Schulich School of Engineering – Department of Civil Engineering

# Meta-Analysis of the Traffic Safety Effect of Reversible Lanes

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- Introduction to Reversible Lanes

- Overview of Previous Work

- Methodology

- Results of Exploratory Analysis – Testing for Bias

- Results – Summary Effects
  – Comparison with previous meta-analysis
  – Results after log transformation

- Conclusion and Future Work

- Reversible lanes a well-known traffic engineering measure in use since the 1930's for use where there is a temporarily high directional imbalance in traffic flow.
  - Permanent (daily congestion mitigation) vs temporary systems (special events and construction)
  - Off-centre systems– use of traffic control, dynamic or static signing, special pavement markings to convey lane change
  - Physically separated system - use of barriers and ramps to convey lane change
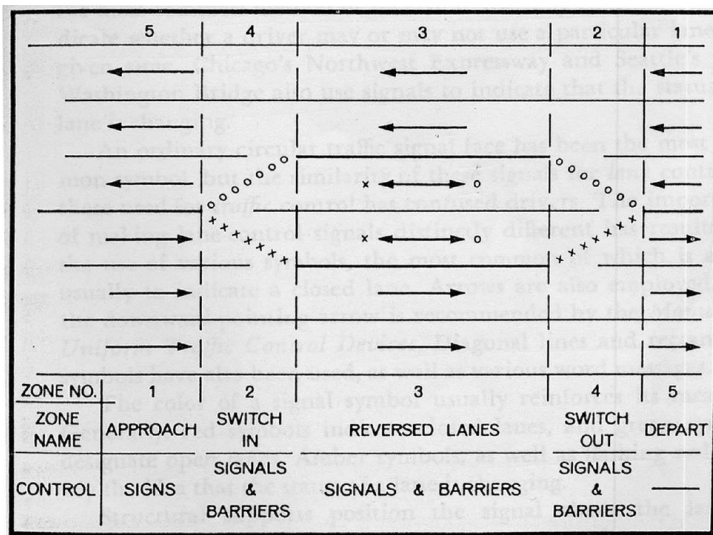
Source: Lathrop 1972 as cited in Wolshon and Lambert 2004
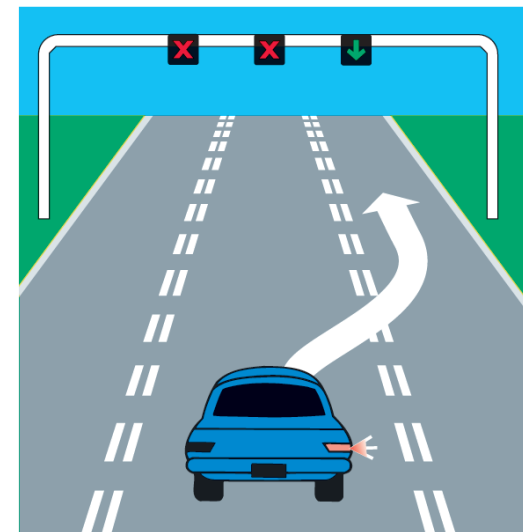
Source: Driver's Guide (Alberta Government, 2016)

Wolshon and Lambert (2004), Guebert (2010)

