A COST EFFECTIVENESS SKETCH METHOD FOR SAFETY INVESTMENT
DECISION-MAKING

Daniel Wu*
Transportation Analyst
Cambridge Systematics
555 12th Street, Suite 1600
Oakland, CA USA 94607
Telephone: 510-879-4326
Dwu@camsys.com

Beth Wemple
Senior Associate
Cambridge Systematics
555 12th Street, Suite 1600
Oakland, CA USA 94607
Telephone: 503-235-0906
Bwemple@camsys.com

Submission Date – August 1, 2013

4,613 words + figures (250 x 5) + table (250 x 3) = 6,613 words

*Corresponding author
**ABSTRACT**

The recent Moving Ahead for Progress in the 21st Century Act (MAP-21) emphasizes a performance-based, outcome-driven planning process to meet performance targets. One area of performance-based planning highlighted by MAP-21 is safety planning. State DOTs and metropolitan planning organizations (MPOs) will be required to document how their strategic highway safety plan (SHSP) supports the state safety performance targets. Presently, to maximize safety improvements for every dollar of investment, a cost-effectiveness analysis is used within sub-disciplines of safety planning, but is rarely used to compare projects across the 4 Es of safety: education, engineering, enforcement, and emergency response.

This paper proposes a sketch method for analyzing cost-effectiveness analysis of safety investment decision-making across the 4 Es. The sketch-level method is appropriate when quantitative project information, such as crash reduction effectiveness, target population, and duration of project effectiveness are unavailable or are not complete. The sketch method results in multi-disciplinary safety investments grouped by their relative cost-effectiveness, allowing practitioners to use this information to prioritize investments for implementation. This paper concludes with results from a demonstration application of the sketch method to safety projects provided by the North Carolina Department of Transportation (NCDOT).
A COST EFFECTIVENESS SKETCH METHOD FOR SAFETY INVESTMENT

INTRODUCTION

When faced with budget constraints, public agencies have to focus funding on cost effective investments. In the traffic safety community, these investments typically address safety issues from four perspectives – engineering, enforcement, education, and emergency service – known as the 4 Es. Until recently, public agencies have evaluated cost effectiveness of safety investments within each perspective, but rarely do agencies evaluate cost effectiveness of projects across the 4Es. Federal programs often limit the need to evaluate across disciplines, as many of them channel funding to specific solutions if not specific programs and projects. For instance, state departments of transportation (DOTs) often compare cost effective metrics, such as benefit cost ratios, for engineering countermeasures funded through the Federal Highway Safety Improvement Program (HSIP); however, state DOTs rarely compare the cost effectiveness of behavioral countermeasures (enforcement, education, and emergency services) in their highway safety programs.

The recently authorized Federal transportation legislation, Moving Ahead for Progress in the 21st Century Act (MAP-21), allows agencies greater funding flexibility and encourages agencies to prioritize resources to investments across the 4Es that reduce the largest number of fatalities and serious injuries. However, information required for a quantitative comparison of investments is often not available or is time-intensive to collect. The sketch method outlined in this paper addresses these gaps and guides practitioners on comparing investments when resource and information constraints preclude a quantitative comparison. The sketch method was developed as a part of a National Cooperative Highway Research Project (NCHRP) 17-46 for building a comprehensive framework for safety investment decisions (1).

Prior to MAP-21, SAFETEA-LU authorized states with Strategic Highway Safety Plans the flexibility to use up to 10 percent of their HSIP funds for non-infrastructure (enforcement, education, and emergency service) safety projects if these projects met infrastructure and safety needs outlined in their State’s Strategic Highway Safety Plans (2). MAP-21 removes this 10 percent cap on flexible funding and expands the definition of highway safety improvement projects such that HSIP funds can be used for both infrastructure and non-infrastructure highway safety improvement projects that are consistent with the State’s Strategic Highway Safety Plan (3). Under this legislation, 4E countermeasures are eligible for HSIP funds if they address a data driven need and can be shown to reduce fatalities and serious injuries. MAP-21 also requires that non-infrastructure projects identified for HSIP funding are consistent with projects identified in the Statewide and Metropolitan Transportation Improvement Program (STIP and TIP), and Long Range Transportation Plans (LRTPs). This requirement highlights the importance for practitioners to compare cost effectiveness across the 4Es and to ensure that state and local level investment priorities are consistent.

