Internal Memorandum

To: Project Management Team

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Subject: Clackamas Regional Center Connections Project
DRAFT - Task 4.2 Transportation System Safety Performance Measures

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This memorandum discusses the use of transportation system safety performance measures (TSSPMs) to inform the development review process and the system development charge (SDC) program within Clackamas County. This memorandum focuses on application within the Clackamas Regional Center Design Plan Area (CRCDPA) to support a Multimodal Mixed-Use Area (MMA) designation, but also discusses opportunities for a countywide implementation. The safety of all transportation system users is a key concern of Clackamas County when assessing the impacts of growth and development within the CRCDPA and elsewhere.

Under Task 4.1.2, a package of multimodal performance measures was recommended to inform long range planning and development review. This task complements the previous recommendation, further exploring practical, data-driven, safety-based performance measures and outlining an approach for their implementation.

The memorandum is divided into the following sections:

- Executive summary
- Safety planning and policy in Clackamas County
- Framework for safety analysis in evaluating land development proposals
- Summary and evaluation of transportation system safety performance measures (TSSPMs)
- Implementation recommendations
- Appendix: Forecasting future safety trends in the Clackamas Regional Center Design Plan Area

Executive Summary

Clackamas County has a strong precedent of policies and planning efforts that support a culture of transportation safety. This memo presents a framework for increasing the role of safety analysis in development review, in accordance with stated planning goals and policies. The framework assesses existing safety performance, estimates the safety impact of development, and identifies and evaluates safety countermeasures.

After considering potential transportation safety performance measures for use with the proposed framework, we recommend an approach that applies a "layered" portfolio of critical crash rate, excess proportion of specific crash types, and the HSM Predictive Method. An all-severity and high-severity critical crash rate analysis is used to identify locations that are not meeting safety performance standards. At these locations, excess proportion of specific crash types is used to diagnose the crash data and inform countermeasure selection. The HSM Predictive Method is an option for more detailed analysis of existing or future safety performance, if recommended by County Engineering.

Safety Planning and Policy in Clackamas County

Clackamas County transportation policies establish a strong precedent in support of data-driven safety analysis methods that identify effective opportunities to reduce crashes. The Clackamas County Transportation System Plan includes safety as a core policy focus, providing high-level direction for other transportation planning efforts. The Clackamas County Transportation Safety Action Plan provides a detailed data-driven assessment of road safety in the county, and identifies a multi-disciplinary approach to reducing high-severity crashes. The development review process also addresses road safety and is guided by the County Comprehensive Plan, the Zoning and Development Ordinance, and the Clackamas County Roadway Standards.

Clackamas County Transportation System Plan

The Clackamas County Transportation System Plan (TSP) establishes high-level direction for the planning, engineering, design, operation, and maintenance of the county's transportation facilities. The TSP includes a long-range vision and transportation network analysis, supported by policy statements and transportation projects. The TSP is included in the County Comprehensive Plan as Chapter 5.

Section 5.B covers roadway safety policies, including:

- Revised TSP Policy 5.B.5 – Support programs that utilize data-driven approaches to improve the safety of the transportation system.
- Revised TSP Policy 5.B.6 – Align County departments, external safety groups, and other public agencies toward common transportation safety goals.
- Revised TSP Policy 5.B.7 – Integrate roadway, safety and traffic data management, health and emergency services data sources.
- Revised TSP Policy 5.B.8 – Integrate Highway Safety Manual (HSM) principles into the planning, engineering, design, operation and maintenance of the transportation system.

Additional items relevant to this memorandum are contained in Section 5.R, policies on improvements to serve development, and Section 5.S, performance evaluation measure policies. Policy 5.R.2 requires new developments and land divisions to provide "off-site improvements necessary to safely handle expected traffic generated by the development and travel by active modes." Policy 5.S.8 directs the county to "evaluate transitioning from transportation concurrency to safety analysis when a traffic impact study (TIS) is required of new development."

Clackamas County Transportation Safety Action Plan

The Clackamas County Transportation Safety Action Plan (TSAP) details specific goals for road safety in the county, and develops a set of multi-disciplinary actions to work toward achieving those goals. The plan is one of the first of its kind performed at a county level, and aims to build and implement a county-wide safety culture. The plan is data-driven, informed by an analysis of historical crash data from throughout the county over a 5-year period.

