Crash Reduction Factor (CRF) Update

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The Caltrans Division of Research and Innovation (DRI) receives and evaluates numerous research problem statements for funding every year. DRI conducts Preliminary Investigations on these problem statements to better scope and prioritize the proposed research in light of existing work on the topics nationally and internationally. Online and print sources for Preliminary Investigations include the National Cooperative Highway Research Program (NCHRP) and other Transportation Research Board (TRB) programs, the American Association of State Highway and Transportation Officials (AASHTO), the research and practices of other transportation agencies, and related academic and industry research.

Background

Recent research conducted by the Federal Highway Administration (FHWA) produced the Desktop Reference for Crash Reduction Factors, FHWA Report No. FHWA-SA-07-015, published in September 2007. These crash reduction factors are commonly used by state departments of transportation (DOTs) to evaluate and compare the cost-effectiveness of alternatives for transportation safety improvements.

Caltrans staff proposed a research project aimed at identifying the CRFs included in the FHWA reference that are appropriate and applicable for California highways. To support this proposed research project, we reviewed recent research, national guidance and related efforts of other state DOTs to determine:

- Key issues and considerations that should drive the scope of the research.
- How DOTs are using CRF tools and data, and calibrating them for state-specific use.
- How much variability is seen in CRF application across states.
- The reliability of proposed CRFs for different safety improvements and how they can be adjusted to fit California's needs.
- How other states are applying bicycle and pedestrian safety countermeasures, and the reliability of CRFs for these improvements.

Summary of Findings

To gain a better understanding of how state DOTs are applying the recent FHWA guidance to their local safety improvement programs, we interviewed six states that have either recently published reports or studies about crash reduction factors or accident modification factors (AMFs), or have a long history of local development of CRFs/AMFs. Our research also included a scan of national and state research efforts to identify additional guidance and tools that Caltrans can use in customizing CRFs for California and in evaluating the reliability of CRFs included in the FHWA guidance.

We have organized our findings in the following sections: **National Guidance, State Application of Federal Guidance, State CRFs/AMFs, Data Expression and Data Reliability, Related Research, Online Tools and Resources, Bicycle/Pedestrian-Specific Research**, and **Gaps in Findings.** Key highlights of our research include:

National Guidance

- FHWA has issued an update to its Desktop Reference for Crash Reduction Factors, published in September 2008, which includes pedestrian and other data.
- NCHRP also provides guidance on measuring safety treatment effectiveness but uses AMFs instead of CRFs. AMFs are a key component of the Interactive Highway Safety Design Model (IHSDM) and will be used in AASHTO's upcoming Highway Safety Manual (HSM).

- The AMF appears more frequently in recently published literature and national research. Some researchers and practitioners feel this indicates a gradual transition that changes the standard from the CRF to the AMF. It is important to note that this transition is essentially a calculation change rather than a new approach to quantifying the estimated effectiveness of a countermeasure.

State Application of Federal Guidance

- Many states are adopting a wait-and-see approach with regard to making significant changes in their current use of CRFs/AMFs. Given the recency of the national guidance, the continuing development of online tools like FHWA's SafetyAnalyst and the upcoming publication of the Highway Safety Manual, many states are continuing to emphasize the use of locally developed factors and tools and have not yet fully embraced all national guidance.
- Of the six states we interviewed, only one state—Minnesota—uses the Desktop Reference as its primary source for CRF/AMF data.
- Texas reviews current research, including the recent FHWA and NCHRP guidance, to determine if any updates to the TxDOT CRFs should be recommended. An annual internal audit of CRFs using actual crash data compares three-year averages of crashes before and after a safety treatment to determine if a specific CRF should be modified. If the national guidance is inconsistent with a locally developed factor that has been subjected to internal audit with actual crash data, the locally developed factor is favored.
- There is no apparent standard for use of the national guidance. While some states use the national guidance to augment their locally developed CRFs/AMFs when a particular CRF/AMF is deemed appropriate and adequately supported by research, other agencies use the national guidance in lieu of a local set of factors.

State CRFs/AMFs

- Several states have recently published CRFs/AMFs for use in their states, some of which may be applicable to Caltrans.

Data Expression and Data Reliability

- Researchers and practitioners are concerned about the reliability of the research supporting CRFs/AMFs and are unwilling to employ CRFs/AMFs that have not been adequately supported by research.
- We identified a range of research approaches that are used in studies to develop CRFs. It may be worth considering the strengths and weaknesses of these approaches when reviewing the sources of the CRFs identified in the FHWA Desktop Reference.

Related Research

- Several states have carried out research aimed at developing CRFs/AMFs and online implementation tools as well as research to evaluate the methodologies in the development of the CRFs/AMFs.

Online Tools and Resources

- Recognizing that CRFs/AMFs evolve, states are developing their own online tools that allow for ready integration of state-specific data, real-time updating of CRFs/AMFs as new research becomes available, and wider access to CRF/AMF information. The Florida Department of Transportation will make CRASH, its locally developed online CRF tool, available for use by other agencies.
- FHWA has leveraged the interest in online tools to manage highway safety improvement programs with the creation of SafetyAnalyst, which is expected to be available as a licensed AASHTOWare product in July 2009.
- FHWA is developing programs to support appropriate use of CRFs, including a Web site that provides access to an extensive collection of CRFs/AMFs (which includes data from recently published national guidance and locally developed factors uploaded by state DOTs), and online workshops that address the application and science of CRFs.

Bicycle/Pedestrian-Specific Research

- Most states appear to have difficulty identifying appropriate bicycle and pedestrian countermeasures and justifying treatments within their safety improvement programs. Some states address this issue by

providing alternative means to justify projects or funding such projects through enhancement rather than safety programs.
- Three recent FHWA-sponsored studies that evaluate the effectiveness of a pedestrian safety plan and the implementation of mostly low- to moderate-cost innovative engineering safety improvements may be of particular interest to Caltrans.

Gaps in Findings

The safety improvement programs of most states are evolving. It is not yet clear how states will incorporate the findings of the recently published NCHRP Report 617, nor do we know how states will implement SafetyAnalyst or the upcoming Highway Safety Manual. It may be helpful to conduct a scan of recently published literature and initiate follow-up contacts with the states surveyed here in late 2009, after public release of SafetyAnalyst and the Highway Safety Manual, to determine if and how states are fully employing the national guidance with regard to CRFs.

State DOTs often lack the research and data necessary to identify locations suitable for the cost-effective application of bicycle- and pedestrian-related countermeasures. States are aided by recent national guidance that includes pedestrian-related CRFs and FHWA-sponsored research on pedestrian safety programs. However, as noted above, states may have difficulty justifying treatments within their safety improvement programs, as these treatments may not meet the required benefit-cost thresholds. Some states address this issue by funding these projects through enhancement rather than safety programs.