REVIEW OF CURRENT METHODS

This section discusses various methodologies for conducting quantitative analysis for prioritizing safety investments. Two methodologies – benefit-cost and cost-effectiveness analysis – are routinely used to compare safety countermeasures, and the methods are well-developed. For example, a survey of safety engineers at state departments of transportation indicated the vast majority used benefit-cost analysis to prioritize safety countermeasure selection (4).

Benefit-Cost Ratio Analysis

Benefit-cost ratio is the ratio of the present-value benefits of a project to the cost of the project. The American Association of State Highway and Transportation Officials’ (AASHTO) Highway Safety Manual (HSM) contains a chapter on the prioritization of engineering safety investments according to their benefit-cost ratio (5). The first step in this prioritization procedure is to calculate the present value of the societal benefits from safety investment implementation. The societal benefits are estimated by multiplying the predicted crash reduction (severity and type) by the state or the local jurisdictions’ estimated societal crash costs by crash severity and collision type. To get the benefit-cost ratio, estimated project benefits are divided by the present value of the estimated project cost. Investments are then ranked from the highest to the lowest ratio for implementation. This method can be used by highway agencies to justify engineering improvements funded through the Federal...
Highway Administration’s (FHWA) HSIP; typically, only projects with ratios greater than one are eligible for HSIP funding (5). The NCHRP Report 622 provides similar procedures for estimating costs and benefits of implementing behavioral (enforcement, education, and emergency service) investments. The report offers benefit-cost ratio range for seven different types of behavioral investments based on existing research and investment implementations (6).

Cost-Effectiveness Analysis
The HSM also provides practitioners guidance on cost-effectiveness analysis for engineering safety investments (5). This analysis directly compares predicted changes in crash frequency to project costs without converting the changes in frequency as monetary values. The analysis produces a cost-effectiveness index calculated as the ratio of the present value of project cost to the estimated change in average crash frequency over the improvement’s life. Practitioners would prioritize projects according to their cost-effectiveness index.

Other Tools
Various software tools help practitioners compare countermeasure effectiveness such as PLANSAFE, Interactive Highway Safety Design Model (IHSDM), and the Level of Service of Safety (LOSS) tool (7,8,9). However these tools focus primarily on estimating the safety benefits of implementing engineering countermeasures, and do not evaluate projects effectiveness in conjunction with their costs.

The SafetyAnalyst software recommends a list a of potential countemeasures needs based on roadway characteristics, traffic volumes, and accidents (10). With the countermeasures selected by end-users, SafetyAnalyst performs an economic appraisal based on cost effectiveness (countermeasure cost per accident reduced), benefit-cost ratio, and net present value (excess present value of monetary benefits over present value of countermeasure costs). Users can then prioritize sites and proposed projects based on the benefit and cost estimates from the economic appraisal. SafetyAnalyst is geared towards site specific engineering improvements, and practitioners would not be able to evaluate the benefits of behavioral safety countermeasures at multiple locations.

Quantitative Evaluation of Safety Investments Across the 4Es
There is limited existing research providing guidance on comparing cost-effectiveness of safety investments across the 4Es. Greene-Roesel et al. outlined a method based on the HSM’s benefit-cost ratio analysis that compared four engineering and behavioral countermeasures on the Geary Boulevard corridor in San Francisco (11). Although the evaluation focused on the Geary Boulevard, consideration of other geographies was necessary to account for the different spatial scales of implementation for the various project types. The steps of this method are:

1. Select safety countermeasures to be analyzed. These countermeasure are determined by the crash history of the site and known traffic, operational, and behavioral factors.
2. Specify the level of deployment of each countermeasure – where and when will these countermeasures be implemented, and their spillover effects.
3. Estimate the crash reduction effectiveness for each countermeasure after implementation using available safety literature. Crash reduction effectiveness is represented as crash modification factors (CMFs) or the multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure.
4. Specify the time period that the countermeasure will be effective.
5. Estimate countermeasure costs given the level of deployment.
6. Estimate the number of target injuries and fatalities that could potentially be affected by the countermeasure.
7. Estimate countermeasure benefits and calculate a benefit-cost ratio.