The TSAP's primary goal is a 50% reduction in fatalities and serious injuries on roadways in Clackamas County by 2022, compared to the 2005-2009 average, or no more than 16 fatalities and 125 serious injuries annually.

Other relevant highlights of the TSAP include:

- A general focus on high-severity crashes that result in death or serious injuries ("Injury A").
- Safety emphasis areas based on the three most frequent contributing circumstances to high-severity crashes: aggressive driving, young drivers age 15-25, and roadway departures.
- The "5E" approach to safety: a multi-disciplinary collaboration including Education, Emergency Medical Service (EMS), Enforcement, Engineering, and Evaluation. The 5E's of safety are represented in the safety countermeasure toolbox, action items, and stakeholder groups formed as part of the TSAP.
- Action Item ENG16: "Fully integrate HSM procedures into the Development Review Process."

Transportation Safety Standards and Requirements

The Clackamas County Transportation Engineering Division provides for the planning, development, and implementation of countywide transportation improvements. Development site review, including the Transportation Impact Study (TIS) and System Development Charge (SDC) programs, are administered through the Division. Professional engineering judgment is a critical element of the development review process, which is guided by the Clackamas County Comprehensive Plan, the Zoning and Development Ordinance (ZDO) and the Clackamas County Roadway Standards.

The development review process and supporting code language, recently updated with recommendations from the TSAP, includes both nominal and substantive road safety provisions. As discussed in the Highway Safety Manual (HSM), nominal safety refers to design standards and other practices of good design that promote safety, while substantive safety refers to crash history and other road safety outcomes.

The ZDO in Section 1007 on Roads and Connectivity sets both safety standards and vehicle capacity standards. Sight distance, clear zones, and vehicle capacity are discussed directly in this section. The majority of the standards and requirements are included by reference to the Clackamas County Roadway Standards and Chapters 5 (the TSP) and 6 (Community Plans and Design Plans) of the Comprehensive Code. Additionally, ZDO Section 1202 on Zone Changes requires that the "safety of the transportation system is adequate to serve the level of development anticipated by the proposed zone change."

The Clackamas County Roadway Standards define the engineering design standards for the County. Nominal safety standards are provided for sight distance (Section 240), roadside and clear zones (Section 245), geometric design (Section 250), traffic signals (Section 260), traffic calming (Section 265), traffic signing (Section 270) and pavement markings (Section 280). The Criteria for Modification of Standards (Section 170.1.2) includes a statement requiring that any proposed modification "fully meets the requirements for safety, function, appearance, and maintainability based upon sound engineering and technical judgment."

Traffic Impact Study (TIS) requirements are defined in Section 295 of the Clackamas County Roadway Standards, and includes substantive safety review. Section 295.1 states "The objective of a transportation impact study (TIS) is to assess the impacts of a proposed project or land use action on the transportation system and identify mitigation for any capacity or safety deficiencies." The scope of the TIS is determined in collaboration with County Engineering, and depends on the magnitude of the development.

The safety component of a TIS must include an analysis of sight distances, access standards, truck circulation, and roadside characteristics, in addition to a review of crash history. Section 295.17.2, Crash History, requires a TIS to consider crash history at all study intersections and all sections of roadway to which access is proposed. Crash rates, frequency, and severity shall be reported at all study intersections. Additionally, a discussion of ODOT's Safety Priority Index System (SPIS) rankings is required if applicable. County Engineering can require a 95th percentile queuing analysis, and may require mitigation if queuing presents a safety issue.

In a TIS, the crash history shall be reviewed to determine crash patterns, severity, and frequency, and make recommendations for safety improvements. Intersection crash rates greater than 1.0 crashes per million entering vehicles and segment crash rates above 5.0 crashes per million vehicle miles traveled require a safety analysis based on the HSM and "may require proportional mitigation." No specific HSM procedures or analysis details are provided in the TIS requirements.

The HSM is discussed throughout the Roadway Standards and is adopted by reference as a design and analysis reference in Section 115.2, and specifically for TIS in Section 295.8.

System Development Charges

The Transportation System Development Charge (SDC) program is described in Clackamas County Code Title 11.03, and enabled by state law in ORS 223.297 through 223.314. SDCs are one-time fees charged to new development to help pay a portion of the costs associated with increasing transportation capacity to meet needs created by growth. SDCs help spread the cost of projects among many developments. The transportation SDC program is discussed further in Task 4.3, "Funding Alternatives for a Multimodal Mixed-Use Area in Clackamas County."