- **General Crash Pattern Analysis**
  - Upchurch 1975 – 16% of crashes after installation related to reversible lanes, 81% of these crashes were due to unauthorized left turn across lane with vehicle travelling in same direction (e.g sideswipe)
- **Simple Before-After Analysis – Typically part of overall before-after performance review**
  - Derose 1966 – Crash frequency decreases 3.5% in 1st after year, 19% in 2nd after year period
  - Agent and Clark 1980 – No significant increase in after period (11% overall increase, but increase was similar during operational and non-operational times)
  - Bretherton and Elhaj 1996 –
    - Overall accident rate increased but increase not significant.
    - Injury and fatal collision rate increase significant to 95%
    - Crash patterns suggest that driver confusion to the treatment partially explains some of the collisions
- **Cross Sectional Analysis**
  - Knoblauch, Parker and Keegel 1984 – average accident rates typically higher on reversible two-way left-turn lanes when compared with similar facilities, result is not statistically significant
  - Dey, Ma and Aden 2011 - Higher number of crashes with and without controlling for traffic volume, higher percentage of crashes during peak periods on reversible segment when compared to nearby non-reversible segments
- **Previous Meta-Analysis (Elvik et al 2009)**
  - 18% increase in injury collisions, 15% increase in peak period collisions, 4% increase in all collisions.
  - Results were heterogenous and results not statistically significant
- **Cursory review of literature appears mixed, leaning towards increase in crashes**
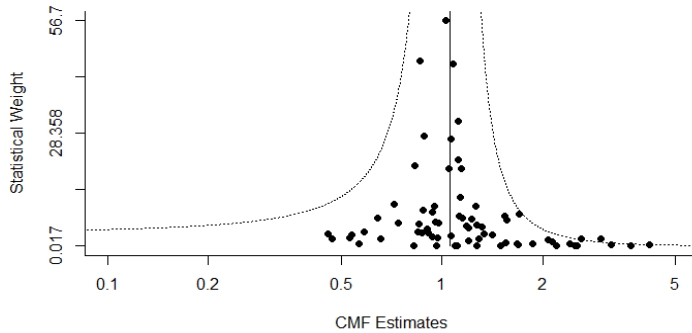
- **Topic definition and systematic search**
  - Based on established guidance on traffic safety meta-analysis (Elvik 2005, Gross, Persaud and Lyon 2010)
  - Topic/Objective:
    - determine the traffic safety effect of reversible lanes
    - from observational studies analyzing collision data
  - Search terms:
    - Transport Research International Documentation: "reversible lanes safety" – 105 results
    - ITE Library: "reversible lanes" – 135 results
- **Definition of study inclusion criteria:**
  - Study age, location unrestricted
  - Study type restriction:
    - Observational studies of collision frequencies and rates on permanent "off-centre" arterial applications (as defined in Guebert 2010)

- **Data Extraction/Conversion to Common Scale**
  - Adapted from Transportation Research Circular E-C142 (Bahar 2010)
    - Includes methodology for accounting for biases
    - $CMF_{unbiased} = \dfrac{A}{B \times \Delta \, traffic \, volume}$
    - $s_{ideal}^2 = \dfrac{\left(\dfrac{CMF_{unbiased}}{r} + CMF_{unbiased}^2\right)}{B}$
    - Mean CMF: $\dfrac{\sum_{i=1}^{n} CMF_{unbiased,i}/s_i^2}{\sum_{i=1}^{n} 1/s_i^2}$ Standard Error: $S = \sqrt{\dfrac{1}{\sum_{i=1}^{n} 1/s_i^2}}$
- **Additional Exploratory Analysis**
  - Systematic Variation Between Studies
    - Homogeneous – No major systematic variation, use Fixed-Effects
    - Heterogeneous – Major systematic variation, use Random- or Mixed-Effects
    - Heterogeneity tested using Q-Statistic
  - Skewness
 - Publication Bias – Use Trim-and-Fill Analysis

Bahar 2010, Elvik 2005, Shadish and Haddock 2009, Duval and Tweedle, 2000

| Author	Publication Year	Location of Study	Type of study
Derose	1966	Dearborn, MI	Simple Before-After
Habermann, Schonleiter and Burmeister	1972	Berlin, Germany	Simple-Before-After
Upchurch	1975	Memphis, TN	Characteristics Study
Agent, Clark	1980	Lexington, KY	Simple Before-After
Lalani and Baird	1981	Phoenix, AZ	Simple Before-After
Knoblauch, Parker and Keegel	1984	USA	Non-Regression Cross-Sectional
Bretherton, Elhaj	1996	Atlanta, GA	Simple Before-After
Dey, Ma and Aden	2012	Washington, DC	Non-Regression Cross-sectional

