Roadway Safety Data Program

COLORADO'S IMPLEMENTATION OF LEVEL OF SERVICE OF SAFETY

STRATEGIES FOR USING GIS TO ADVANCE HIGHWAY SAFETY

CASE STUDY

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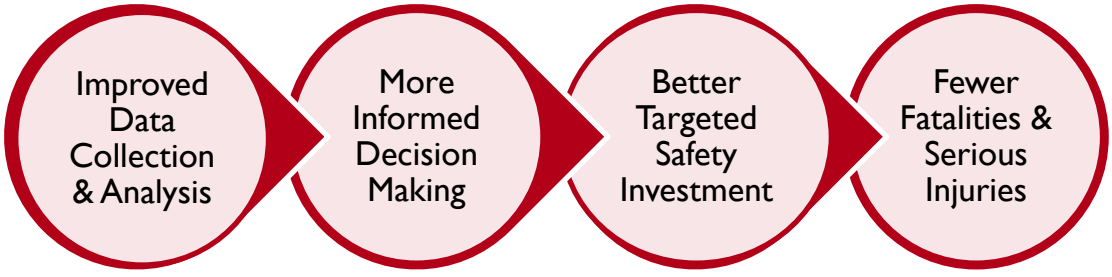

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Safe Roads for a Safer Future
Investment in roadway safety saves lives
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CASE STUDY OVERVIEW

OBJECTIVE

The objective of this case study is to illustrate how Colorado uses GIS to spatially integrate roadway data with crash data, develop SPFs, visualize data, and implement the Level of Service of Safety (LOSS) method to assess a roadway's safety performance.

BACKGROUND

Design engineers at the Colorado Department of Transportation (CDOT) developed the LOSS method as an alternative to using crash rates for evaluating safety. The LOSS method compares a roadway segment's observed crash frequency and severity to the crash frequencies and severities predicted by Safety Performance Functions (SPFs).[1] Relying on crash rates alone to identify safety deficiencies is problematic because crash rates imply a linear relationship between exposure and safety. However, the number of crashes fluctuates based on traffic volume.[2]

Transportation agencies that model crash frequency and severity based on annual average daily traffic (AADT) develop SPFs for public roadways, including segments and intersections. They stratify SPFs by the number of lanes, number of legs, traffic control, terrain, environment, and functional classification.[1] Once transportation engineers and planners develop the SPFs, they can employ the LOSS method. While it is possible to segment roadway data in tabular form, using a Geographic Information System (GIS) greatly facilitates segmentation of these roadways. More specifically, GIS enables analysts to spatially link data describing roadway geometry with crash data. For intersections, it is necessary for analysts to use some special context to link intersecting roadways, as a tabular dataset cannot use GIS to link intersecting roads.[3]

When analysts evaluate the magnitude of a safety problem, they assess it from two angles—*frequency* and *severity*. As such, they develop distinct SPFs, one for the total number of crashes and the other for injury and fatal crashes. With LOSS, analysts use quantitative assessment and qualitative description measures to characterize the safety of a roadway segment or an intersection and establish four levels of service safety. These levels are based on how the predicted frequency or severity of crashes deviates from observed crashes at a specific AADT. The comparison relies on the standard deviation of predicted crashes to assign a roadway segment to a particular level of safety. The four LOSS categories indicate the potential for crash reduction, from high to low. Figure 1 uses an SPF calibrated for total crashes expected on six-

lane urban freeways to illustrate the LOSS concept. Different crash severities (e.g., injuries versus fatalities) may have different LOSS levels, thereby generating several levels for a single segment or an intersection.[1]

The AASHTO *Highway Safety Manual* (HSM) incorporated LOSS into the first edition. While LOSS lent itself well to the safety decision-making process in the DOT environment, it did not initially address correction for the regression to the mean (RTM) bias. By adopting an Empirical Bayes (EB) procedure, the latest HSM version uses the LOSS method, along with correction for RTM bias. The EB method combines the observed crash frequency with the predictive model estimate and uses a weighted adjustment factor that is based on the variance of the SPF model. After the adjustment, LOSS levels can be categorized with more certainty and in an intuitive percentile-based reporting method.[4]

