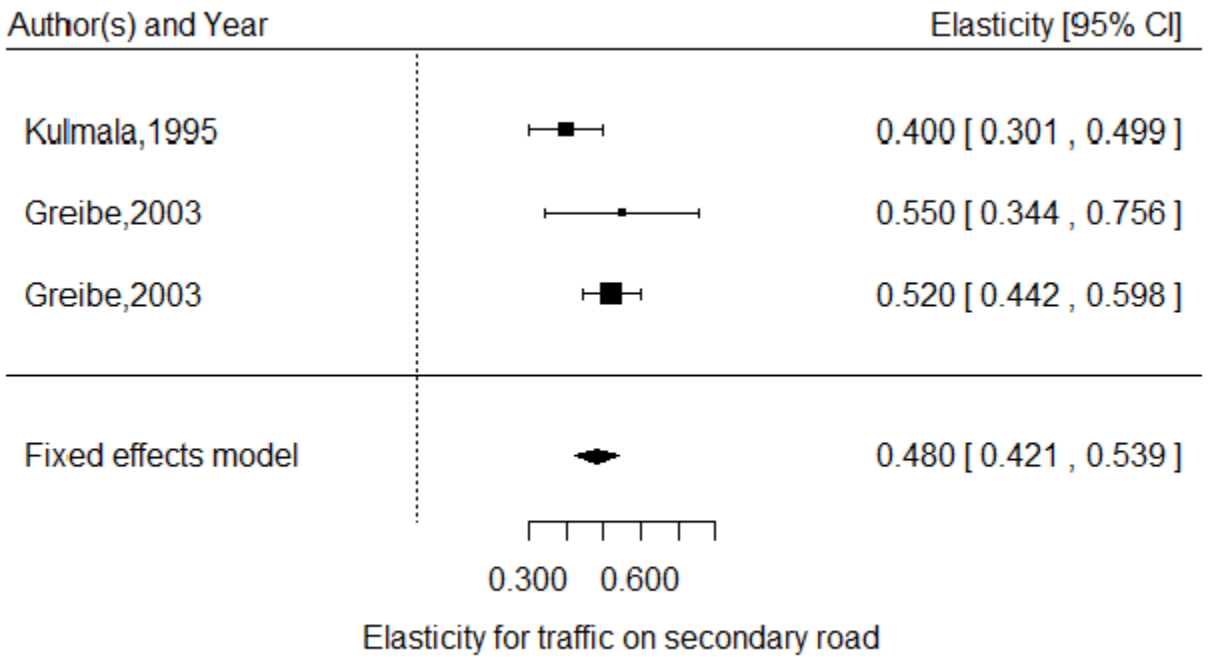


Figure 2: Forest plot for 4-arm junctions

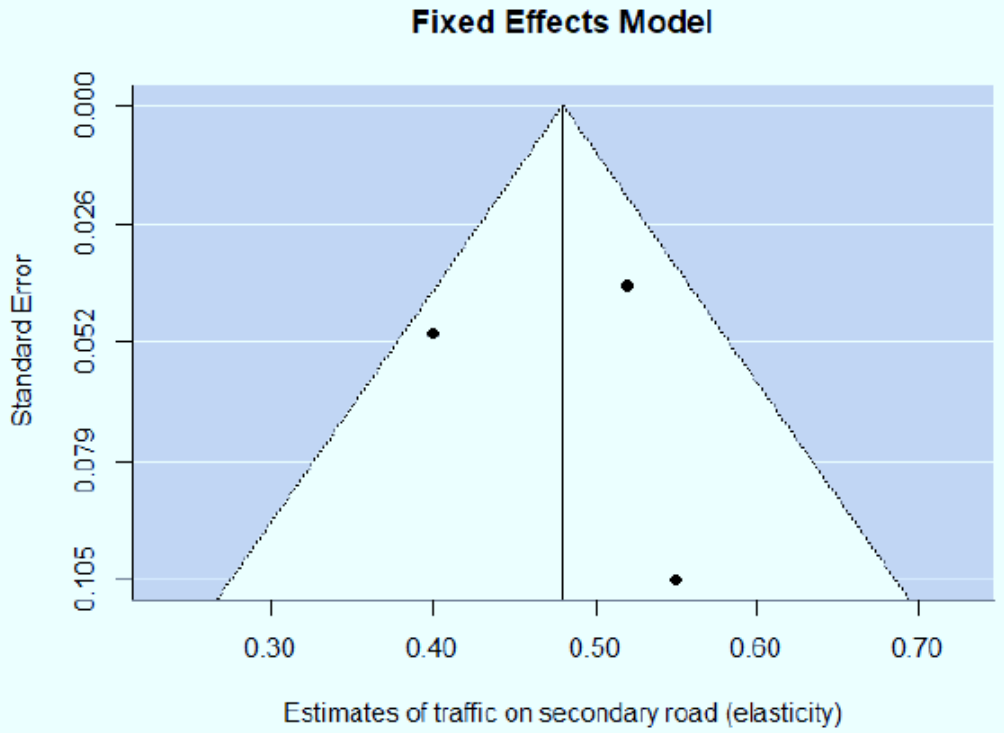


Figure 4: Funnel Plot for crash frequency (effect of secondary road traffic at 4-arm junctions).

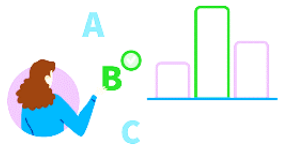
Analysis & Results

- Meta-regression

Table 5: Meta-regression for the impact of individual study characteristics on the overall estimate of the secondary road traffic flow.

Variable	Estimate	Std. Error	p-value	95% CI
Constant term	-47.5976	20.4029	0.0197	(-87.5866, -7.6086)
Year	0.0240	0.0102	0.0185	(0.0040, 0.0440)

- More recent estimates tend to report greater impacts of traffic flow on crash frequency as the “Year” variable has a positive coefficient (significant at a 95% level).