Continuing concern about the reliability of the research supporting CRFs/AMFs will limit the application of certain factors found in the research. More research using rigorous study methodologies is required to develop AMF/CRFs with a high level of predictive certainty that cover a wider range of countermeasures.

Next Steps

Caltrans might consider the following related to updating CRFs for California:

- Additional national guidance, through NCHRP and the Highway Safety Manual, is coming soon. It might be worth reviewing this guidance when customizing CRFs/AMFs for Caltrans.
- In reviewing the national guidance, Caltrans should select those CRFs/AMFs that are appropriately supported by research. NCHRP Report 617 includes only AMFs of high or medium-high quality; FHWA's Desktop Reference takes a broader approach and differentiates CRFs based on the quality of supporting research. When published, the Highway Safety Manual will include additional AMFs.
- Some other state-specific CRFs/AMFs may be applicable to Caltrans. Consider modifying the selected factors using California traffic and crash data. See the recently published examples below under **State CRFs/AMFs.**
- Online tools, such as FHWA's SafetyAnalyst and FDOT's CRASH, may be applicable to the overall Caltrans program.
- The type of research approach used by the investigator in evaluating and customizing CRFs for California will affect the reliability of those CRFs. Refer to **Data Expression and Data Reliability** below.

National Guidance

Below we highlight reports recently issued by FHWA, NCHRP and TRB with regard to CRFs. The first three documents are referenced throughout this Preliminary Investigation.

Desktop Reference for Crash Reduction Factors
FHWA Report No. FHWA-SA-08-011, September 2008
http://safety.fhwa.dot.gov/tools/crf/desk_ref_sept2008/desk_ref_sept2008.pdf
This version of the Desktop Reference is an update of the September 2007 Report No. FHWA-SA-07-015 and reflects new pedestrian and other data. The new report documents the estimates of the crash reduction that might be expected if a specific countermeasure or group of countermeasures is implemented with respect to intersections, roadway departure and other nonintersection crashes, and pedestrian crashes. The CRFs represent the information available to date from a variety of sources in the transportation literature.

Where available, the Desktop Reference includes multiple CRFs for the same countermeasure to allow the reader to review the range of potential effectiveness. The CRFs are useful as a guide, but FHWA cautions that it remains necessary to apply engineering judgment and to consider site-specific conditions which will affect the safety impact of a countermeasure. Other key points:

- The Desktop Reference includes a wide range of CRFs, from low to high quality. CRFs derived from more rigorous study methodologies are reflected in bold type; study type is noted, when available.
- FHWA provided a more expansive list of treatments to allow researchers to compare treatments, locations and study data.
- If all elements of the treatments are equal, researchers will most likely select the more statistically reliable factor. However, there may be other issues that will lead the researcher to take another approach. FHWA acknowledges that the challenge facing practitioners is to know which factor to use and how to apply it.

Related documentation includes the following Issue Briefs:

Intersection Safety Issue Brief: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes
http://www.transportation.org/sites/scohts/docs/Intersection%20Issue%20Brief.pdf

Pedestrian Safety Issue Brief: Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes
http://www.transportation.org/sites/scohts/docs/Pedestrian%20Issue%20Brief.pdf

Roadway Departure Issue Brief: Toolbox of Countermeasures and Their Potential Effectiveness for Roadway Departure Crashes
http://www.transportation.org/sites/scohts/docs/Roadway%20Departure%20Issue%20Brief.pdf
Issue Brief: Traffic Signals
http://www.ite.org/safety/issuebriefs/Traffic%20Signals%20Issue%20Brief.pdf

Accident Modification Factors for Traffic Engineering and ITS Improvements
NCHRP Report 617, May 2008
http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_617.pdf
In this report, NCHRP uses AMFs to measure safety treatment effectiveness. AMFs are a key component of the Interactive Highway Safety Design Model and will be used in the upcoming Highway Safety Manual.

Researchers developed or modified AMFs for high-priority treatments by reviewing the literature and ongoing research. A survey of state DOTs expanded the list to 100 treatments. Of the 100 treatments reviewed, 23 were found to have credible AMFs available; these served as the starting point for the development of AMFs in this study. For an AMF to be deemed credible, researchers required that the estimate have a high or mid-high level of predictive certainty. Two approaches were used in developing the AMFs: rigorous statistical evaluation of crash data, with priority given to conducting as many empirical Bayes[1] before-and-after evaluations of the high-priority treatments as possible, and two analysis-driven expert panels. Other key points:

- The report contains 35 AMFs that researchers verified, modified or developed that are considered to be of high or medium-high quality.
- Unlike the Desktop Reference, this report focused on only higher-quality factors.
- The factors from this report will also appear in the upcoming Highway Safety Manual. The HSM will also include additional factors of lower quality.
- The project developed a procedure for ranking needed AMF research that identifies 13 high-priority treatments needing AMF development.

[1] When applied in the context of CRFs, empirical Bayes methodology is a statistical procedure used to estimate the long-term annual number of crashes at a site using a weighted average of the site's short-term crash count and the average crash experience of similar sites.

See the following appendices for additional detail:

Appendix A: Methodology for Determining Crash-Harm Rating for Treatments
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_617appendixA.pdf

Appendix B: Effects of Converting Rural Intersections from Stop to Signal Control
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_617appendixB.pdf

Appendix C: Safety Effects of Four-Lane to Three-Lane Conversions
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_617appendixC.pdf

Appendix D: Safety Effects of Improving Pavement Skid Resistance
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_617appendixD.pdf

Appendix E: Evaluation of the Safety Effectiveness of Urban Signal Treatments
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_617appendixE.pdf

Appendix F: An Empirical Examination of the Relationship Between Speed and Road Accidents
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_617appendixF.pdf

Appendix G: Accident Modification Factors for Median Width
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_617appendixG.pdf

Highway Safety Manual
TRB/AASHTO, anticipated delivery date late 2009
http://www.highwaysafetymanual.org/
The purpose of the Highway Safety Manual is to provide practitioners with the best factual information and tools to facilitate roadway design and operational decisions based on consideration of their safety consequences. The new manual features a synthesis of validated highway research, procedures that are adapted and integrated to practice, and analytical tools for predicting impact on road safety. Other key points:

- A draft will be completed by March 31, 2009, and turned over to AASHTO as the first edition of the HSM.
- AASHTO subcommittees and standing committees will review and ballot the HSM.
- Actual publication date will depend on the results of the review and balloting, but it is projected to be in late 2009.
- The HSM will expand on the AMFs found in NCHRP Report 617 to include lower-quality factors as well as the high- to medium-high quality factors included in NCHRP Report 617.
- FHWA indicates that the HSM is intended to serve as a document that provides best practices rather than a policy, guideline or design manual that establishes requirements to be met by states.