The County intends to pursue changes to the existing SDC program that will create a multi-modal SDC program based on person-trips. Capital projects with a safety component may be funded by an SDC program, provided the projects also increase the capacity of the transportation system.

Capacity is defined in Section 11.03.020 as “the maximum rate of flow at which persons or vehicles can be reasonably expected to traverse a point or uniform segment of a lane or roadway during a specified time period under prevailing roadway, traffic, and control conditions, usually expressed as vehicles per hour or persons per hour.” Similarly, ORS 223.307.2 states “an increase in system capacity may be established if a capital improvement increases the level of performance or service provided by existing facilities or provides new facilities.” An SDC program must publish the methodology used to calculate charges, and can only be used for projects on an adopted Capital Improvement Projects (CIP) list.

Safety-focused projects that do not address capacity in the traditional sense may be considered to increase the capacity of the system, as the projects reduce the frequency and severity of crashes. Crashes, especially high-severity crashes, reduce the capacity of the transportation system by closing or restricting access to travel lanes and roadways. The FHWA report “Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation” (2005), identifies traffic incidents such as crashes as one of the seven root causes of congestion. Even crashes that are moved out of travel lanes can influence traffic flow by distracting drivers.

In contrast with the development review process, an SDC can help to fund safety projects across a wider area of influence. An SDC also could contribute to countermeasures that are not specific to one location. Systemic engineering countermeasures applied to many county projects, access management initiatives, and non-engineering capital expenditures such as red-light cameras would fall into this category.

Safety programs that focus on education, enforcement, or evaluation are typically not capital projects and thus would be ineligible to be funded through an SDC program. Funding for these programs would need to be provided from a different legal framework.

Framework for Safety Analysis in Evaluating Land Development Proposals

This section outlines a framework for using quantitative safety analysis as a regular component of land development proposal evaluation, beyond the County's current practices. This section discusses the general methodology requirements, procedures, and desired outcomes of such a methodology. The next section evaluates specific tools and performance measures that could be used in the methodology.

The overall goal of this methodology is to provide an implementable process to maintain or improve roadway safety with each new development. The key requirements identified for this process are the ability to achieve the following tasks in an objective and consistent manner:

1. Evaluate the baseline safety performance of sites impacted by the development.
2. Determine the safety impact of the development.
3. Identify appropriate additional safety countermeasures and evaluate their impact.

A safety-based development review process should also be feasible to implement on a day-to-day basis. Professional engineers should be able to provide the needed analysis without undue burden, and the process should be scalable for developments both large and small. Procedures should be grounded in best-practices and reasonably transparent and understandable to the public and developers.

Each of these requirements is discussed in more detail below.

Evaluate the baseline safety performance of sites impacted by the development

The first step in a safety-based land development review would be to evaluate the existing safety performance of road intersections and segments (called "sites" in HSM terminology) that will be impacted by the land development proposal. As with current development review procedures, the impacted study sites would be identified in the scoping process with county Engineering.

The initial safety performance evaluation serves a critical function by setting a baseline value for the performance measure. A pre-defined safety performance standard should be established, so that existing safety performance can be assessed as acceptable or in need of improvement. Safety performance measures may or may not determine an inherent performance standard as a part of the analysis. Ideally, the performance measure should address safety for all modes of travel and have the flexibility to focus on high-severity crashes or other focus areas from the TSAP.

In some situations, it may be desirable to evaluate separately both existing conditions and future (opening day) baseline conditions, such as when development will occur after other projects that have yet to be built. An ideal performance measure could incorporate future year volume projections or design changes.

An important consideration when evaluating baseline safety performance is the sensitivity to recent crash history. Crashes, especially high-severity crashes, are inherently rare and random events. Therefore, the recent crash history of a study site can change dramatically from one year to another. As a result, the baseline safety performance of a study site may change depending on the time of analysis.

The ideal safety performance measure provides stability and predictability to developers while also reflecting the observed crash history. Using an average of multiple years (typically five) of crash data can help reduce volatility, but care must be taken to ensure crash data is only from years representative of existing infrastructure conditions.