All Effect Estimates

Injury Crashes
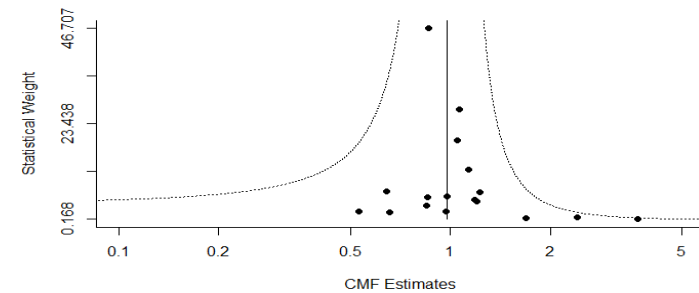
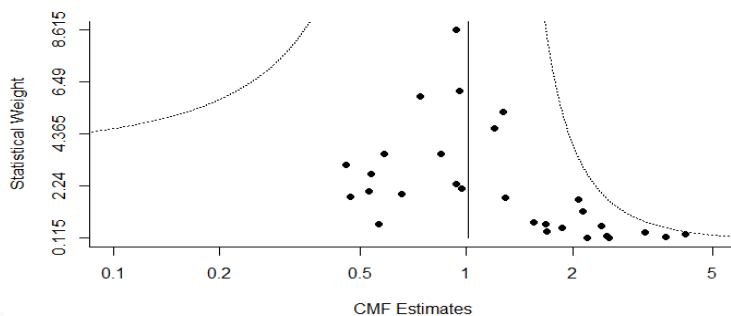## Property Damage Only Crashes
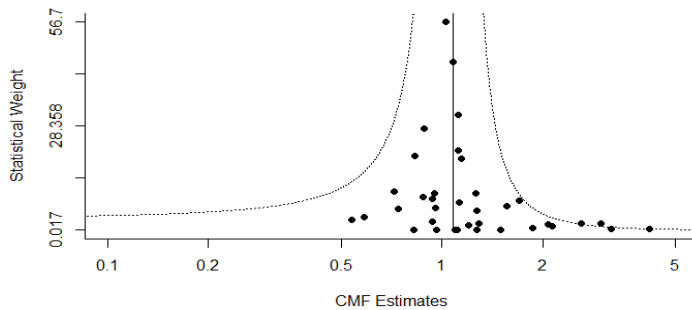
Unspecified Severity – All Collision Types
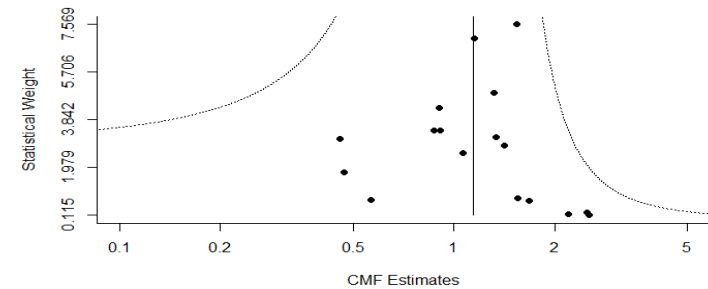
Peak Period Crashes

Off-Peak Period Crashes
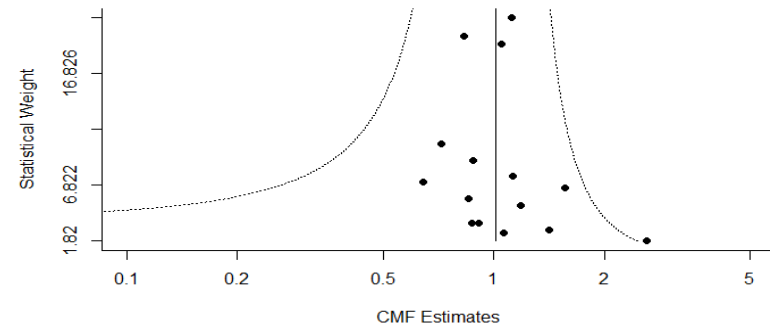
Severity	Collision Type	Number of Effect Estimates	Sum of Statistical Weights	Proportion of Statistical Weights	Heteroge-neity Test Statistic (Q)	p-value	Skewness
Injury	All	17	46.813	0.088	6.020	0.988	0.541
PDO	All	17	151.491	0.286	6.383	0.983	2.194
Unspecified	All	36	331.325	0.626	31.653	0.631	1.907
Unspecified	Peak Period	29	63.462	0.120	17.316	0.942	0.985
Unspecified	Off Peak Period	15	127.243	0.240	10.572	0.719	2.108
All Estimates		70	529.629	1.000	45.398	0.988	1.792