Provided with the information for these seven steps, practitioners can compare the benefit-cost ratio and prioritize engineering and safety countermeasures implemented at different levels of geography and for different time periods of implementation.
Limitations with the Quantitative Evaluation Method

While the quantitative evaluation method developed by Greene-Roesel et al. allows a comparison of a set of diverse safety investments, practitioners are often faced with time and information constraints. In some instances, such as grant funding prioritization, practitioners are faced with a large number of projects and time constraints thus limiting the depth of analysis possible for each. Many elements of candidate investment opportunities are not quantitatively known (e.g., crash modification factors, costs, and locations), or no basis exists for making assumptions. In particular, behavioral projects such as enforcement or education can have qualitative, anecdotal results that vary by context. Results from the quantitative method may also be strongly influenced by assumptions made along the way. For example, a practitioner could assume a drunk driving education program influenced the driving behaviors of 1,000 motorists, instead the program only influenced the behaviors of 200 motorists, the program would be less cost effective than the practitioner had assumed. Rather than presenting a single benefit-cost ratio or cost-effectiveness index with a project, it might be necessary to conduct a sensitivity analysis to show a range for this ratio or index based on different assumptions.

PROPOSED METHOD

This paper proposes a sketch method that is appropriate when quantitative information is unavailable or when detailed results are not required in analyzing a large number of safety investments. FIGURE 1 shows the steps in the sketch-level method.

FIGURE 1 Sketch Method Overview.

The sketch method relies on scoring investments with three scores developed through reference to quantitative and qualitative information:

1. Effectiveness score indicates the relative effectiveness of the countermeasure.
2. Problem score indicates the relative size of the target crash population potentially affected by the countermeasure.
3. Cost score indicates the annualized cost of the countermeasure relative to other measures.

The three scores can be used to graphically illustrate relative investment costs, effectiveness, and potential impact. Practitioners can group investments into four tiers and implement them by relative priority, as shown in FIGURE 2:

- Tier 1: Higher effectiveness investments that address a larger target crash population
- Tier 2: Higher effectiveness investments that address a smaller target crash population.
- Tier 3: Lower effectiveness investments that address a larger target crash population.
- Tier 4: Lower effectiveness investments that address a smaller problems crash population.
FIGURE 2 Project Prioritization Tier System.

Effectiveness Score

The sketch method’s first step is assigning an effectiveness score of one to four for each investment by looking up effectiveness information in the national safety research literature. This score represents the countermeasure’s effectiveness and the quality of the research used to derive countermeasure’s effectiveness. The scoring process is based on the uniform effectiveness typology proposed in TABLE 1.