The outcome of this step is a baseline safety performance measure value at each study site, and identification of any study sites that do not meet the safety performance standard.

Determine the safety impact of the development

The second step in a safety-based land development review is to determine the safety impact of the development. This would involve identifying how much new traffic flows through study sites that do not meet the safety performance standard, while considering the effect of any infrastructure changes proposed with the development.

As with traditional development review the first element to consider is the trips generated by the new development and the distribution of those trips on the transportation system. The County is considering a person-trips methodology to replace the current vehicle-trips approach to system development charges and the development review process. Ideally, the safety performance measure should be sensitive to the modal distribution of trips generated. Most safety performance measures rely on annual average daily traffic volumes, so it is important that a process is in place to accurately expand peak hour volumes to annual average daily volumes if needed.

In parallel with updating study site traffic volumes to reflect the impact of the development, the safety analysis should consider the safety effects of design modifications or other safety countermeasures proposed as part of the development. Ideally, the safety performance measure would capture the impact of any and all design modifications. However, not all potential design changes have undergone the research necessary to quantify their impact on safety. Additionally, research often provides a range of potential impact values. Therefore the methodology should continue to allow Engineering staff to apply their professional judgment and be flexible to adapt to the current state of the practice. One approach to considering the safety impact of design changes and other countermeasures is for the county to maintain an approved list of Crash Modification Factors for different design treatments and safety countermeasures. This is the approach ODOT uses for administering the All Roads Transportation Safety (ARTS) program.

The outcome of this step is a quantified value for a development's safety impact. A basic safety performance measure would identify study sites that do not meet the safety performance standard. In this case, a development's safety impact could be defined as the new traffic volume through these sites. Advanced safety performance measures could quantify a development's safety impact in terms of an increase in forecast crash frequency (or high-severity crash frequency), which is a more direct measure of anticipated safety impact.

Identify appropriate additional safety countermeasures and evaluate their impact.

The third and final step in a safety-based development review process is to identify appropriate additional safety countermeasures (beyond those already planned or proposed with the development) and evaluate their impact. Safety countermeasure recommendations will always be made using professional judgment, but some safety performance measures can help to inform that decision.

Through an iterative process, an appropriate set of countermeasures can be identified and evaluated to meet the safety performance standard or satisfy the County Engineer that the safety concern would be adequately addressed. Here again, it will be important for the County to have a defined methodology for selecting and applying Crash Modification Factors to estimate the impact of safety countermeasures. It is also important to keep in mind that the feasible countermeasures available at the study sites may not have an estimated impact sufficient to bring the site into compliance with the safety performance standard.

The outcome of this step is a list of additional projects for safety countermeasures at study sites that fail to meet the safety performance standard. The accompanying analysis should demonstrate the extent to which countermeasures are estimated to impact the safety performance measure.

Summary of a Framework for Safety Analysis in Evaluating Land Development Proposals

The general framework proposed here outlines a method for further integrating quantitative safety analysis into the land development process. The process determines the safety impact of individual developments using transportation system safety performance measures, then identifies and evaluates actions needed to remedy that safety impact. The outcome is a development review process that functions to continually evaluate road safety in Clackamas County at a high level of detail.

A critical element of this framework is the transportation system safety performance standards. Safety performance measures cannot be effectively used for development review without adopted safety performance standards.

Clackamas County's 5E approach to safety recognizes that the County's safety goals cannot be met through engineering actions alone and a comprehensive solution will also involve education, enforcement, emergency medical services, and evaluation. The County should consider if and how to address non-engineering countermeasure options within the development review process. If possible, the County should consider fee and funding structures that allow the flexibility to put money toward non-engineering programs that enhance roadway safety.

An unresolved detail for the County to consider about this process is how to define a developer's proportional share of a development's safety impact, and through what actions the developer can remedy that impact. Four basic options to consider are:

1. Charge a uniform safety impact fee based on forecast traffic volume through study sites determined to not meet safety performance standards. This approach does not require the identification of additional countermeasures.
2. Charge a uniform safety impact fee based on the estimated crash frequency increase attributable to the development. This approach does not require the identification of additional countermeasures.
3. Require developers to provide countermeasures sufficient to allow all study sites to meet safety performance standards. Developers could be given the option to pay the cost of countermeasures instead, with the County handling implementation. As a development incentive, some or all of the cost to provide countermeasures could count against SDCs or other traffic impact fees.
4. Require developers to pay for a proportional share of countermeasures sufficient to allow all study sites to meet safety performance standards. As a development incentive, some or all of the cost to provide countermeasures could count against SDCs or other traffic impact fees.