Evaluations of Low-Cost Safety Improvements Pooled Fund Study
FHWA, 2007 and 2008
http://www.tfhrc.gov/safety/evaluations/
The goal of this research is to develop reliable estimates of the effectiveness of the safety improvements that are identified as strategies in the NCHRP Report 500 Guides. Each report provides a CRF and economic analysis for a specific safety strategy using the empirical Bayes methodology for observational before-and-after studies.

Reports for Phase I, Retrospective Evaluation, include:

Safety Evaluation of Increasing Retroreflectivity of STOP Signs
http://www.tfhrc.gov/safety/pubs/08041/08041.pdf

Safety Evaluation of Flashing Beacons at STOP-Controlled Intersections
http://www.tfhrc.gov/safety/pubs/08044/08044.pdf

Safety Evaluation of STOP AHEAD Pavement Markings
http://www.tfhrc.gov/safety/pubs/08043/08043.pdf

Safety Evaluation of Installing Center Two-Way Left-Turn Lanes on Two-Lane Roads
http://www.tfhrc.gov/safety/pubs/08042/08042.pdf

State Application of Federal Guidance

To gain a better understanding of how state DOTs are applying the recent FHWA and NCHRP guidance to their local safety improvement programs, we reviewed the activities of several states that have either recently published reports or studies about CRFs or AMFs, or have a long history of local development of CRFs/AMFs. We contacted state DOT staff or affiliated researchers to ask the following questions:

1. Are you using CRFs or AMFs in your analyses of safety treatment effectiveness?
2. Had you developed your own CRFs/AMFs prior to availability of the FHWA or NCHRP guidance? Are these locally developed factors available for our review?
3. Will you now use the FHWA or NCHRP guidance?
4. If you will use the FHWA or NCHRP guidance, are you modifying the CRFs/AMFs for application in your state? If yes, how?
5. If you are now using an online tool you have developed to update or apply CRFs/AMFs, can you tell us more about the tool?
6. Are you now using or do you plan to use one of the FHWA online tools (Interactive Highway Safety Design Model or SafetyAnalyst)?
7. How are you addressing bicycle and pedestrian countermeasures?

Summary of Findings

Our informal survey involved six states: Florida, Kentucky, Minnesota, Oregon, Texas and Washington. The individuals we contacted offered varying degrees of detail in response to our questions. In summary, we learned:

- All states have reviewed and most are already using FHWA's Desktop Reference in some form. Only one state—Minnesota—uses the Desktop Reference as its primary source for CRF/AMF data.
- None of the states has reviewed the recent NCRHP report and incorporated its findings into their programs. Most say they intend to.
- Two states that have created or adapted their own CRFs/AMFs (Kentucky and Oregon) make these factors available for public review. See the **Survey Results** below for links to these documents. Other current examples of state-specific CRFs/AMFs that may be applicable to Caltrans appear in **State CRFs/AMFs** below.
- Two states have developed their own online tools. Florida's online tool updates and applies its CRFs; see the contact information in the **Survey Results** below to request additional information about using the tool in California. Oregon makes use of an online tool developed through a recent research project, but the tool's database remains static as a result of software issues.
- Four of the six states are beta testing SafetyAnalyst. Most states indicate an interest in using the tool but have not determined how the new tool will be integrated into their overall programs. Most states mentioned the possibility of using selective modules.
- All states indicate that they are waiting to see the final results of projects in process, like the Highway Safety Manual and SafetyAnalyst, to make final determinations on further modifications to their safety improvement programs.
- Most states appear to have difficulty identifying appropriate bicycle and pedestrian countermeasures and justifying treatments within their safety improvement programs.

Survey Results

Florida

Contact: Joseph B. Santos, P.E., Transportation Safety Engineer, State Safety Office, FDOT, Joseph.Santos@dot.state.fl.us, (850) 245-1502.

1. Now using CRFs, but plans to convert CRFs to AMFs to be consistent with content in the upcoming Highway Safety Manual.
2. Created its own CRFs; the CRFs are not available for public review.
3. Using the FHWA guidance on a case-by-case basis. If a specific countermeasure is not included in the FDOT CRASH application, a CRF in FHWA's Desktop Reference may be used if it is appropriate and

reasonable based on the study used to generate the CRF. FDOT anticipates using NCHRP Report 617 in developing AMFs for the CRASH Web update that is planned for this year.

4. A factor from the national guidance may be employed when a local factor is not available. The national measure is reviewed for appropriateness to the local situation and statistical reliability. Modification of the national measure is not made prior to its initial use.
5. CRASH is a Web-based system used to gain input from district personnel to enter safety project types and limits to obtain project and program effectiveness for safety infrastructure projects. Input gained from personnel and analysis conducted with the application assists in developing CRFs specific to projects completed in Florida, completing benefit-cost reports for projects and generating the FHWA annual report for program effectiveness. A second phase of CRASH is being developed that will include a geographical information systems component to show project location.
6. Using Interactive Highway Safety Design Model (IHSDM) for design projects and participating in development of SafetyAnalyst. FDOT envisions an interface between CRASH and SafetyAnalyst but does not plan to initiate that project this year.
7. Includes improvements like pedestrian countdown timers in its safety program.

Kentucky

Contact: Ed Harding, Department of Transportation Safety, KYTC, ed.harding@ky.gov, (502) 564-9900, ext. 3481.

1. Uses CRFs.
2. The 1996 report produced by the Kentucky Transportation Center, Development of Accident Reduction Factors (see http://www.dot.state.mn.us/trafficeng/safety/hes/kentucky_report.pdf), provided a set of reduction factors that continue to be used by KYTC.
3. Have reviewed the Desktop Reference and pulled a few countermeasures from that report to add to KYTC's own set of factors. Have not yet reviewed the NCHRP report.
4. No indication that KYTC revises the national factor before using it.
5. No online tool to create/manage CRFs.
6. Not using IHSDM and not yet clear how SafetyAnalyst will be implemented.
7. No information provided with regard to bicycle and pedestrian countermeasures, though the set of factors now used by KYTC includes countermeasures to address pedestrian safety.

Minnesota

Contact: David Engstrom, State Traffic Safety Engineer, Office of Traffic, Safety and Technology, Mn/DOT, David.Engstrom@dot.state.mn.us, (651) 234-7016.

