14 Multi-Objective Optimization Model for Urban Street Design- Aimee Flannery
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Summary:

For decades transportation legislation actions have demonstrated the desire to plan, design and operate multi-modal surface transportation systems. The push for multi-modal operations stems from several key concerns including environmental impacts, natural resource scarcity, rising fuel costs and dependency on foreign oil, and the declining health of Americans due to their reliance on personal automobile travel. However, it has been determined that the methods needed by engineers and planners to design such facilities are currently lacking in their ability to reflect travelers’ perceptions of service by mode which is needed to successfully design such multi-modal transportation systems. In addition, design guidance does not include methods by which engineers and planners can weigh the range of potential alternative designs to optimize the design of streets to comfortably accommodate all modal travelers.

The purpose of this study was to develop a Multi-objective Optimization Model to support the design of Complete Streets and to identify optimal urban street designs that achieve a predefined level of service rating for travelers on an urban arterial including auto, pedestrian and bicycle modal users, while meeting geometric design standards. To achieve this goal, existing Cumulative Logit Level of Service (LOS) Models were utilized for the auto, pedestrian and bicycle modes that incorporate traveler’s perceptions of Level of Service and provide a distribution of perceived LOS to assist decision makers.

The objective function and the constraints for the Multi-objective Optimization Model were developed using the existing Cumulative Logit Models for auto, pedestrians, and bicycle modes. The variables used in the model were found to be statistically significantly correlated to traveler’s perception of LOS including: Space Mean Speed (SMS) and Median Presence (MP) for the auto mode; Number of Traffic Lanes (NL), and Sidewalk Width (SWC) for the pedestrian mode and Number of Traffic Lanes (NL), Bike/Shoulder Width (BW) and Posted Speed Limit (PSL) for bicycle mode.

The objective of the Multi-objective Optimization Model was to design an urban street so as to minimize LOS D or worse (E or F) provided to auto, pedestrian, and bicycle modes on urban streets for a set of constraints. Conversely, optimize the urban street design so as to maximize LOS to D or better provided to auto, pedestrian, and bicycle modes. Thus, the set of optimized geometric variables obtained for an urban street design will accommodate all modes simultaneously with the user perception taken into account.

The sets of constraints in the model were based on the level of satisfaction of the users of auto, pedestrian, and bicycle modes which can also conflict with each other. For example, auto drivers perceive a higher level of satisfaction when the average travel speed is higher or equivalent to the posted speed limit and the roadway has multiple lanes. By contrast, pedestrians and bicyclists perceive a higher level of satisfaction when their facilities adjoin streets with low traffic speed and fewer traffic lanes. The main constraint of the optimization model was as follows:

Optimized ROW = Given ROW
Optimized ROW = Median Width + (No. Traffic Lanes X Traffic Lane Width + SW Width + Grass Strip + Bike Lane Width) X 2
The Right of Way (ROW) constraint was developed to reflect the state of the practice and established standards by governing bodies such as the American Association of State Highway and Transportation Officials (AASHTO, 2004). In addition, a set of new decision variables as well as a set of non-decision variables were added to aid the design of a Complete street and livable community.

The sensitivity analysis using the multi-objective optimization model was conducted for the following scenarios:

- For a given Right of Way width obtain optimal number of traffic lanes with optimized lane width, median width, sidewalk width, and bike lane width
- For a given Right of Way width and given number of lanes obtain optimal lane width, median width, sidewalk width, and bike lane width

For example, for a 100 feet ROW width and three traffic lanes in each direction, the model provided optimal lane width for the traffic lanes to be 12 feet, sidewalk width to be 9 feet, and bike lane width to be 5 feet on each side of the road. The model did not provide a median in this case.