Multiobjective Optimization of Lane and Shoulder Widths at Rural Two-lane Highways

Samuel Labi, Sikai Chen, Yu Qiao, Paul V. Preckel, Qiang Bai and Wubeshet Woldemariam

MOTIVATION
- Wider lanes and shoulders generally help to reduce crashes.
- For 2-lane roads:
  - Total Roadway Width (TRW) = 2(Shoulder width + lane width)
- For fixed TRW, what fractions to lane width & shoulder width?
- Which is safer?
  - Wider lanes with narrow shoulders? OR
  - Narrow lanes with wide shoulders?
- For a given TRW, need to quantify the tradeoffs between shoulder and lane widths, in terms of total life-cycle agency and user costs.

DATA DESCRIPTION
- Crash prediction models: 2006 INDOT study (Labi, 2006).
- Construction & maintenance cost data
  - Shoulder: Iowa State University 2001 study
  - Lane: Wisconsin and Washington DOT studies.

METHODOLOGY
- Examples of crash prediction models
  - Property damage only
    \( \text{Fatal} + \text{Injury} \) = \( 4.06689 + 0.8706 \times LN(LENGTH) + 0.6259 \times LN(AADT) - 0.0617 \times LW - 0.0119 \times SW - 0.0190 \times FR + 0.0163 \times ARAD + 0.1100 \times AGRAD \)
  - Fatal-injury
    \( \text{fatal} \) = \( 6.6231 + 0.9237 \times LN(LENGTH) + 0.8526 \times LN(AADT) - 0.0928 \times LW - 0.0321 \times SW - 0.0156 \times FR + 0.0262 \times ARAD + 0.0541 \times AGRAD \)
- Nonlinear Optimization framework
  Obj: Minimize
  \[ T(LW, SW) = 2\left( \frac{V_{\text{agency}}(CC_1 \times LW + CC_2 \times SW)}{L} + \frac{(1+\gamma)^{N-1}}{(1+\gamma)^{N-1}} \sum_{i=1}^{N} c_{F}\mu_{k}(LW, SW) \right) \]
  S.T.: 
  \[ 2LW + 2SW = TRW; \quad LW \geq MLW \]

RESULTS (continued)
- Total life cycle benefits across road functional classes for different TRWs

CONCLUSIONS
- Study developed a framework for determining the optimal allocation of shoulder and lane widths on two-lane rural highways.
- For minor arterials and major collectors:
  - Optimal solutions (funnel diagrams) are similar.
  - Optimal solutions have zero shoulder widths (lanes take up all TRW)
  - Low weights of the user cost, the optimum has a lane width of 10 ft., and the shoulder takes up the remaining TRW.
- For principal arterials
  - Optimal solution: lane width of 10 ft.; the rest of the TRW taken up by shoulder.
- Highway agencies can use the developed framework or decision support charts to determine the optimal lane and shoulder widths for a given highway functional class, total available roadway width, and other factors.

ACKNOWLEDGEMENTS & DISCLAIMER
- Steven Lavrenz is acknowledged for initial work on this paper.
- The support of the JTRP program is greatly acknowledged, which made this study possible.
- This poster is based on a paper that has been accepted for publication in Transportmetrica Journal.