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

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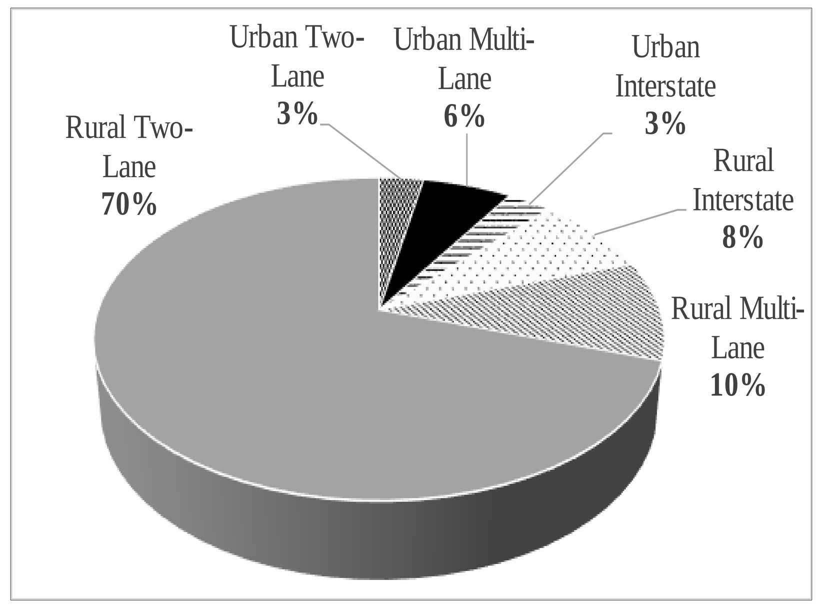
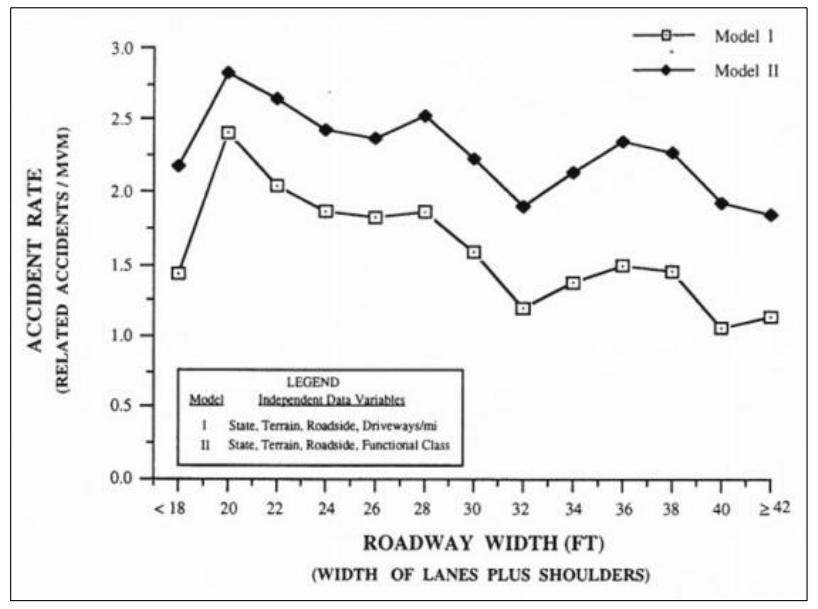
MOTIVATION