The County should be also consider the risk of unintended or inequitable outcomes to any proposed process. A modified TIS process with more emphasis on safety could provide a disincentive to invest in locations with safety concerns. There is also a risk of reduction in SDC funding if developers are given the option to invest in local safety countermeasures in lieu of paying general SDC fees.

Summary and Evaluation of Transportation System Safety Performance Measures

This section provides an overview of potential Transportation System Safety Performance Measures (TSSPM) that could be used as part of a framework for land development review or as part of a safety-based system development charge. For each, the following topics are addressed:

- Safety performance measure summary
- Implementation
- Strengths and weaknesses for development review

Crash Frequency and Crash Rate

Crash frequency is simply the number of observed crashes, while crash rate adjusts for traffic volume.

Safety Performance Measure Summary

Crash frequency is the most basic TSSPM and measures the number of total crashes, or crashes of a particular severity or type, in a given time period. Crash frequency is strongly correlated to traffic volume, although the relationship is non-linear. All else being equal, there will be more crashes at a location with more vehicle traffic. This means that high-traffic locations will often dominate a crash frequency analysis.

Crash rate normalizes the crash frequency by exposure, measured by traffic volume. Annual Average Daily Traffic (AADT) is used to report exposure for intersections as million entering vehicles (MEV) and for segments as million vehicle miles traveled (MVMT). Crash rate analysis allows high-risk, low-volume sites to be distinguished from low-risk, high-volume sites.

Crash rate can be interpreted as the risk to individual users of the transportation system, while crash frequency can be interpreted as the total burden to society. Both are important when considering road safety.

Because crashes are random events, crash frequency and crash rate naturally change over time at a site. Using averages over multiple years of observation helps to produce more reliable values, but crash frequency and crash rate will change from one analysis time period to another. Regression-to-the-mean (RTM) is the statistical tendency for a location with a high frequency of crashes in one time period to return to a lower crash frequency in the next time period. The long-term expected average crash frequency at a location can be difficult to determine from a short-term trend due to RTM.

Implementation

Crash frequency and crash rate analysis are simple to implement, given crash data and traffic volume data. No additional development is needed before these TSSPM can be used on a daily basis. Crash frequency and crash rate are extensively used now, forming the basis of Clackamas County's Transportation Safety Action Plan (TSAP) goals and Transportation Impact Study (TIS) safety investigation requirements. ODOT's Safety Priority Index System (SPIS) is based on measures of crash frequency and crash rate, with considerations for injury severity.

Strengths and Weaknesses for Development Review

Crash frequency and crash rate are necessary basic performance measures, but are limited and should be complemented with additional analysis.

Table 1: Crash Frequency and Crash Rate TSSPM Evaluation

	Strengths	Weaknesses
Evaluate Baseline Safety Performance	• Simple to implement. • Directly reflects user experience.	• Does not set performance standard. • Susceptible to RTM.
Determine Safety Impact of Development	• None.	• Does not estimate development impact on safety.
Identify and Evaluate Countermeasures	• Crash patterns can be qualitatively assessed for countermeasure selection. • Crash Modification Factors can be used to provide basic quantitative estimates of countermeasure impact.	• Analysis does not identify locations where treatments will likely be most effective. • Relies on judgment and experience to identify countermeasures. • Susceptible to RTM bias in evaluating countermeasures.
Implement on a Daily Basis	• Low level of effort to implement. • Minimum data needs. • In common use currently.	• Values highly likely to change year to year (RTM).

Crash Modification Factors (CMFs)

Crash Modification Factors (CMFs) describe the estimated change in crash frequency for a particular safety countermeasure, derived from academic and professional research.

Safety Performance Measure Summary

CMFs are given as multiplier values applied to a crash frequency. A CMF with a value of 1.0 would produce no change in estimated crash frequency, while a CMF with a value of 0.5 would cut estimated crash frequency in half. CMFs should always specify a base condition and a treatment condition, and an analysis should always use the CMF value that best matches the site conditions. CMFs should also specify what type of crash it applies to, or if it is expected to apply to all crashes equally. CMFs may apply only to a specific vehicle movement or injury severity level.