TABLE 1 Measures of Effectiveness from Safety Research Literature

<table>
<thead>
<tr>
<th>Source</th>
<th>Highly Effective</th>
<th>Effective</th>
<th>Somewhat Effective</th>
<th>Unknown or Ineffective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash Modification Factor Clearinghouse</td>
<td>CMF &lt; 0.7 and Quality Score 4-5</td>
<td>0.7 &lt; CMF &lt; 1, and Quality Score 4-5</td>
<td>CMF &lt; 1, and Quality Score 3</td>
<td>Quality Score &lt; 3 or CMF &gt; 1</td>
</tr>
<tr>
<td>HSM</td>
<td>CMF &lt; 0.7 and Adjusted Standard Error &lt; 0.2</td>
<td>0.7 &lt; CMF &lt; 1 and Adjusted Standard Error &lt; 0.2</td>
<td>CMF &lt; 1 and 0.2 &lt; Adjusted Standard Error &lt; 0.4</td>
<td>CMF &gt; 1 or N/A or Adjusted Standard Error &gt; 0.4 or N/A</td>
</tr>
<tr>
<td>Countermeasures that Work</td>
<td>5 stars</td>
<td>4 stars</td>
<td>3 stars</td>
<td>≤ 2 stars or Star Rating Unavailable</td>
</tr>
<tr>
<td>NCHRP 500/NCHRP 17-17(3)</td>
<td>Proven</td>
<td>Proven</td>
<td>Likely</td>
<td>Tried or Experimental</td>
</tr>
<tr>
<td>NCHRP 622</td>
<td>Proven</td>
<td>Proven</td>
<td>Likely</td>
<td>Unknown/Uncertain/Unlikely</td>
</tr>
<tr>
<td>Effectiveness Score</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
Engineering Countermeasures

The effectiveness of engineering investments is evaluated according to the treatment’s CMF – a multiplicative factor used to calculate the expected change in crash frequency and/or severity associated with implementing a safety countermeasure investment – and the reliability of the safety research that the CMF is based on. This information is drawn from two main sources: the HSM (5) and the FHWA Crash Modification Factors Clearinghouse (12). Countermeasures drawn from the HSM receive the highest score of four if they have low CMFs (CMF < 0.7) and low standard deviation. Similarly, countermeasures drawn from the CMF Clearinghouse receive the highest score of a four if they have a low CMF (CMF < 0.7) and a CMF quality score of 4 or 5 (representing the highest-quality studies according to the CMF Clearinghouse).

Behavioral Countermeasures

Behavioral investment’s crash reduction effectiveness is based on countermeasure effectiveness ratings from three behavioral safety resources: National Highway Traffic Safety Administration’s Countermeasures that Work (13), the NCHRP Report 500 Series: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan Transportation Research (14), and the NCHRP Report 622: Effectiveness of Behavioral Highway Safety Countermeasures (6). Each of these resources has its own method of measuring countermeasure effectiveness. For instance, the Countermeasures that Work report gives five stars to countermeasures demonstrated to be effective by several high-quality evaluations with consistent results, and gives two stars to countermeasures with undetermined effectiveness.

Problem Score

Top-down method

The next sketch method step examines the relative magnitude of safety problems targeted by a project – the problem score. The problem score is determined using a top-down method that first selects a common geography of analysis for all projects of interest. For example, if a practitioner is focusing on projects competing for state-level resources, the common geography is the state. This method assumes that practitioners are interested in looking strategically at statewide safety problems and prioritizing projects based on whether they address significant statewide safety problems. FIGURE 3 shows an example of this top-down method applied to safety problems in North Carolina. The vertical bars in FIGURE 3 represent the average annual number of fatal and serious injuries crashes of key safety problems from 2008 to 2010 in North Carolina (14). A safety problem is assigned a statewide problem score from one to four as indicated at the top of FIGURE 3 one being the safety problem with the lowest number of fatal and serious injuries.

The sketch method assigns countermeasure problem score based on the safety problem that a countermeasure targets. For example, if a countermeasure targets unrestrained people, the problem score would be four, whereas a countermeasure that targets rear end crashes would receive a score of two. Note that the thresholds for the statewide problem score categories are based on natural breaks in the data and are subject to individual judgment. In the example shown in FIGURE 3, these thresholds between the score categories were set as 800, 300, and 100 annual fatal and serious injuries crashes.

Bottom-up method

An alternative method to assigning problem score involves determining the approximate number of crashes that could be addressed by each specific countermeasure. However, this estimation requires knowing or estimating the number of people potentially impacted by behavioral countermeasures and the expected duration of impact, which may not be well-defined. For these reasons, the sketch method did not proceed with a bottom-up method.
The sketch method’s third step is to determine an investment’s cost score relative to the cost of other investments. As shown in TABLE 2, the total engineering or behavioral project cost is annualized over the duration of the project to compare projects with varying service lives. For engineering projects, the annualized cost is the total project cost divided by the project’s service life in years as provided by the applicant’s funding application.

