Transferability of CMFs

Crash Modification Factor
CMF = (Expected crashes with)/(Expected crashes w/out)

Transferability: “Whenever a future action is contemplated, CMF estimates that come from experience with similar actions implemented in the past and in other locations must be relied upon”

External Validity: (1) “generalizability of empirical findings to new environments, settings, or populations” (2) Going from “It worked somewhere” to “It’ll work here”

Transportability: “license to transfer causal effects learned in experimental studies to a new population, in which only observational studies can be conducted”
Our Project

SITUATION
• Existing CMFs are statistical summaries of driver/vehicle mixes from last ~20 years
• This will change if/when automated vehicles increase market share
• Can existing knowledge be ‘transferred’ to new situation?

OBJECTIVE
• Exploratory analysis of how to transfer a CMF, estimated for one set of conditions, to a different set of conditions.

METHODOLOGY
• Apply “transportability” analyses developed by Pearl and Bareinboim to plausible crash scenarios.

Example Scenario 1: Pedestrian Crashes and Speed Humps

X = 0, no speed hump
  1, speed hump
Y = 0, pedestrian not hit
  1, pedestrian hit
S = 0, your street
  1, my street
V = vehicle speed
Transportability Analysis

Key Fact:
Node \( V \) blocks paths from \( X, S \) to \( V \)

\[
CMF = \frac{\sum P(Y = 1 | V = v) P(V = v | S = 0, X = 1)}{\sum P(Y = 1 | V = v) P(V = v | S = 0, X = 0)}
\]

CMF for my street

\[
CMF^* = \frac{\sum P(Y = 1 | V = v) P(V = v | S = 1, X = 1)}{\sum P(Y = 1 | V = v) P(V = v | S = 1, X = 0)}
\]

Example Scenario 2

\( Y = \) crash occurrence/non-occurrence
\( X = \) absence/presence safety treatment
\( U = \) input to \( Y \) affected the treatment
\( V = \) input to \( Y \) not affected by treatment
\( S = \) selection node, denoting original or new situations
‘Recalibration’ Formula for Scenario 2

\[
CMF^* = CMF \left( \frac{\sum P(V = v | S = 1) P(V = v | Y = 1, X = 1, S = 0)}{\sum P(V = v | S = 0) P(V = v | Y = 1, X = 0, S = 0)} \right)
\]

What is this stuff?

CMF* = new CMF  
CMF = old CMF

P(V=v|S=1)  distribution of V in new situation

P(V=v|S=0)  distribution of V in old situation

P(V=v|Y=1,X=1,S=0)  distribution of V in crashes, old situation, with modification

P(V=v|Y=1,X=0,X=0)  distribution of V in crashes, old situation, without modification
First Simulation Study: Pedestrian Hybrid Beacons

CMFs for PHBs
0.31 (Tucson)
0.24 (several cities)

Goal: transfer current CMF estimate
Original situation: all vehicles human-operated
New situation: 50% vehicles equipped with autobraking

Pedestrian Crash Model

\[ Y = \text{Crash outcome (0/1)} \]
\[ X = \text{PHB installation (0/1)} \]
\[ t = \text{driver reaction time (sec)} \]
\[ a = \text{driver braking rate (ft/sec}^2) \]
\[ v_1 = \text{vehicle initial speed (ft/sec)} \]
\[ d_1 = \text{initial distance (ft)} \]
\[ \text{gap} = \text{vehicle gap (sec)} \]
\[ S1 & S2 = \text{original/new situation (0/1)} \]
\[ \text{accept} = \text{whether or not the pedestrian accepts the gap (0/1)} \]
\[ r_1 = \text{pedestrian reaction time (sec)} \]
\[ v_2 = \text{pedestrian walking speed (ft/sec)} \]
\[ d_2 = \text{distance from pavement edge to conflict zone (ft)} \]
\[ w = \text{vehicle width (ft)} \]
First Simulation Study: Results

Simulation model calibrated to reproduce
CMF approximately equal to those reported (CMF=.27)
Pedestrian injury severities similar to those from Twin Cities

Results
CMF* from direct simulation: (.249,.265)
CMF* from recalibration: (.262, .265)

Little difference between CMF and CMF* because simulated
PHB operates on via ped behavior

Second Simulation Study: Left-Turn Lane Offsets

Lane Widening CMFs from literature
0.985 (Nebraska study)
0.886 (Florida study)
Left Turn Crash Simulation Model

$q = \text{opposing traffic flow}$

$h = \text{traffic stream gap}$

$tc = \text{left-turning vehicle's turning time}$

$v = \text{opposing vehicle speed}$

$d = \text{opposing through vehicle's position}$

$\text{accept} = 0, \text{gap rejected by LT driver}$

$1, \text{gap accepted by LT driver}$

$tp = \text{opposing driver's reaction time}$

$f = \text{opposing driver's braking rate}$

$Y = 0, \text{no crash}$

$1, \text{crash between}$

$SDa = \text{available sight distance of LT driver}$

$\text{block} = 0, \text{if opposing LT lane not occupied}$

$1, \text{if opposing LT occupied}$

$X = 0, \text{LT lane offset =-10 feet}$

$1, \text{LT lane offset =-8 feet}$

$S = 0, \text{no automation}$

$1, 50\% \text{ emergency brake assist}$

Simulation Site

Intersection geometry: Winnetka and Golden Valley Road
Model calibrated to
Approximate CMFs from literature
Crash features similar to 8 reconstructed LT crashes
### Results from Direct Simulation

#### All Human Drivers

<table>
<thead>
<tr>
<th>Condition</th>
<th>Offset</th>
<th>Crashes</th>
<th>Crash Probability</th>
<th>CMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>X=0</td>
<td>-10 ft</td>
<td>855</td>
<td>.00168</td>
<td>0.97</td>
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<td>X=1</td>
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<td>.00163</td>
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</table>

#### 50% Auto Braking

<table>
<thead>
<tr>
<th>Condition</th>
<th>Offset</th>
<th>Crashes</th>
<th>Crash Probability</th>
<th>CMF</th>
</tr>
</thead>
<tbody>
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<td>0.94</td>
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<tr>
<td>X=1</td>
<td>-8 ft</td>
<td>408</td>
<td>.00080</td>
<td></td>
</tr>
</tbody>
</table>

### CMFs via Transport Formula

\[
CMF^* = (CMF) \left[ \frac{\int \frac{g(tp, f | Y = 1, X = 1, S = 0)}{g(tp, f | S = 0)} \, dt \, df}{\int \frac{g(tp, f | Y = 1, X = 0, S = 0)}{g(tp, f | S = 0)} \, dt \, df} \right]
\]

\[
= (0.93) \left( \frac{0.502}{0.502} \right) = 0.93
\]
CONCLUSIONS

• Pearl and Bareinboim “transportability” analysis potentially applicable to assess “transferability” of a CMF

• Application requires graphical causal model explaining how CMF works

• At this point, method most useful in identifying what data are needed to support transferability

• Ongoing Work
  – Reconstruction of NHTSA crashes
  – Application of transportability to sight distance at stop-controlled intersections

THANK YOU

QUESTIONS?