- 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

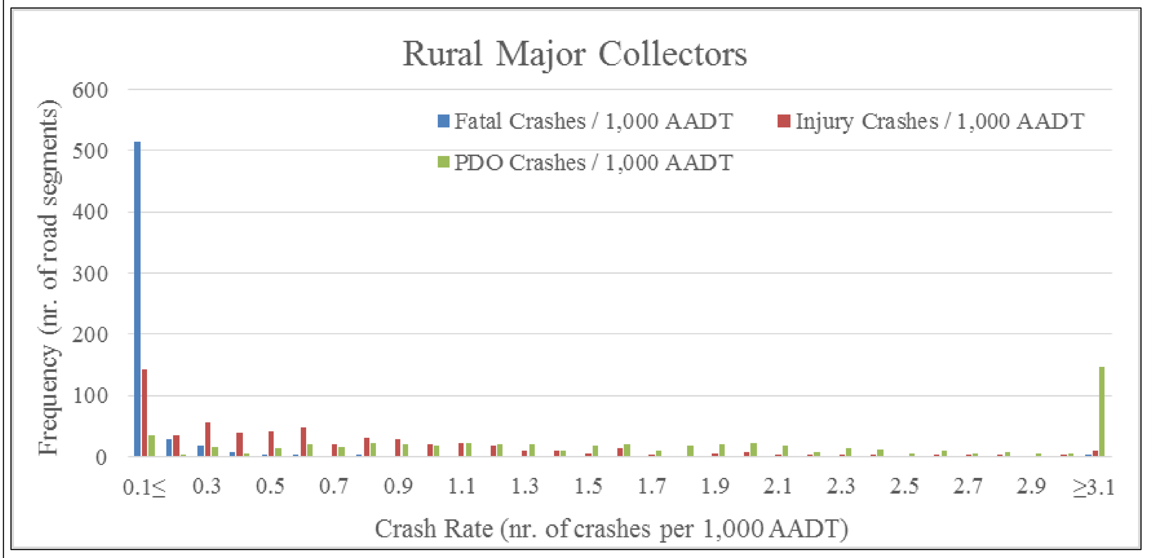
- Crash prediction models: 2006 INDOT study (Labi, 2006).
- Construction & maintenance cost data
  - Shoulder: Iowa State University 2001study
  - Lane: Wisconsin and Washington DOT studies.

METHODOLOGY

- Examples of crash prediction models

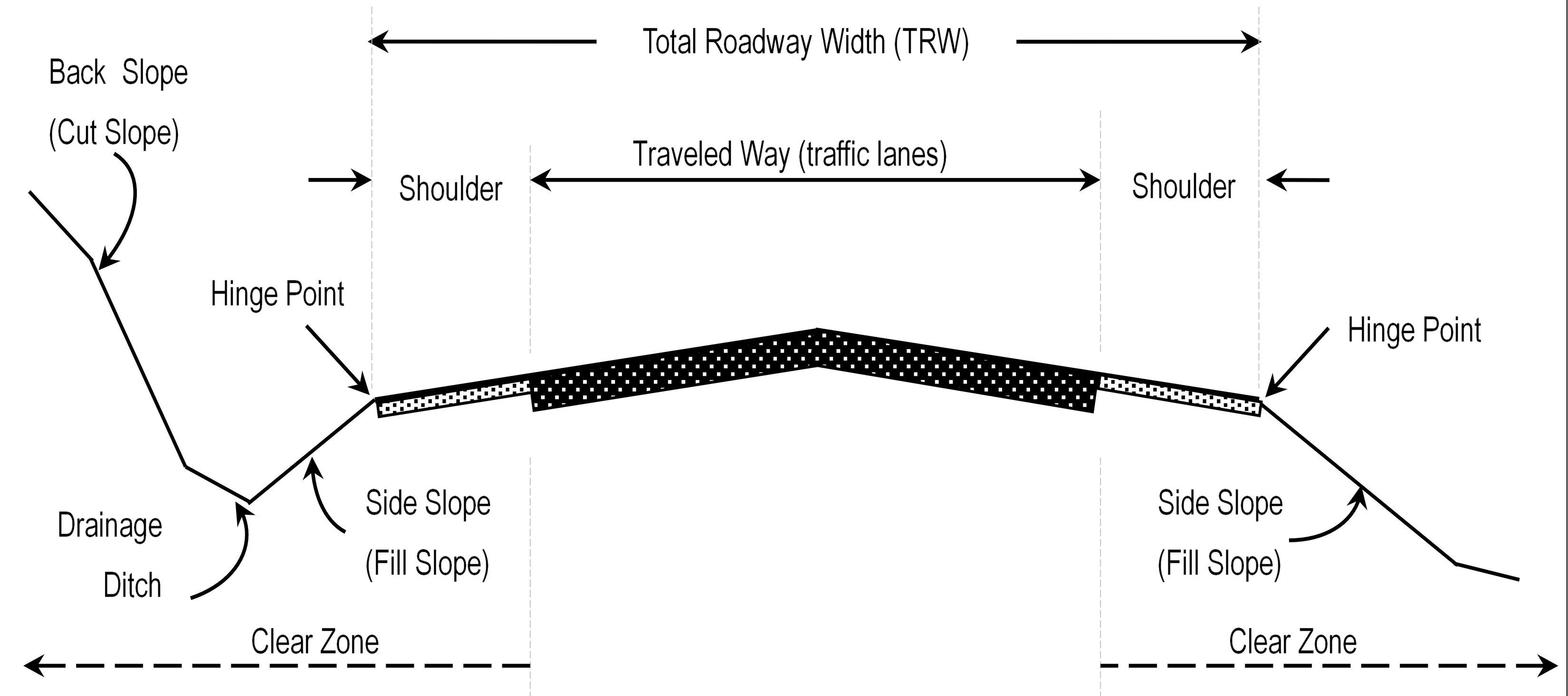
$$\mu_{Property\ damage\ only} = \exp[-4.06689 + 0.8706 * LN(LENGTH) + 0.6259 * LN(AADT) - 0.0617 * LW - 0.0119 * SW - 0.0190 * FR + 0.0163 * ARAD + 0.1100 * AGRAD]$$