For behavioral projects, the annualized cost is the total project cost divided by the project’s assumed funding duration as specified in its funding request; most behavioral projects have a funding duration of one year and are funded through an annual grant cycle. However, some types of behavioral projects are expected to have impacts lasting beyond the conclusion of its funding duration. Based on research, the duration is assumed to be two years for DUI checkpoints and three years for seatbelt enforcement programs (15,16). Research on duration of effectiveness is limited for other behavioral countermeasures, and is currently being addressed as part of an active NCHRP study on Benefit-Cost Methodology for Behavioral Highway Safety Countermeasures (17). Therefore, this sketch method assumes all other behavioral projects have effectiveness duration of one year.

After annualized costs are calculated for engineering and behavioral projects, the sketch method scores a project (one to three) based on its relative annualized cost to other projects under evaluation; a cost score of one indicates that the project cost is relatively low in comparison to other projects. Note that the score category thresholds were determined by natural breaks in the ranking of the relative annualized costs of all subjects and are subject to individual judgement; for the example in TABLE 2, the thresholds were determined as $50,000 and $125,000.
TABLE 2 Cost Score Based on Annualized Project Cost

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Total Cost</th>
<th>Duration</th>
<th>Annualized Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conduct motorcycle safety checkpoints</td>
<td>$29,000</td>
<td>1</td>
<td>$29,000</td>
</tr>
<tr>
<td>Install shoulder guard rail</td>
<td>$1,200,000</td>
<td>10</td>
<td>$120,000</td>
</tr>
<tr>
<td>Child protection safety training and outreach</td>
<td>$564,000</td>
<td>1</td>
<td>$564,000</td>
</tr>
</tbody>
</table>

APPLICATION AND RESULTS

Sketch Method Application to Sample Projects from North Carolina

This section summarizes the results of applying the sketch method to 31 engineering and behavioral projects from North Carolina. These projects were selected from 156 behavioral (education and enforcement) projects drawn from North Carolina’s Governor’s Highway Safety Program (GHSP) project applications for the fiscal year (FY) 2012, and 74 engineering projects drawn from the North Carolina Department of Transportation’s (NCDOT) 2010 High Hazard Elimination program applications.

Projects were grouped into representative categories, and two to three representative projects were selected from each category and scored. Projects also were selected to represent the variations in cost and scope within each category. For engineering projects, the groups were based on similar safety improvements:

- Median improvements;
- Directional crossover and channelization;
- Turn lanes;
- Superelevation improvement;
- Roadway widening;
- Shoulder improvements;
- Traffic signal improvements;
- Pavement marking improvements; and
- Streetlight repair/upgrades.

For behavioral projects, the groups were based on projects addressing similar behavioral safety issues:

- Child protection safety;
- Local traffic enforcement/education;
- Alcohol impairment enforcement/education;
- Motorcycle safety;
- Young driver outreach;
- Hispanic outreach; and
- Law enforcement training/equipment upgrades.

The sketch method was applied to 31 projects that represent these engineering and behavioral safety improvements and issues.