Exploratory Analysis – Trim-and-Fill Analysis

Severity	Collision Type	Original Estimate	95% CI	Trim-and-Fill Estimate	95% CI	Number of Missing Studies	Percent Difference
Injury	All	1.140	(0.854, 1.427)	1.131	(0.845, 1.416)	2 L	0.21%
PDO	All	0.980	(0.820, 1.139)	0.971	(0.812, 1.130)	2 L	0.22%
Unspecified	All	1.076	(0.968, 1.183)	1.040	(0.933, 1.146)	7 L	0.85%
Unspecified	Peak Period	1.014	(0.768, 1.261)	0.932	(0.692, 1.173)	8 L	2.11%
Unspecified	Off Peak Period	1.012	(0.838, 1.186)	1.012	(0.838, 1.186)	0	0.00%
All Estimates		1.054	(0.969, 1.139)	1.028	(0.943, 1.112)	12 L	0.63%

Results - Summary Effects

Severity	Collision Type	Estimated CMF	Standard Error	z-value	p-value	95% CI
Injury	All	1.140	0.146	7.802	<.0001	(0.854, 1.427)
PDO	All	0.980	0.081	12.057	<.0001	(0.820, 1.139)
Unspecified	All	1.076	0.055	19.578	<.0001	(0.968, 1.183)
Unspecified	Peak Period	1.014	0.126	8.081	<.0001	(0.768, 1.261)
Unspecified	Off Peak Period	1.012	0.089	11.414	<.0001	(0.838, 1.186)
All Estimates		1.054	0.044	24.253	<.0001	(0.969, 1.139)

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Severity	Collision Type	Study Estimate	95% CI	Elvik et al (2009) Estimates	95% CI	Percent Difference
Injury	All	1.14	(0.85, 1.43)	1.18	(0.84, 1.66)	0.86%
PDO	All	0.98	(0.82, 1.14)		N/A	
Unspecified	All	1.08	(0.97, 1.18)	1.04	(0.95, 1.13)	0.84%
Unspecified	Peak Period	1.01	(0.77, 1.26)	1.15	(0.97, 1.37)	3.13%
Unspecified	Off Peak Period	1.01	(0.84, 1.19)		N/A	
All Estimates		1.05	(0.97, 1.14)		N/A	

- Raw odds ratios distribution is skewed, mean estimate may be larger than true mean

- Transform CMF to log(CMF), $s_{ideal} = \sqrt{\dfrac{1}{A} + \dfrac{1}{B} + \dfrac{1}{C} + \dfrac{1}{D}}$

Severity	Collision Type	Q-statistic	p-value	Estimated CMF	Standard Error	z-value	p-value	95% CI
Injury	All	5.375	0.994	1.280	0.116	2.122	0.034	(1.019, 1.608)
PDO	All	10.724	0.826	1.033	0.080	0.404	0.686	(0.884, 1.207)
Unspecified	All	67.251	0.001	1.230	0.045	4.571	<.0001	(1.126, 1.344)
Unspecified	Peak Period	27.129	0.511	1.434	0.102	3.532	0.000	(1.174, 1.752)
Unspecified	Off Peak Period	21.782	0.083	1.109	0.075	1.382	0.167	(0.958, 1.285)
All Estimates		87.460	0.066	1.189	0.037	4.632	<.0001	(1.105, 1.279)

Agresti 2010, Fleiss, Levin and Paik 2003

- In general, collisions expected to increase with installation of reversible lanes

- Use of raw odds ratios - significant and homogeneous CMF estimates in line with previous estimates
  - 2% decrease (PDO) to 14% increase (injury) in collisions
  - Skewed distribution

- Log-transformed odds ratios – higher CMF estimates, varying levels of heterogeneity, significance
  - 3.3% increase (PDO) to 43% increase (Peak period crashes)

- More study needed, work ongoing

- Develop and continue researching way to account for non-normal distribution of CMFs, while accounting for study quality, confounders

- Continue systematic search – published and non-published

Questions?

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