Implementation

CMFs are available for a wide range of site conditions and countermeasures. CMFs can be found from sources including the HSM Part D, the CMF Clearinghouse, and ODOT's All Roads Transportation Safety (ARTS) program. However, many countermeasures or site conditions lack the research necessary to create quantitative CMFs. Other countermeasures will report a range of possible CMF values.

Strengths and Weaknesses for Development Review

CMFs are the primary tool to estimate the impact of countermeasures on safety performance quantitatively. CMFs can be used with most other TSSPMs, and feature prominently in the HSM Predictive Method.

Table 2: Crash Modification Factors TSSPM Evaluation

	Strengths	Weaknesses
Evaluate Baseline Safety Performance	• N/A	• N/A
Determine Safety Impact of Development	• Easy to implement	• Appropriate CMFs may not be available for some countermeasures.
Identify and Evaluate Countermeasures	• Provides quantitative estimates of countermeasures	• Appropriate CMFs may not be available for some countermeasures.
Implement on a Daily Basis	• Many common countermeasures have CMFs available. • Limited data needs • National databases available	• Appropriate CMFs may not be available for some countermeasures.

Critical Crash Rate

Critical crash rate is a method for identifying sites with a unusually high crash rates.

Safety Performance Measure Summary

Critical crash rate is a TSSPM from the Highway Safety Manual (HSM) that is used to identify sites experiencing a crash rate that is significantly higher than peer locations. The observed crash rate at each site is compared to a calculated critical crash rate that is unique to each site. Sites that exceed the critical crash rate are identified as a safety focus site with an opportunity for safety improvement.

The critical crash rate is determined using the average crash rate of similar sites in a reference population. The analysis also uses observed crash data, traffic volume, and a statistical constant that represents a desired level of significance.

Implementation

Because critical crash rate uses a reference population, it requires somewhat more effort to implement than crash rate alone. A reference population is a collection of many representative sites from throughout a geography, all of a similar categorical type. Categories can be defined using characteristics such as functional class, traffic control, geometric design elements, land use, or traffic volumes.

The HSM uses land use type (rural or urban), traffic control (signalized, stop controlled, roundabout), and number of intersection legs (4-leg or 3-leg) to define intersection categories. Road segment categories use land use type (rural or urban), median type (divided or undivided), and number of travel lanes.

Reference population categories and descriptive statistics (average crash rates) are necessary before implementation and should be updated regularly. Critical crash rate is commonly used to identify a threshold crash rate value in safety analysis, including in ODOT's Transportation System Plan guidance. ODOT provides a spreadsheet tool for calculating critical crash rates.

Strengths and Weaknesses for Development Review

Critical crash rate provides a solid foundation for improved safety analysis, but is limited to identifying areas of safety concern and provides little additional utility.

Table 3: Critical Crash Rate TSSPM Evaluation

	Strengths	Weaknesses
Evaluate Baseline Safety Performance	• Easy to implement • Identifies threshold for performance. • Accounts for exposure.	• Reference population selection and performance strongly influences results. • Only identifies outlier locations. • Susceptible to RTM.
Determine Safety Impact of Development	• Identifies developments that increase traffic at high-risk sites.	• Does not quantify the estimated impact of development on safety.
Identify and Evaluate Countermeasures	• Identifies sites where countermeasures are likely to be effective. • Crash patterns can be qualitatively assessed for countermeasure selection. • Crash Modification Factors can be used to provide basic quantitative estimates of countermeasure impact.	• Relies on judgment and experience to identify countermeasures. • Susceptible to RTM bias in evaluating countermeasures.
Implement on a Daily Basis	• Low level of effort to implement. • Limited data needs. • Widely used.	• Most sites will not exceed their critical crash rate. • Identified sites may change year to year (RTM). • Requires reference population.

Excess Proportion of Specific Crash Types

Excess proportion of specific crash types is used to analyze the types of crashes observed at a site.

Safety Performance Measure Summary

Excess proportion of specific crash types is a TSSPM from the HSM that identifies sites where specific types of crashes (target types) are overrepresented as a proportion of all crashes at the location. This TSSPM is used to diagnose crash patterns at a site, and does not evaluate the frequency or rate of crashes. At sites with an excess proportion of a specific crash type, countermeasures targeted to that crash type are likely to be effective.