$$\mu_{fatal+injury} = \exp[-6.6231 + 0.9237 * LN(LENGTH) + 0.8526 * LN(AADT) - 0.0928 * LW - 0.0321 * SW - 0.0156 * FR + 0.0262 * ARAD + 0.0541 * AGRAD]$$



Estimated unit crash cost values ($ per crash)	
Fatal + Injury	$509,086
PDO	$5,244

METHODOLOGY (continued)



- Nonlinear Optimization framework

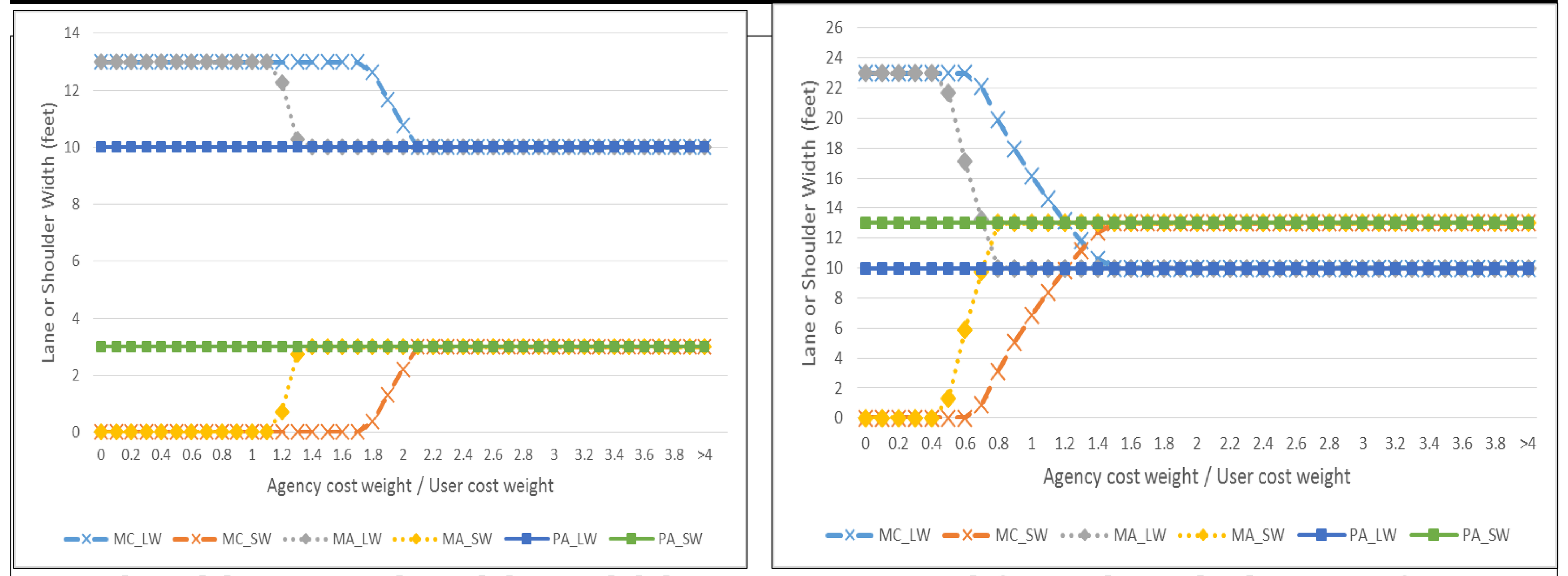
Obj: Minimize

$$T(LW, SW) = 2\{w_{agency}[(CC_l * LW + CC_s * SW)L + \frac{(1+i)^N - 1}{i(1+i)^N}(MR_l * LW + MR_s * SW)L] + w_{user}\frac{(1+i)^N - 1}{i(1+i)^N}\sum_1^k c_k \mu_k(LW, SW)\}$$