1. Uses CRFs.
2. Prior to publication of the Desktop Reference, Mn/DOT used the reduction factors contained in the 1996 report produced by the Kentucky Transportation Center, Development of Accident Reduction Factors (see http://www.dot.state.mn.us/trafficeng/safety/hes/kentucky_report.pdf). Mn/DOT is now using the Desktop Reference as its primary source for factors. Another factor may be used, but documentation supporting the use of the alternate factor must be provided.
3. While Mn/DOT is making active use of the Desktop Reference, it has not yet considered how the recent NCHRP report or the upcoming Highway Safety Manual may be incorporated into its program.
4. Does not make modifications to the Desktop Reference factors.
5. No online tool to create/manage CRFs.
6. Does not plan to use IHSDM. Now beta testing SafetyAnalyst and preparing to load data for the system. Not yet known if implementation of SafetyAnalyst will replace current tools and processes.
7. Noted difficulty in gathering bicycle and pedestrian volume data. Find that many of their bicycle/pedestrian projects are funded through enhancement rather than safety programs given the likelihood that an acceptable benefit-cost factor cannot be achieved.

Oregon

Contact: Tim Burks, Highway Safety Engineering Coordinator, Traffic Management Section, ODOT, timothy.w.burks@odot.state.or.us, (503) 986-3572.

1. Uses CRFs and has no plans to transition to AMFs.
2. Uses two sets of locally developed CRFs. The older set of CRFs (see http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/Counter_Measures.pdf) was

developed without supporting references. The second set of CRFs (see http://its.pdx.edu/CRF/CRFweb/SPR612_OnePageCRFs.pdf) was developed as part of a 2006 research project. Half of the 94 factors are supported by references.

3. May use FHWA's Desktop Reference in conjunction with locally developed CRFs. Traffic investigators are instructed to use judgment in applying CRFs in a manner consistent with ODOT policies. For example, ODOT does not include overlay projects in its safety program. ODOT is creating a spreadsheet that compares the two sets of locally developed CRFs with the Desktop Reference, with the proposed long-term goal of developing one set of factors. Have not yet reviewed the NCHRP guidance to determine how those factors may be integrated into the ODOT program.
4. Are not modifying the national guidance, but will make determinations as to which factors can be used in the ODOT program.
5. Crash Reduction Factors Search Form, an online Web tool available at http://its.pdx.edu/CRF/CRFweb/, was developed as part of a 2006 research project. While ODOT traffic investigators can use this tool through the Portland State University Web site, the tool is not available on an ODOT platform due to software compatibility issues. While the tool was developed to be updated in real time to allow for modifications to locally developed factors and the addition of new factors, the database is static and will not be updated unless ODOT migrates the application to an in-house server. At this time, there are no plans to do so.
6. Not using IHSDM, though have reviewed the product. Not participating in the SafetyAnalyst beta test, but will review the product after its public release to determine if the appropriate data is available to allow for implementation of specific modules. Questioning whether SafetyAnalyst can be calibrated for ODOT's use. Now using the locally developed Safety Priority Index System (SPIS) to perform network screening and identify and prioritize sites that have promise as sites for potential safety improvements. Will continue with SPIS and consider running SPIS and SafetyAnalyst concurrently before making a final decision on SafetyAnalyst implementation.
7. Difficult to justify bicycle/pedestrian projects using standard factors and measures. Adopted use of the Highway Safety Program—Risk Narrative Form found at http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/word/2007_Risk_Narrative_Form.doc that can be submitted to justify expenditures on bicycle/pedestrian safety-related projects when volume or crash data is lacking or the benefit-cost factor does not meet accepted standards.

Texas

Contacts: John Mounce, Center Director, Center for Transportation Safety, Texas Transportation Institute, j-mounce@tamu.edu, (979) 458-3346.
Debra Vermillion, Safety Construction Programs and Data Analysis Branch Manager, Traffic Operations Division, TxDOT, dvermil@dot.state.tx.us, (512) 416-3137.

1. Uses CRFs.
2. Locally developed factors are not available for public review.
3. Texas Transportation Institute conducts an ongoing evaluation of TxDOT's safety program. As part of the review of input variables for benefit-cost analyses, TTI looks at current research, including the recent FHWA and NCHRP guidance, to determine if any updates to the TxDOT CRFs should be recommended. TTI also conducts an annual internal audit of CRFs using actual crash data, comparing three-year averages of crashes before and after a safety treatment to determine if a specific CRF should be modified. If the national guidance is inconsistent with a locally developed factor that has been subjected to internal audit with actual crash data, the locally developed factor is favored.
4. All factors are subjected to an internal audit using actual crash data, and modifications to factors are made as necessary.
5. No online tool to create/manage CRFs; uses its own Safety Improvement Index to generate benefit-cost analyses.
6. The central office has no plans to use IHSDM or SafetyAnalyst, though districts may have plans to use one of these tools.
7. While TxDOT has a few bicycle/pedestrian countermeasures in its safety programs, it does not routinely do these types of improvements through these programs.

Washington
Contact: John Milton, Director of Enterprise Risk Management, WSDOT, MILTONJ@wsdot.wa.gov, (360) 704-6363.

1. Uses both CRFs and AMFs; moving toward AMFs given the use of AMFs in SafetyAnalyst and IHSDM.
2. Factors being used locally are not available for public review.
3. Will review national guidance and incorporate it where possible in the WSDOT program. Still in the implementation stages.
4. Not clear whether national factors are subjected to local modification.
5. No online tool to create/manage CRFs.
6. Beginning to incorporate parts of IHSDM and SafetyAnalyst. Interested to see how the Highway Safety Manual will be implemented by states.
7. Research for bicycle/pedestrian countermeasures is often less statistically oriented and experimental designs can be challenged. Most pedestrian improvements are associated with other projects and not subject to a specific benefit-cost analysis.

State CRFs/AMFs

Below are several current examples of state-specific CRFs/AMFs that may be applicable to Caltrans:

Illinois Department of Transportation
Appendix E: Countermeasure Effectiveness & Crash Reduction Factors, November 2006
http://www.dot.state.il.us/safetyEng/Appendix%20E.pdf

North Carolina Department of Transportation
North Carolina Project Development Crash Reduction Factor Information, May 30, 2007
http://www.ncdot.org/doh/preconstruct/traffic/Safety/Resources/project_guide/regionalfactors.pdf

Ohio Department of Transportation
Estimates of Countermeasure Effectiveness Reduction (CRF) Factors, revised July 2007
http://www2.dot.state.oh.us/planning/Safety/2006data/Crash%20Reduction%20Factors%20FY2008.PDF

Oregon Department of Transportation
Crash Reduction Factors, March 2006
http://its.pdx.edu/CRF/CRFweb/SPR612_OnePageCRFs.pdf
See the PDF for a comprehensive list of CRFs developed as part of a 2006 research project. See http://its.pdx.edu/CRF/CRFweb/ and click on each countermeasure category, then click each result to see a summary that includes a discussion of the CRF and references.