- The type of junction was not found to be influential.



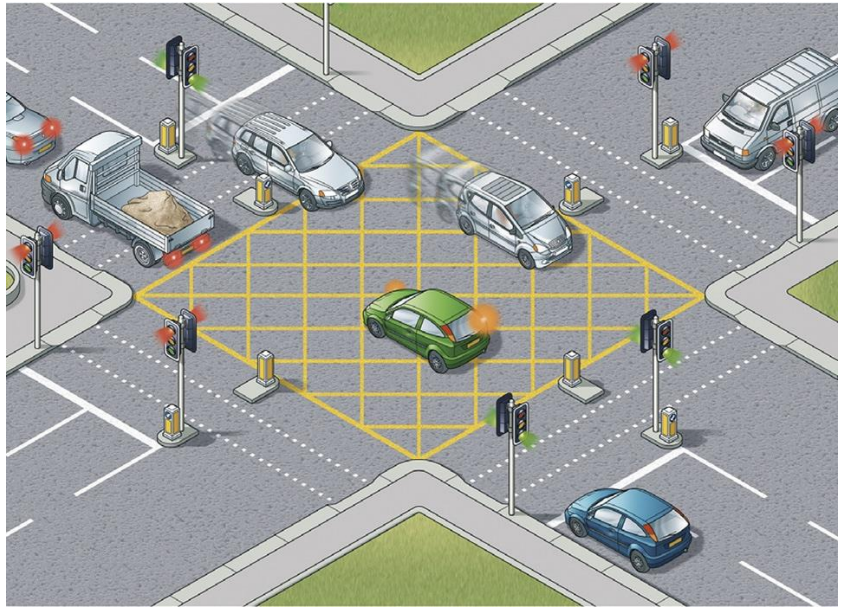
Conclusions

- One random effects meta-analysis for 3-arm junctions, and one fixed effects meta-analysis for 4-arm junctions were conducted.
- This is the first meta-analysis of studies including the particular risk factor and a first attempt to quantify a part of the widely reported safety effect of traffic flow in junctions.
- The sample size is limited as, while most studies used multivariate methods to estimate the effect of distribution of flow over arms at junctions, the distributions used and variables included differ considerably. As a result, the risk factor is expressed with different variables in different studies.