Sketch Method Application Results

TABLE 3 presents the relative cost effectiveness of the 31 projects by combining the effectiveness, problem, and annualized scores.
<table>
<thead>
<tr>
<th>Project No.</th>
<th>Project Description</th>
<th>Effectiveness Score</th>
<th>Problem Score</th>
<th>Cost Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering Projects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Raised median and pedestrian improvements</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>18.26 miles of single face guard rail</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Directional crossover with median U-turn</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Roundabout in-lieu of existing intersection</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Left-turn lanes on all approaches and install a traffic signal</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Provide a continuous center-left turn</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Left-turn lane and pavement friction treatment</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Widen for a third travel lane</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>Install raised centerline pavement markers and upgrade existing signage</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>Add two-foot paved shoulders plus a minimum four-foot grass shoulders for 7.4 miles</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>Install shoulder guard rail</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>Extend the acceleration ramp and install snow-plowable RPM</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>Install shoulder rumble strips (four shoulders total) for 21 miles</td>
<td>4</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>Convert existing stop control intersection to signalized</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>Realign routes for continuous movement</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Behavioral Projects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Child protection safety training and outreach</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>17</td>
<td>Special needs seat distribution and conference/state fair outreach</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td>Local traffic safety enforcement (seat belt, speed and child safety seat)</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>Dedicated traffic safety unit (traffic safety and DWI enforcement)</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>20</td>
<td>Purchase in-car video to increase DWI arrest and to use for prosecution</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>BAT mobile unit program (check pts and outreach)</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>22</td>
<td>Mem units for monitoring high-risk DWI offenders</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>23</td>
<td>Underage alcohol prevention outreach and enforcement</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>24</td>
<td>Purchase motorcycles for training and expand motorcycle safety training facility</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>25</td>
<td>Conduct motorcycle safety check points</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>26</td>
<td>Improvement of driver education program implementation</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>27</td>
<td>Meeting room rental for young drivers safety conference</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>28</td>
<td>Fatal alcohol Goggles (for underage alcohol prevention outreach)</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>29</td>
<td>Hispanic driver safety outreach and child safety seat check</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>30</td>
<td>Crash investigation training, Radar and LIDAR for enforcement training program</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>31</td>
<td>Technology purchase to improve enforcement (radars, cameras, and trackers)</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>
Tiering Projects for Implementation

The final scores can be illustrated graphically by grouping projects into tiers for implementation. In FIGURE 4, each project is represented by a numbered circle, with the number corresponding to the project as listed in TABLE 3. FIGURE 4’s x-axis represents the effectiveness score, the y-axis represents the problem score, and the circle size represents the cost score of the project. Note that in FIGURE 4, all projects located in the same dashed line grid cell have the same effectiveness and problem scores regardless of their positions in the cell. Projects are color coded by type with engineering projects represented in black with white font, enforcement in light grey with black font, education in white with black font, and hybrid projects in dark grey with white font. Hybrid projects contain more than one type of behavioral countermeasure; for example, a hybrid project can consist of alcohol prevention outreach and enforcement.

FIGURE 4 Cost Effectiveness of Engineering and Behavioral Projects with Prioritization Tiers.

Tier 1 projects should be prioritized before the other tiers as they could deliver the most benefits and address the most significant problems. About the same number of engineering and behavioral projects fall into Tier 1, as well as projects of varying cost levels. Tier 2 projects would be prioritized after Tier 1 as they address less significant problems, but are equally as effective. Tier 3 projects would follow Tier 2 projects; even though they address significant problems, it is uncertain if they would be as effective as projects in Tiers 1 and 2. Finally, Tier 4 projects would have the lowest priority as they are not as effective and target less significant problems. Projects in Tiers 3 and 4 could also be submitted for further evaluation or pilot testing to confirm their effectiveness.

FIGURE 5 is another way of looking at the results, where projects are represented by slices of a pie, and the size of the slice is proportional to the annualized cost of the project. This graph is particularly useful for practitioners with a set budget; practitioners could select individual projects up to their set budget based on each individual project’s cost relative to the total tier project cost. Note that there are more engineering projects in Tiers 1 and 2, indicating that they are more effective. This is because there is a limited number of studies on the effectiveness of behavioral measures. As more information about the effectiveness of behavioral measures emerge, the distribution of projects in the tiers may alter.
CONCLUSIONS

The sketch method application allows the comparison of different project types, aids practitioners in making informed decisions by focusing on the most cost effective project types, when faced with resource and time constraints. In light of MAP-21’s emphasis on a comprehensive approach to safety investments, it is crucial that agencies can quickly compare engineering and behavioral projects of different crash reduction measures, geographic scope, duration of effectiveness, and cost. The sketch method’s results could also be represented in two cost-effectiveness graphs that allow practitioners to visualize and compare larger number of strategies. These graphs organize potential investments into prioritization tiers, and allow practitioners to efficiently identify projects for implementation.