Data Expression and Data Reliability

Transportation researchers use different **Estimates of Safety Treatment Effectiveness** and a variety of **Research Methodologies** to conduct the research from which crash reduction factors and accident modification factors are derived. Please see below for a brief discussion that can provide for a more informed review of the literature on the safety effects of engineering treatments.

Estimates of Safety Treatment Effectiveness

Both CRFs and AMFs reflect the percentage reduction or increase in crashes that can be expected after implementing a treatment or program. The two terms are simply different ways of expressing safety treatment effectiveness.

AMFs typically range in value from 0.5 to 2.0, with a value of 1.0 representing no effect on safety. AMFs less than 1.0 indicate that the specified component is associated with fewer crashes, while AMFs above 1.00 indicate that the treatment can be expected to result in an increase in crashes. CRFs typically range in value from 0.10 to 0.90. Larger CRFs in this range indicate a more significant reduction in crashes due to the improvement.

An AMF is developed by dividing the CRF by 100 and subtracting the result from 1.00. Using this calculation, a treatment shown to reduce crashes by 15 percent (CRF = 0.15) would have an AMF of 0.85 (1.00 − 15/100).

FHWA uses CRFs in its Desktop Reference; NCHRP uses AMFs in Report 617. AMFs from NCHRP Report 617 will also appear in the Highway Safety Manual to be released in late 2009. While recent research indicates a burgeoning interest in the use of AMFs and some say that the AMF is increasingly becoming the standard for estimating safety effectiveness, many states still use CRFs in their benefit-cost analyses.

Research Methodologies

While a variety of methodologies have been employed to evaluate road safety treatments, the empirical Bayes (EB) approach is considered by many researchers and practitioners to be the preferred methodology. EB methodology is a statistical procedure used to estimate the long-term annual number of crashes at a site using a weighted average of the site's short-term crash count and the average crash experience of similar sites. Use of EB methodology addresses two problems of safety estimation: It increases the precision of estimates beyond what is permitted by the use of a limited number of years of accident history, and it corrects for the regression-to-mean bias. EB methodology is used in FHWA's Interactive Highway Safety Design Model and SafetyAnalyst, as well as the Highway Safety Manual and NCHRP Report 617.

Other research methodologies employed in evaluating road safety treatments include the following:

Simple before-and-after

- A study in which the crash experience and other factors before a site or a group of sites are modified is compared with the crash experience after the modification to estimate the safety effect of the change.
- Does not correct regression-to-mean bias.
- Not able to control for other factors that could affect crash frequency.

Comparison group before-and-after

- A group of sites, used in before-and-after studies, that are untreated but are similar to the treated sites. The comparison group is used to control for changes in safety other than those due to a treatment.
- Assumes before-and-after ratio of crashes is same for comparison and treatment sites.
- Does not correct regression-to-mean bias.
- Susceptible to a number of potential biases or alternate explanations for the observed change.
- Accuracy relies on the validity of the assumption of similarity between the treatment and comparison sites.

Cross-sectional

- A study in which the crash experience of different sites is examined and differences in crash experience among sites are attributed to differences in specific site characteristics.
- Difficult to find two sites that are exactly identical except for one aspect.

Meta-analysis

- A statistical technique that combines the independent estimates of safety effectiveness from separate studies into one estimate by weighting each individual estimate.

Related Research

Implementation efforts undertaken by states, including development of CRFs/AMFs and Web-based tools, as well as analyses of research methodologies used to develop CRFs/AMFs, are documented in the following reports, papers and articles.

Improving Management and Analysis of Highway Safety Improvement Projects through a Statewide Web-based Information System, Albert Gan, Haifeng Wang, Kaiyu Liu, ITE 2008 Technical Conference and Exhibit, 2008.
This paper describes a Web-based information system that was designed to meet the Florida Department of Transportation's need for a system that automates the benefit-cost analysis of proposed safety improvement projects and assesses the effectiveness of safety improvement projects. The system provides a central location for district officers to enter safety improvement projects and update CRFs as new improvement projects become available, to perform benefit-cost analysis to better identify effective improvement projects, and to perform before-and-after

analysis to evaluate the effectiveness of safety improvement programs. The system can serve as a prototype for other states that have an interest in computerizing the maintenance and analysis of their safety improvement projects. Find more information about the system, which is known as CRASH, in the **Online Tools** section of this Preliminary Investigation.

Calibration Factors Handbook: Safety Prediction Models Calibrated with Texas Highway System Data
Texas Transportation Institute, Report No. FHWA/TX-08/0-4703-5, October 2008
http://tti.tamu.edu/documents/0-4703-5.pdf
Researchers developed safety prediction models for intersections and highway segments in Texas. Models were developed for urban and suburban arterial intersections, urban and suburban arterial street segments, rural multilane highway segments, and urban and rural freeway segments. They were subsequently calibrated using Texas highway system data. Selected AMFs were also developed and calibrated. These factors address several geometric design elements, including turn bay presence, median width, barrier presence and weaving section length.

Methodology for Estimating the Variance and Confidence Intervals for the Estimate of the Product of Baseline Models and AMFs, Dominique Lord, *Accident Analysis & Prevention 40*, 2008: 1013-1017.
This manuscript describes a methodology for estimating the variance and 95% confidence intervals for the estimate of the product between baseline models and AMFs. The methodology, used in the upcoming Highway Safety Manual, is separated into two parts: the first part covers the proposed approach for estimating the variance of the estimate of the product between baseline models and AMFs; and the second part presents the method for estimating the variance of baseline models. Several examples are presented to illustrate the application of the methodology.

Procedure for Developing Accident Modification Factors from Cross-Sectional Data, James A. Bonneson, Michael Paul Pratt, Transportation Research Board Annual Meeting 2008 Paper #08-0323.
http://www.trb.org/am/ip/paper_detail.asp?paperid=19885
This paper describes a procedure for developing AMFs using a cross-sectional study. It is recognized that AMFs are most accurately derived from controlled experiments and observational before-and-after studies. However, the execution of experiments and before-and-after studies is not always practical or feasible. The procedure described in this paper is intended to be used in this situation. The procedure is demonstrated through the development of a curve radius AMF for rural two-lane highways.

Crash Reduction Factors for Education and Enforcement
Ohio Research Institute for Transportation and the Environment, Ohio University, Report No. FHWA/OH-2007/11, May 2007
http://www2.dot.state.oh.us/research/2007/Safety/134220-FR.pdf
A comprehensive literature and Web search was conducted to determine driver education, licensing and enforcement practices, and CRF values used by other states and countries. An electronic survey of all states was also conducted to get information about driver education, licensing programs, testing and enforcement measures, the state of the art in traffic safety practices, and CRFs. Based on the analysis of all the information obtained only a limited number of quantitative CRFs exist for any of the driver education, licensing and enforcement measures in any of the states in the U.S.