☞ Limitations : reduced transferability

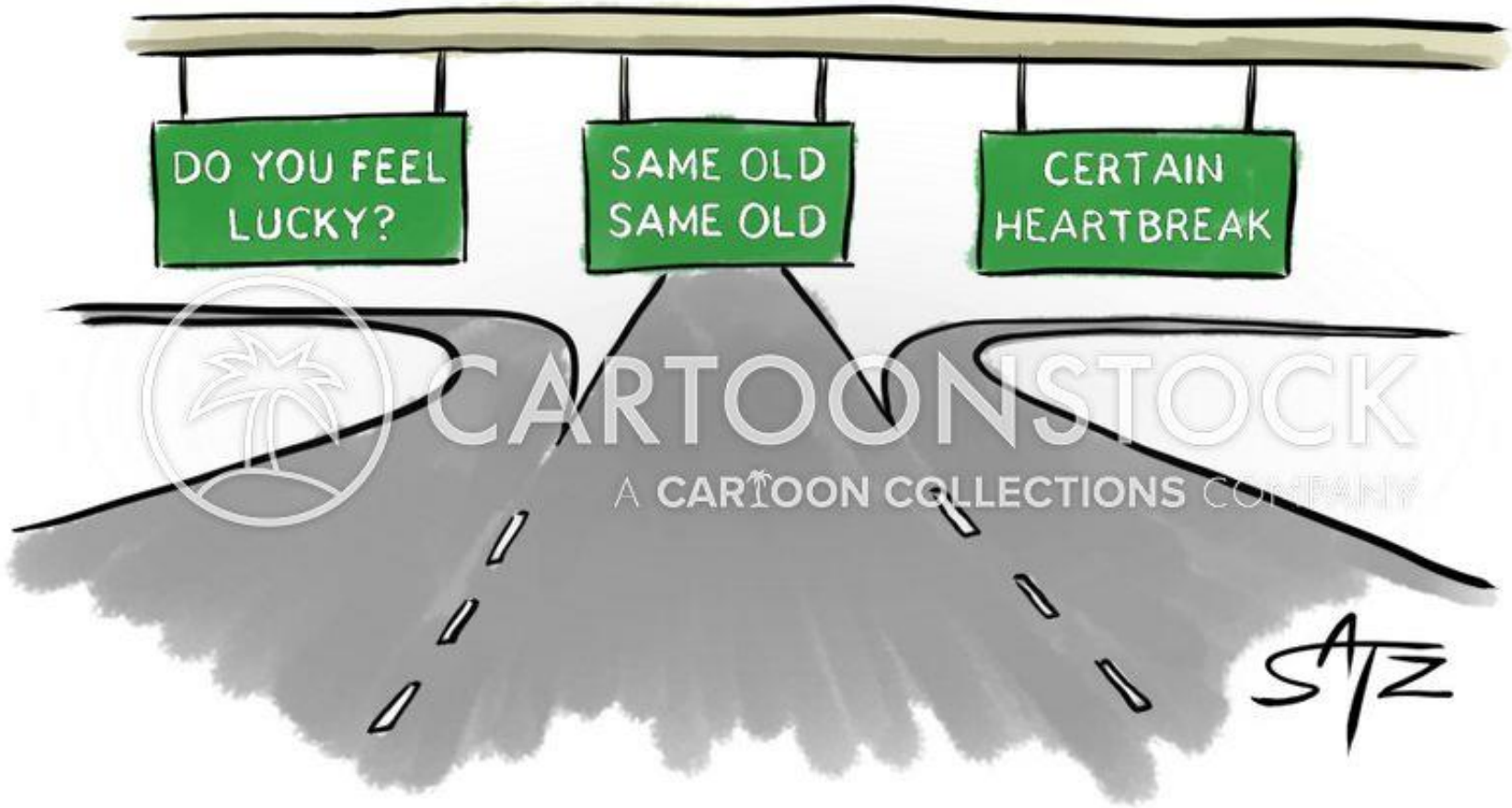
Conclusions

- This study has taken a step further our understanding of the importance of the distribution of traffic flow over arms at junctions regarding road safety.
- From the review of the considered studies and the synthesis of the results, a more robust conclusion can be drawn about the effect of this special risk factor.
- It has been confirmed that an increase on the secondary road traffic signifies an increase in crash numbers and that traffic flow imbalance in a junction affects considerably its safety.



This knowledge gained can be proved beneficial for the road safety of junctions if applied to future road design and especially, if integrated to junction design principles

The end!
Thank you!



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