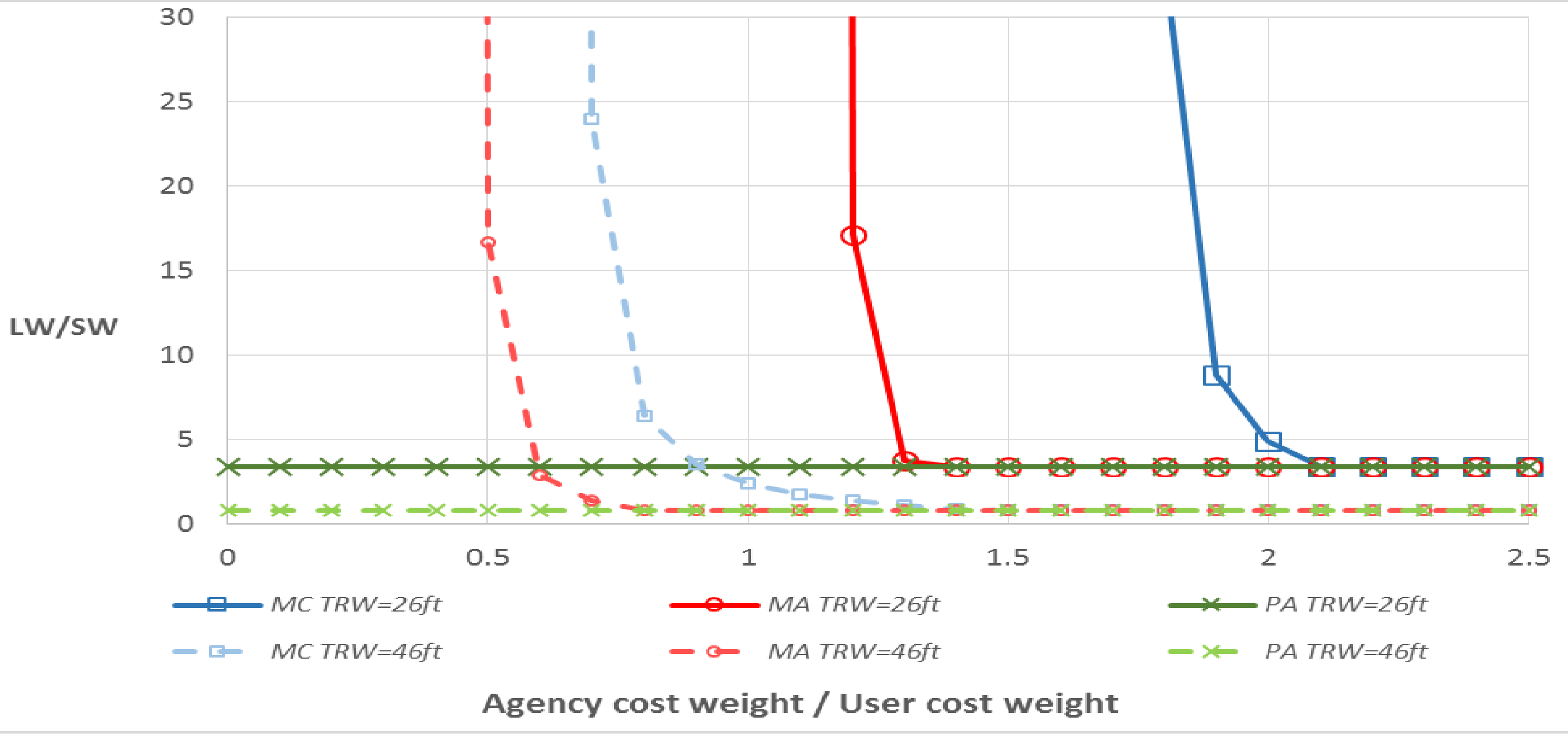
s.t.:

$$2LW + 2SW = TRW; \quad LW \geq MLW$$

RESULTS



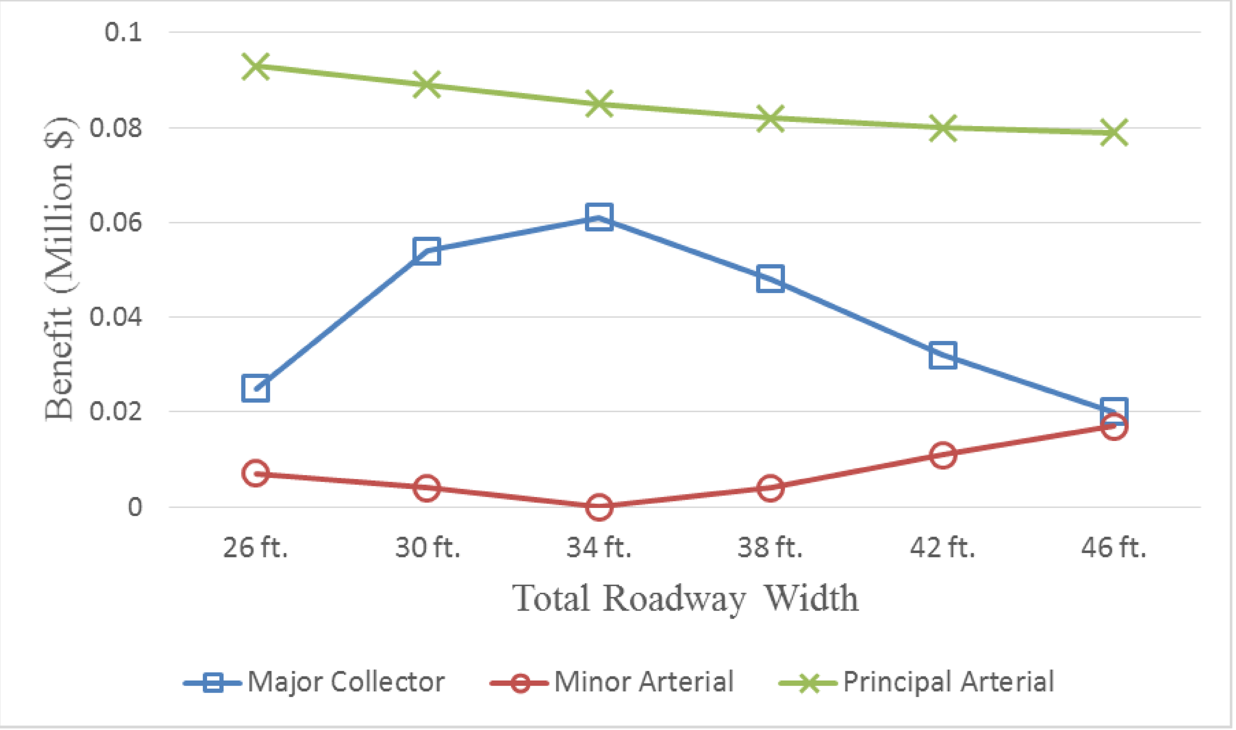
Optimal lane & shoulder widths across road functional classes for different TRWs (24 and 46 ft.)



Optimal lane and shoulder width RATIO for different weights of agency and user cost, for different TRWs and road classes

RESULTS (continued)

Total LCB (M $) / TRW	Major Collector			Minor Arterial			Principal Arterial		
	Current practice	Optimal	Benefit	Current practice	Optimal	Benefit	Current practice	Optimal	Benefit
26 ft.	1.516	1.491	0.025	1.578	1.571	0.007	1.792	1.699	0.093
30 ft.	1.465	1.411	0.054	1.485	1.481	0.004	1.582	1.493	0.089
34 ft.	1.418	1.357	0.061	1.401	1.401	0	1.409	1.324	0.085
38 ft.	1.374	1.326	0.048	1.327	1.323	0.004	1.268	1.186	0.082
42 ft.	1.333	1.301	0.032	1.262	1.251	0.011	1.153	1.073	0.080
46 ft.	1.296	1.276	0.020	1.204	1.187	0.017	1.060	0.981	0.079



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.
  - For high user cost weights, the optimal solutions have zero shoulder width (lanes take up all TRW)
  - For 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.

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