The following are the four LOSS categories used:

- LOSS-I. Indicates low potential for crash reduction;
- LOSS-II. Indicates low to moderate potential for crash reduction;
- LOSS-III. Indicates moderate to high potential for crash reduction; and
- LOSS-IV. Indicates high potential for crash reduction.[2]

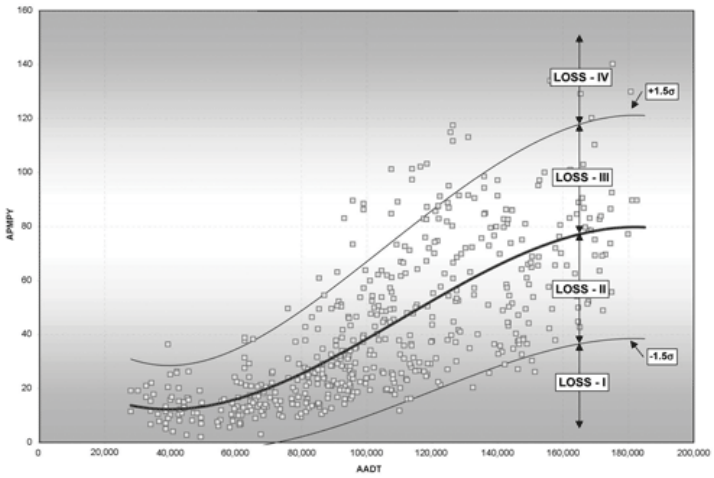

Figure 1: LOSS concept using SPF

LOSS provides information only on the magnitude of the safety problem; it does not specify the reason for the problem. CDOT uses direct diagnostics and pattern recognition techniques to better understand the nature of safety problems. These diagnostic methods use what are essentially tests of proportions: they use the binomial distribution and a set of stratified diagnostic norms to detect abnormalities in crash types and related characteristics. Integrating LOSS with diagnostic analysis provides a comprehensive analysis of the nature and magnitude of the safety problems on segments and intersections.[1]

By blending quantitative assessment and qualitative description, LOSS can categorize a roadway segment's or intersection's safety performance in relation to the expected frequency and severity of crashes predicted by its SPF. Additionally, it facilitates effective communication about

safety problems to other professionals, the traveling public, and elected officials. Engineers and planners can apply the information gathered from the LOSS method to many types of projects, including resurfacing, reconstruction, realignment, widening, and in documents such as Environmental Assessments (EA) and Environmental Impact Statements (EIS).[3]

Using GIS allows agencies to spatially integrate roadway data with crash data. Integration is necessary because developing SPFs requires homogeneous roadways (i.e., roadways with similar geometric features).[6] Once the LOSS method is complete, GIS is also essential for visualizing the data. Visualization tools greatly aid the final step of the LOSS methodology, which includes prioritizing safety countermeasures. GIS is particularly helpful during prioritization, which is consistent with the roadway safety management process; it also helps analysts observe spatial trends and communicate those trends to decision makers.[3]

KEY ACCOMPLISHMENT

The principal output of LOSS is a collection of calibrated SPFs for highway types and intersections configurations. By analyzing these, analysts can develop sophisticated predictive and diagnostic tools, which in turn informs policies or safety countermeasures to maximize crash reduction across a State—and within budget constraints. The key accomplishment is a reduction in crashes.[2] In addition to helping improve roadway safety, the information collected from LOSS has provided substantive conceptual and analytical inputs to Colorado's HSM implementation. The HSM, in turn, provides a realistic estimate of the expected crash frequency per unit of traffic exposure over a unit of time for various kinds of transportation facilities.[4] Agencies can use GIS to map this information. This provides the ability to integrate data with visualization, which is needed to understand levels of LOSS within an area and optimize the steps taken to improve safety.