Challenges with the Sketch Method

Several challenges exist in applying the sketch method:

- Practitioners might not be able to score projects because they have no direct impact on safety outcomes. For example, investment in a crash data search engine could improve crash reporting, however, research is limited on the magnitude of crash reduction from improving crash reporting.

- Applicants for project funding might not provide well defined descriptions on project implementation, such as the crash types that are targeted during traffic enforcement or the geographic scope of the project. In many cases, this information gap precludes estimating the size of the crash population expected to be impacted by specific behavioral measures. However, if the methods were regularly applied, practitioner’s project descriptions and information could improve.

- Proposed safety projects may contain multiple components, and each component may have a different effectiveness in addressing injuries and fatalities. While the HSM recommends that CMFs be multiplied to obtain an estimate of overall crash reduction for...
the project, this sketch method chose the component of each project with the highest effectiveness (5).

- It is difficult to determine annualized project costs for behavioral projects when the duration of impact is unknown. In most cases, the sketch method assumed that the duration of effectiveness is the same as funding duration; in most cases, funding duration lasts one year.
- The sketch method should be used to place projects into broad tiers (e.g., most cost-effective, least cost-effective), not to score individual projects.
- Application of this sketch method may mean that quantitative information available for certain projects is not fully used. For example, in comparing a group of 20 behavioral and engineering projects, it may be possible to quantitatively estimate cost-effectiveness for some of the engineering measures, but not the behavioral ones. To compare all the projects the same way, they must all be scored using the same scoring system even though some quantitative calculations are possible.
- The results of the scoring process are specific to the projects included in the process and can’t be compared with the results of another set of projects, since the scores are based on relative comparisons among the measures.
- This sketch-level process uses a scoring system for each project element; one to four for problem and effectiveness scores, and one to three for annualized cost. The practitioner is free to choose a different score range (e.g. one to five) for each element, but clear criteria will need to be established and documented for assigning scores.

Additional Research Areas

Additional research areas to improve the sketch method include:

- More effectiveness information for a wider range of project types, including combinations of projects. Currently, only limited quantitative information exists, especially for behavioral safety and emergency response projects. NCHRP 17-60 is an active study that is taking a quantitative analytical approach that uses criteria to determine the value of countermeasures (17).
- More high-quality before-and-after evaluations of specific safety strategies are needed to significantly advance the state of the practice. Additional information on duration of effectiveness, geographic area of effectiveness, and on the amount of funding required to produce results, especially for behavioral projects, is also needed.
- Consistent definitions of effectiveness: a variety of qualitative and quantitative effectiveness measures exist with slightly different definitions. More uniformity in qualitative and quantitative measures of effectiveness is needed to allow apples-to-apples comparisons between different types of safety countermeasures.
- Better quality crash data: evaluating certain projects types can be difficult if crash data are inadequate. Particularly, a lack of linkage between crash data records and injury and fatality outcomes makes evaluation of emergency response strategies difficult.

ACKNOWLEDGEMENTS

This research was conducted as a part of the NCHRP 17-46 project. The authors would like to thank the NCHRP Project Panel and Mark Bush for their contribution and feedback on the proposed sketch method. In applying the sketch method, the North Carolina Department of Transportation provided the authors with detailed project applications from the 2012 Governor’s Highway Safety Program (GHSP) and the 2010 North Carolina Department of Transportation’s (NCDOT) High Hazard Elimination program applications. In particular, Kevin Lacy (Project NCHRP Panel Chair) and his team at NCDOT provided guidance on extracting project information from these applications. Finally, the authors would like to thank Susan Herbel, Ryan Greene-Roesel, and David Preusser for their review of the proposed sketch method, and its application and results.
REFERENCES