Development of Crash Reduction Factors for Overhead Flashing Beacons at Rural Intersections in North Carolina, Brian G. Murphy, Joseph E. Hummer, *Transportation Research Record 2030*, 2007: 15-21.
The purpose of this project is to develop CRFs for overhead flashing beacons at rural two-way stop sign–controlled intersections in North Carolina that reflect North Carolina conditions and decision making. Thirty-four treatment sites were chosen for analysis. Each treatment site was a rural four-leg intersection with no turn lanes and two-way stop control and had at least three years of after-period crash data available. Empirical Bayes before-and-after techniques were used to overcome the threat of regression to the mean. On average, all categories of crashes studied decreased in the after period.

Online Tool for Delivering Research Results: Update to Oregon Department of Transportation Database of Crash Reduction Factors, Christopher M. Monsere, Aaron Breakstone, Robert Lawrence Bertini, Douglas W. Bish, *Transportation Research Record 2009*, 2007: 113-120.
This paper describes the results of Report No. FHWA-OR-DR-06-11, which appears below. The project updated the Oregon Department of Transportation database with CRFs and then incorporated the CRFs into an online tool. Researchers describe the methodology for cataloging a total of 94 crash countermeasures, reviewing the literature and developing the interactive online tool. The tool allows users to search on the basis of key parameters for the countermeasures most appropriate to a particular highway safety improvement project and to access relevant citations from the literature review database. A case study describes how a traffic safety professional might use this online tool in practice. While the online tool resulting from this research project is available for use by ODOT on the Portland State University Web site, it has not been established on ODOT servers and has not been updated to reflect new CRF data.

Update and Enhancement of ODOT's Crash Reduction Factors
Portland State University and Oregon State University, Report No. FHWA-OR-DR-06-11, June 2006
http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/Crash_Reduction_Factors.pdf
This study provided a comprehensive update to the Oregon Department of Transportation's CRFs database. The CRFs were updated after thorough review and quality assessment of recent literature and input from an expert advisory group. This report provides a summary of national and international concurrent and complementary research, discusses the methodology used to review CRFs and outlines development of an interactive Web page. (See http://its.pdx.edu/CRF/CRFweb/.) The Web page is being used by ODOT staff, but the underlying database remains static and has not yet been updated or migrated to ODOT servers.

Updating South Dakota Crash Frequencies and Crash Reduction Factors
South Dakota Department of Transportation, Report No. SD2004-06-F, August 2004
http://www.state.sd.us/Applications/HR19ResearchProjects/Projects/SD2004_06_Final_Report.pdf
This report offers the methodology and findings of the updates to South Dakota's accident reduction factors (ARFs) and severity reduction ratios (SRRs). The ARFs and SRRs focused on South Dakota safety improvement projects.

Online Tools and Resources

Several online tools are in use or will soon be available to assess road safety or update and apply CRFs or AMFs. In this section we review two **National Tools** developed by FHWA and a **Locally Developed Tool** used by FDOT.

National Tools and Resources

Both of the FHWA tools we discuss below are in varying stages of development and distribution. Further development of both tools relates to the upcoming publication of the Highway Safety Manual.

Interactive Highway Safety Design Model
http://www.tfhrc.gov/safety/ihsdm/ihsdm.htm
FHWA's Interactive Highway Safety Design Model is a suite of software analysis tools for evaluating safety and operational effects of geometric design on two-lane rural highways. IHSDM can check designs against relevant design policy values, estimate the crash frequency expected for a specified geometric design, and estimate other safety and operational performance measures that help diagnose factors which contribute to expected safety performance.

IHSDM includes six evaluation modules:

Policy Review Module: Checks highway-segment design elements for compliance with relevant geometric design policies.
Crash Prediction Module: Estimates the frequency and severity of crashes that could be expected on a highway based upon its geometric design and traffic characteristics.
Design Consistency Module: Helps diagnose safety concerns at horizontal curves by providing estimates of the magnitude of potential speed inconsistencies.

Intersection Review Module: An expert system that systematically evaluates an existing or proposed intersection geometric design to identify potential safety concerns and suggest possible treatments to address those concerns.
Traffic Analysis Module: Uses the TWOPAS (TWO-lane PASsing) traffic simulation model to estimate traffic quality of service measures for an existing or proposed design under current or projected future traffic flows.
Driver/Vehicle Module: Simulates driving behavior and vehicle dynamics on a two-lane highway, providing predicted time histories of speed and other response variables, along with statistical measures of safety-related performance metrics.

IHSDM's Crash Prediction Module serves as the software implementation of Part C of the upcoming Highway Safety Manual. While IHSDM now addresses only two-lane rural highways, an update is in process that will include two additional project-level crash prediction methods in IHSDM:

- Rural multilane highways.
- Urban and suburban arterials.

All three of the project-level crash prediction methods (two-lane rural highways, rural multilane highways and urban and suburban arterials) will also appear in Part C of the HSM.

In advance of the publication of the HSM and update of IHSDM, information about the two new project-level crash prediction methods can be found in the following NCHRP project reports:

Methodology to Predict the Safety Performance of Rural Multilane Highways
NCHRP Web-Only Document 126, February 2008
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w126.pdf

Phases I and II: Methodology to Predict the Safety Performance of Urban and Suburban Arterials
NCHRP Web-Only Document 129, March 2007
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w129p1&2.pdf

Contact: Ray Krammes, Office of Safety R&D, FHWA, Ray.Krammes@fhwa.dot.gov, (202) 493-3312.

SafetyAnalyst
http://www.safetyanalyst.org/
Being developed as a cooperative effort by FHWA and 30 participating state and local agencies, SafetyAnalyst is an online tool that addresses site-specific safety improvements which involve physical modifications to the highway system. A nine-month evaluation period is expected to be complete by June 30, 2009. Beginning in July 2009, FHWA expects SafetyAnalyst to be available for licensing as an AASHTOWare product. SafetyAnalyst is the software implementation of Part B of the Highway Safety Manual.

SafetyAnalyst can identify accident patterns at specific locations and determine whether those accident types are overrepresented. This online tool also determines the frequency and percentage of particular accident types systemwide or for specified portions of the system.