TARGET AUDIENCE

Highway safety professionals, transportation planners, and transportation engineers can use LOSS methodologies.

The CDOT established and began the LOSS method when developing the methodologies in 2002. It was developed and implemented by Safety Programs Engineer and Safety Engineer. Since the implementation, the agency's analysts have applied it to all State projects.[1]

DOTs and other transportation agencies can use the methodology presented in this paper. Staff members who have experience with SPF data usually implement this process. It is crucial to

note that States must calibrate this method to account for local factors, such as the prevalent characteristics of crash reporting, climate, driver behavior, and design practices, among others.[2]

PROGRAM AND PROCESSES

CDOT IMPLEMENTATION OF THE LOSS PROGRAM

CDOT applies LOSS to all infrastructure and behavioral projects. Over the seven years of sustained application of these advanced methods on all infrastructure and behavioral projects, the CDOT achieved an unprecedented 36 percent fatal crash reduction. Figure 2 provides an example of a CDOT LOSS map. It includes LOSS severity levels, as well as land use, county, and municipal boundaries.[4]

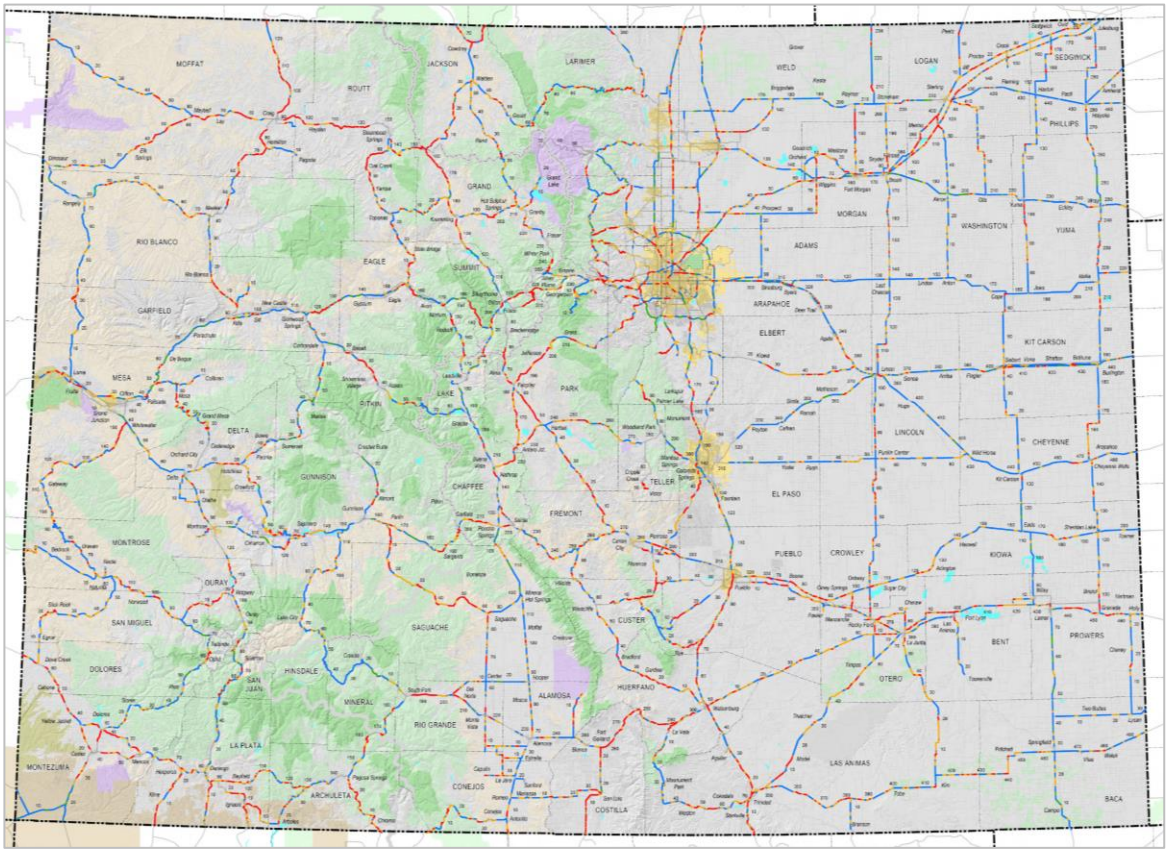

Figure 2: Statewide Highway Intersection Level of Service of Safety for Injury and Fatal Crashes where Coinciding with Recognized Crash Patterns

CDOT uses GIS as a visualization tool. However, integrating crash and roadway data is a necessary step in developing the SPFs. The crash data are linked to the roadway type based on location—in this case using a GIS. Both datasets are based on a linear reference system. However, using a coordinate system can georeference some crash data.[5]

CDOT has found LOSS to be very effective. Between 2002 and 2011, fatal crashes in Colorado declined by 36 percent without a reduction in travel or increase in safety expenditures (Figure 3).[1, 4]