The excess proportion of specific crash types is determined using the average proportions of crash types in a reference population. The analysis also uses observed crash proportions and a statistical constant that represents a desired level of significance. This TSSPM is commonly used to evaluate the observed collision types and crash severities at sites, and could also be used to identify overrepresentation of vulnerable populations. This TSSPM may not work well at locations with few observed crashes of the target types.

Implementation

As with critical crash rate, reference populations need to be defined and analyzed before implementation. Additional information is needed from the reference population for this TSSPM, compared with critical crash rate.

Excess proportion of specific crash types requires limited data, but involves more than typical statistical analysis for implementation. ODOT provides a limited spreadsheet tool that implements excess proportion of specific crash types. The spreadsheet is currently being revised to accommodate more flexible use.

This TSSPM is not often used currently, although upcoming ODOT guidelines will recommend it for widespread use as a complement to the critical crash rate in system analysis. A similar method of identifying crash patterns is used in the ODOT Safety Investigations Manual.

Strengths and Weaknesses for Development Review

Excess proportion of specific crash types is a useful diagnostic addition to a safety analysis, but is not sufficient to be the only TSSPM used.

Table 4: Excess Proportion of Specific Crash Types TSSPM Evaluation

	Strengths	Weaknesses
Evaluate Baseline Safety Performance	• Easy to implement • Identifies threshold for performance. • Results can focus on a specific type of target crash. • Indirectly accounts for exposure, since relative proportions are used.	• Does not evaluate magnitude of safety concern. • Does not consider exposure. • Reference population selection and performance strongly influences results. • Does not work well at sites with few crashes of the target type. • Only identifies outlier locations. • Results may change based on changing crash data.
Determine Safety Impact of Development	• Identifies developments that increase traffic at sites with unusual crash patterns.	• Does not quantify the estimated impact of development on safety.
Identify and Evaluate Countermeasures	• Quantitative identification of crash patterns aids countermeasure selection. • Crash Modification Factors can be used to provide basic quantitative estimates of countermeasure impact.	• Does not directly address crash frequency or crash rate outcomes. • Does not estimate magnitude of countermeasure impact.
Implement on a Daily Basis	• Low level of effort to implement. • Limited data needs.	• Identified sites may change year to year. • Requires reference population.

Highway Safety Manual Predictive Method

The Highway Safety Manual Part C Predictive Method (HSM Predictive) uses site-level roadway and traffic data to model the estimated safety performance of a site.

Safety Performance Measure Summary

HSM Predictive is based on a collection of different underlying models, called Safety Performance Functions (SPFs), each developed for a specific type of roadway through extensive research efforts. The HSM includes sets of SPFs for urban and suburban arterials up to 5 lanes, rural two-lane and multi-lane highways, and freeways and interchanges. Within these categories are SPFs for different intersection control types and road segment cross sections. Results are given in estimated crash frequency, and depending on the SPF used may include a breakdown by type and severity of estimated crashes.

Pedestrian and bicyclist crash prediction is provided, but the underlying process is less robust than the process for vehicle crashes.

Predictions for a specific site condition combine SPFs with Crash Modification Factors (CMFs) and local calibration factors. ODOT Research has calibrated many of the HSM predictive models (excluding freeways and interchanges) to Oregon conditions. The HSM also provides a methodology for developing new local SPFs, and ODOT is pursuing local SPFs for roundabouts and corridor access management. In-progress FHWA research is developing SPFs for 6-lane arterials and one-way streets in urban and suburban contexts.

HSM Predictive can be used to evaluate historical performance against what is considered to be "typical" performance for the site characteristics. It can also be used to estimate and evaluate future performance considering changes in traffic volumes or design modifications. HSM Predictive can produce two types of estimates, predicted crash frequency and expected crash frequency.

Predicted crash frequency is the direct outcome of the SPF, CMFs, and calibration factors. Predicted crash frequency is calculated using only traffic data and roadway data, without considering observed crash history. Expected crash frequency combines the predicted crash frequency with the observed crash history, using a weighting process called Empirical-Bayes Adjustment.