The SafetyAnalyst toolbox includes:
Network Screening Tool: Identifies sites with potential for safety improvements.
Diagnosis Tool: Used to diagnose the nature of safety problems at specific sites.
Countermeasure Selection Tool: Assists users in the selection of countermeasures to reduce accident frequency and severity at specific sites.
Economic Appraisal Tool: Performs an economic appraisal of a specific countermeasure or several alternative countermeasures for a specific site.
Priority Ranking Tool: Provides a priority ranking of sites and proposed improvement projects based on the benefit and cost estimates determined by the economic appraisal tool.
Countermeasure Evaluation Tool: Provides the capability to conduct before-and-after evaluations of implemented safety improvements.

Individual state use of SafetyAnalyst is expected to vary. FHWA indicates that many states are planning to use SafetyAnalyst to manage their highway safety improvement programs as a comprehensive application that replaces a series of ad hoc local processes. Some states have indicated an intention to use only certain modules and expect to continue to use their own locally developed programs or processes, such as benefit-cost analyses. Participating states acknowledge the challenges associated with ensuring that the necessary data is available and properly converted for implementation of SafetyAnalyst.

Contact: Ray Krammes, Office of Safety R&D, FHWA, Ray.Krammes@fhwa.dot.gov, (202) 493-3312.

In addition, FHWA is working on two projects to aid states in identifying and using CRFs: a **Web Clearinghouse of CRF/AMF Data** and **Online Workshops** for the practitioner.

Web Clearinghouse of CRF/AMF Data

Scheduled to be launched in beta form by early summer and publicly launched by September 2009, this project will provide users with an expansive online collection of CRFs/AMFs taken from the recently released national guidance, including the Desktop Reference and the upcoming Highway Safety Manual. In addition to including factors in those recently published documents, the new Web site will allow for real-time updating as new research becomes available and selective querying by CRF or AMF. The new online resource is also expected to allow states to upload their locally developed factors to encourage sharing of CRF/AMF data. A technical review panel will review all state submissions for appropriateness before the state documents are publicly posted.

Online Workshops

Two online workshops that combine self-paced activities with guided training are expected to be available through the National Highway Institute beginning in March 2009. The two sessions are:

- **The Application of Crash Reduction Factors:** This two-hour session combines one hour of self-paced work that is completed before a one-hour guided Webinar. In this course, you will learn the background of CRFs, including terminology, the components of a CRF and how to identify and interpret appropriate CRFs. In addition, you will gain hands-on experience with safety diagnosis and the application of CRFs to compare the effectiveness of countermeasures.

- **The Science of Crash Reduction Factors:** In this three-hour session that includes both self-paced activities and guided training, you will learn how to critically assess the quality of CRFs by understanding the measurement of safety as well as the statistical and methodological issues that affect the development of quality CRFs.

FHWA expects to offer free participation prior to the workshops' official launch in March 2009. Watch FHWA's newsletter, *Safety Compass,* at http://safety.fhwa.dot.gov/newsletter/safetycompass/index.htm for more information.

Locally Developed Tool

While both Florida and Oregon have developed online tools to update and apply CRFs, we discuss only Florida's tool, CRASH, below. The tool developed for Oregon is not being actively updated due to software limitations, while Florida's CRASH continues to be updated and is expected to interface with SafetyAnalyst.

CRASH (FDOT)

http://lctr.eng.fiu.edu/CRASH.htm

CRASH (Crash Reduction Analysis System Hub) is used by the Florida Department of Transportation Safety Office to update and apply CRFs for Florida. It also provides a platform for FDOT to support applications of the SafetyAnalyst system.

CRASH automates the following tasks:

- Recording and maintaining improvement projects.
- Updating CRFs based on the latest available improvement project and crash data.
- Applying calculated CRFs in the benefit-cost analyses of specific projects.

Developed in 2005 as a Microsoft ASP.NET Web application, CRASH runs on FDOT's intranet system and works with Microsoft Access databases. The system includes the following database components:

- Safety improvement projects since 1992.
- Historical crash records from 1984 through 2003.
- CRFs and associated statistics.
- User management information.

CRASH includes six functional components that work with the four back-end databases:

Project Analysis: Allows users to start, edit and view projects.

Historical Projects: Allows users to add, edit and view projects, as well as generate standard Highway Safety Improvement Program reports and generate before-and-after statistics for selected projects to evaluate their effectiveness.

Future Development: Reserved for future development in support of FDOT application of SafetyAnalyst.

Administration: Used by the system administrator or a designated person to perform administrative functions, such as user management, viewing summaries of CRFs, updating CRFs after the new project and data are added, and add and edit safety improvement project types.

Online Help: Provides access to the CRASH online help, tabulated CRFs from other states, state-by-state CRFs, and the final report for the project that develops the Web application.

Contact: Provides contact information for technical support and general information on the system.

A 2009 update to CRASH will convert the CRASH databases from Microsoft Access to SQL Server, provide geographical informational systems mapping capabilities, and develop a process to populate and generate annual reports.

FDOT will make the CRASH prototype available to other interested agencies; see contact information below to request additional information.

Contact: Joseph Santos, P.E., Transportation Safety Engineer, State Safety Office, FDOT, Joseph.Santos@dot.state.fl.us, (850) 245-1502.

Bicycle/Pedestrian-Specific Research

In the following we highlight **Online Tools** that provide Web-based bicycle and pedestrian countermeasure selection systems, **National Guidance** for selection of countermeasures, and **Related Research** that provides the results of three pedestrian safety projects and discusses the development of bicycle and pedestrian safety indices.

Online Tools

Bicycle Countermeasure Selection System (BIKESAFE)

http://www.bicyclinginfo.org/bikesafe/

BIKESAFE's resources provide an overview of bicycling in today's transportation system, information about bicycle crash factors and analysis, and recommendations for selecting and implementing bicycling improvements. Tools allow the user to select appropriate countermeasures or treatments to address specific bicycling objectives or crash problems.

Pedestrian Safety Guide and Countermeasure Selection System
http://www.walkinginfo.org/pedsafe/
Online tools provide the user with a list of possible engineering, education or enforcement treatments to improve pedestrian safety and/or mobility based on user input about a specific location.

National Guidance

Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes
FHWA, May 2008
http://safety.fhwa.dot.gov/ped_bike/ped/ped_tctpepc/ped_tctpepc.pdf
This four-page document estimates the crash reduction that might be expected if a specific countermeasure or group of countermeasures is implemented with respect to pedestrian crashes. Most of the CRFs included in this document also appear in FHWA's Desktop Reference; some of the crash reduction estimates include bicyclists.

A Guide for Reducing Collisions Involving Bicycles
NCHRP, Guidance for Implementation of the AASHTO Strategic Highway Safety Plan: Volume 18, 2008
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v18.pdf
This guide includes road treatments, countermeasures and other options to reduce bicycle crashes.