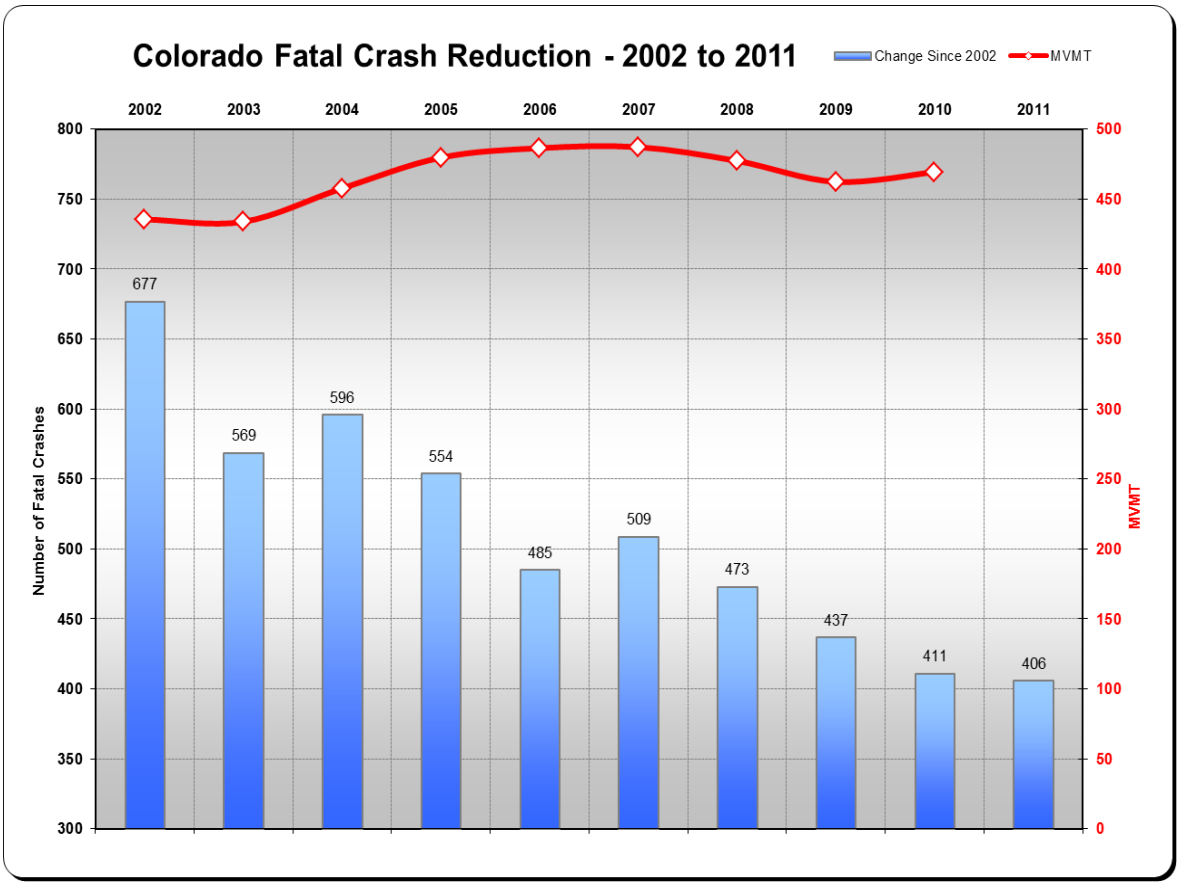

Figure 3: Colorado Fatal Crash Reduction

SUMMARY

BENEFITS/RESULTS

CDOT's pioneering work on LOSS led to the creation of a sophisticated predictive and diagnostic tool able to maximize potential crash reduction while not stretching already-exhausted budgets. These efforts have proven successful, with crash reductions of up to 36 percent. LOSS has also expedited the process of estimating the effects of different measures on safety because transportation agency stakeholders can develop their analyses based on a single authoritative document.[1, 4]

The specific benefits and strengths of the LOSS method include the following:

- Accounts for variance in crash data and traffic volume, thereby establishing a threshold for comparison.
- Using the Empirical Bayes method corrects for the RTM bias.
- Facilitates communication regarding the magnitude of the safety problem.
- Provides unifying frame of reference to make decisions about which safety countermeasures or roadway improvements will lead to the greatest increases in roadway safety.
- Aligns models of roadway safety the actual measures safety performance.
- Builds consensus on the often emotionally charged issue of road safety.[4]

LOSS provides a sound, intuitive, and easily interpreted tool to identify and describe safety problems. GIS, in turn, allows officials to visualize the LOSS data and thereby increase efficiency for addressing safety issues.

IMPLEMENTATION CHALLENGES

Using LOSS depends on the availability of SPFs for segments and intersections. This work generally requires specialized in-house technical expertise or resources allocated to consulting services. Integrating the data requires personnel with database and GIS expertise. Developing or using SPFs and LOSS also requires knowledge of the HSM and facility with advanced statistics. Most safety engineers are becoming more knowledgeable in these methodologies.[2]

FUNDING/COST

Typical approximate costs for the development of State-specific knowledge base are comprised of*:

1. Data-prep=$100,000
2. Development of segment SPF/LOSS/Stratified Diagnostic Norms=$150,000
3. Development of intersection SPF/LOSS/Stratified Diagnostic Norms=$250,000

(*These are estimates only and will vary based on a State's needs and level of resources/capability)

It is important to note that agencies can calibrate the LOSS boundaries after they estimate the SPF model parameters. Developed SPFs can significantly reduce the costs related to LOSS. Spatially enabled data (crash and roadway) can vastly improve the efficiency of the integration component. Nonspatial data require georeferencing, which can add to the cost.[2]

TIME FRAME

Implementing the LOSS approach requires a minimum of 3 years' crash data. Analysis also necessitates crash data by location and any information used to generate SPFs, which can be gathered for the selected time period. Time for data analysis varies, depending on required depth of study.[6]

LESSONS LEARNED

- Use LOSS methodology in combination with some kind of diagnostic technique to develop effective safety countermeasures.
- GIS is an important part of leveraging LOSS information.[2]

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EXPLANATION OF TERMS

AADT	–	Annual Average Daily Traffic
DOT	–	Department of Transportation
EA	–	Environmental Assessment
EIS	–	Environmental Impact Study
FHWA	–	Federal Highway Administration
GIS	–	Geographic Information System
HSIP	–	Highway Safety Improvement Program
HSM	–	Highway Safety Manual
LOSS	–	Level of Service of Safety
SPF	–	Safety Performance Function

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