- See page 160 of the PDF for a discussion of prioritizing and selecting among alternative strategies.
- Appendix O, found at http://safety.transportation.org/htmlguides/implement/ProcAppO.htm, provides guidance in estimating the effectiveness of a program during the planning stages.

A Guide for Reducing Collisions Involving Pedestrians
NCHRP, Guidance for Implementation of the AASHTO Strategic Highway Safety Plan: Volume 10, 2004
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v10.pdf
Researchers indicate that the relative rarity of pedestrian crashes makes it difficult to assess impacts at a given location and over reasonable lengths of time.

- See page 29 of the PDF for an index of strategies by implementation time frame and relative cost.
- See page 119 of the PDF for a discussion about the establishment of crash reduction goals.

Related Research

Miami-Dade Pedestrian Safety Project: Phase II, Final Implementation Report and Executive Summary
University of Florida, Gainesville, Cooperative Agreement DTFH61-01-X-00018, August 25, 2008
http://safety.fhwa.dot.gov/ped_bike/ped/ped_scdproj/miami/pedsafety_miami.pdf
The Miami-Dade comprehensive pedestrian safety planning and engineering project is one of three projects in the U.S. funded by FHWA to evaluate the effectiveness of a pedestrian safety plan to target higher-injury areas and the implementation of a range of mostly low-to-moderate-cost innovative engineering safety improvements. This project has three primary goals: the installation of pedestrian countermeasures; the scientific evaluation of the countermeasures in order to determine their efficacy; and to produce a significant crash reduction along the treated high crash corridor. Findings include:

- Probability of a pedestrian violation at midblock signals is a joint function of perceived risk and wait time. Reducing wait time leads to very high levels of compliance.
- In-street pedestrian signs are best placed close to the crosswalk; no advantage is gained by installing multiple signs.
- Pedestrian push buttons that confirm the press lead to more pedestrians pressing the button and more pedestrians that press the button waiting for the "Walk" indication.
- Rectangular LED rapid flash beacons are associated with high levels of yielding on multilane high-volume roads during the day and night.
- The "Turning vehicles yield to pedestrians" symbol sign appeared no more effective than the conventional test message sign.

San Francisco PedSafe Phase II, Working Draft: Final Report and Executive Summary
San Francisco Municipal Transportation Agency and University of California, Berkeley, Cooperative Agreement DTFH61-02-X-00017, January 11, 2008
http://safety.fhwa.dot.gov/ped_bike/ped/ped_scdproj/sf/pedsafety_sf.pdf
San Francisco PedSafe, a comprehensive pedestrian safety planning and engineering project, is the second of three FHWA-funded projects. This report concentrates on the Phase II countermeasure implementation efforts, focusing primarily on the implementation experience and overall lessons learned. Findings include:

- Particularly cost-effective countermeasures appear to be the in-pavement "Yield to Pedestrians" signs and pedestrian countdown signals.
- "LOOK" pavement stencils seemed to have negligible value.
- Flashing beacons and in-pavement crosswalk lights both appeared effective at inducing drivers to yield to pedestrians at uncontrolled crosswalks.
- The radar speed trailer was more effective than the fixed speed display sign at reducing driver speeds.
- There were essentially no common suggestions by pedestrians surveyed for improving intersection safety.

Pedestrian Safety Engineering and Intelligent Transportation System-Based Countermeasures Program For Reducing Pedestrian Fatalities, Injuries, Conflicts, and Other Surrogate Measures
Iowa State University and University of Nevada, Las Vegas, Cooperative Agreement Number DTFH61-01-1X-00134, September 15, 2008
http://safety.fhwa.dot.gov/ped_bike/ped/ped_scdproj/lasvegas/pedsafety_lasvegas.pdf
The third of the three projects funded by FHWA, the intent of this program is to serve as an example of a successful implementation of pedestrian safety countermeasures that can be applied across the country. Some of the countermeasures deployed in Phase 2 were selected in consultation with the Miami-Dade County and San Francisco teams to permit a comparative evaluation of countermeasures at three different locations in the country. Findings include:

- "Turning Vehicles Yield to Pedestrians" signs resulted in significant improvement in motorists' yielding behavior and significant reduction in the percent of pedestrians trapped in the middle of the street.
- Advance yield markings for motorists resulted in significant improvement in motorists' yielding behavior.
- Warning signs for motorists resulted in no significant improvement in either motorist or pedestrian measures of effectiveness.
- Portable speed trailers provided for a significant increase in motorists' yielding distance.

Appendices to the report are available as separate documents:

Appendix A: Pictures and drawings of countermeasures
http://safety.fhwa.dot.gov/ped_bike/ped/ped_scdproj/lasvegas/appendix_a.pdf

Appendix B: Site drawings
http://safety.fhwa.dot.gov/ped_bike/ped/ped_scdproj/lasvegas/appendix_b.pdf

Bicyclist Intersection Safety Index, Daniel L. Carter, William W. Hunter, Charles V. Zegeer, J. Richard Stewart, Herman Huang, *Transportation Research Record 2031*, 2007: 18-24.
Researchers developed a macro-level bicycle intersection safety index that allows engineers, planners and other practitioners to use data on the traffic volume, the number of lanes, the speed limit, the presence of a bike lane, the presence of parking, and the presence of traffic control to give a rating for an intersection approach according to a six-point scale. Using video data and online ratings surveys, this study obtained data on avoidance maneuvers and safety ratings at 67 intersection approaches and developed a Bike ISI model that incorporated both measures of safety. Once safety index values are assigned to each site, the practitioner can then select the sites with the highest index values and conduct more detailed reviews of those sites to determine whether any treatments are needed to improve the safety of the intersection.

Index for Assessing Pedestrian Safety at Intersections, Charles V. Zegeer, Daniel L. Carter, William W. Hunter, J. Richard Stewart, Herman F. Huang, Ann Hong Do, Laura S. Sandt, *Transportation Research Record 1982*, 2006: 76-83.

This study developed an index that allows practitioners to prioritize intersection crosswalks with respect to pedestrian safety. The study involved collecting data on pedestrian crashes, conflicts and avoidance maneuvers as well as subjective ratings of intersection video clips by pedestrian professionals. Sixty-eight pedestrian crosswalks were selected for the pedestrian analysis from Philadelphia, Pennsylvania; San Jose, California; and Miami-Dade County, Florida. A predictive model was developed primarily on the basis of intersection ratings and avoidance maneuvers. Variables in Ped ISI included the number of through lanes, 85th percentile vehicle speed, type of intersection control (signal or stop sign), main street traffic volume and area type. Ped ISI can be used to identify which crosswalks in a city have the highest priority for pedestrian safety improvements.