The expected crash frequency provides the most reliable estimate of the long-term expected crash history at a site. By using both the observed crash history and HSM Predictive model, the expected crash frequency reduces the impact of RTM. Expected crash frequency can be calculated for sites where there is crash data available for the analysis period, or where site conditions are mostly similar to conditions during the crash data period. Expected crash frequency cannot be calculated for new or significantly modified roadways.

HSM Predictive modeling can inform many different TSSPMs, but three of the most useful are Net Change in Predicted Crash Frequency, Net Change in Expected Crash Frequency, and Excess Expected Crash Frequency.

Net Change in Predicted Crash Frequency is the difference in predicted crash frequency between two different HSM Predictive scenarios. For example, consider a no-build scenario estimated to have 10 crashes per year and a build scenario estimated to have 7 crashes per year. In this case, the build scenario has a net change in predicted crashes value of -3 crashes per year. If expected crash frequency can be calculated for both scenarios, the Net Change in Expected Crashes provides a similar TSSPM that also considers observed crash history.

Excess Expected Crash Frequency is a TSSPM that evaluates safety performance for a site's existing conditions. Excess Expected Crash Frequency is defined as the expected crash frequency minus the predicted crash frequency. The result quantifies the difference between a site's crash experience and the anticipated performance of a site with the same characteristics. Positive values of Excess Expected Crash Frequency indicate an opportunity for effective crash reduction.

Implementation

HSM Predictive modeling requires a high level of effort to implement on a network-wide basis, although studies with limited scope can be implemented easier. The model is data-hungry, and requires more data than is currently available in most roadway information databases. Even for data that is already available, effort is required to format it to be usable with HSM Predictive modeling. Typical implementations in Oregon use spreadsheet tools provided by ODOT, but they must be modified if used for many sites. Software packages are available that can help implement HSM Predictive modeling. Clackamas County would need to establish a data collection methodology and analysis tool workflow to implement HSM Predictive on a daily basis.

Many state departments of transportation have begun implementing elements of the Highway Safety Manual, including HSM Predictive modeling. This has been encouraged and facilitated though National Cooperative Highway Research Program (NCHRP) 17-50: "Lead State initiative for Implementing the Highway Safety Manual." Recent publications from NCHRP 17-50 indicate that HSM Predictive is being used as a tool during design exception analysis. However, it does not seem that HSM Predictive is yet used as a standard element in development review.

Strengths and Weaknesses for Development Review

HSM Predictive provides a robust foundation for a highly-quantified safety analysis, although level of effort for implementation is high. HSM Predictive models are not available for some roadway types.

Table 5: HSM Predictive TSSPM Evaluation

	Strengths	Weaknesses
Evaluate Baseline Safety Performance	• State-of-the-art quantitative safety performance evaluation and forecasting. • Considers specific site conditions. • Identifies threshold for performance. • Quantifies all sites, not just outliers. • Results can often focus on a specific severity or type of crash. • Accounts for exposure and RTM.	• Limited by available SPFs and CMFs. • Results may change based on changing crash data.
Determine Safety Impact of Development	• Provides quantitative evaluations of existing and future conditions. • Results are in units of crash frequency.	• Limited by available SPFs and CMFs.
Identify and Evaluate Countermeasures	• Flexible evaluation of countermeasures and design modifications. • Quantifies estimated impact of countermeasures on safety. • Results can often identify a specific severity or type of crash that is	• Limited by available SPFs and CMFs.

	higher than anticipated.	
Implement on a Daily Basis	• Provides easy to communicate results. • Allows for objective and uniform evaluations. • Software available to aid implementation.	• Data-hungry, may require new data to be collected. • High level of effort to implement. • Expected crash frequency may change year to year. • Implementation manually over a large area is time consuming.

PLANSAFE

PLANSAFE provides regional scale evaluation and forecasting of safety performance.

Safety Performance Measure Summary

PLANSAFE is a tool for safety performance evaluation and prediction at a regional scale, using elements from a travel demand model and GIS datasets. PLANSAFE can predict crash frequency by severity or other focus crash types, using one of many included SPFs used. The PLANSAFE unit of analysis is Census Block Groups or travel demand model transportation analysis zones (TAZs).

The PLANSAFE predictive models (similar to but unique from the HSM predictive models) use observed crash data, demographic and economic variables, and road network geometry and traffic volumes, to evaluate current safety performance and predict how performance will change with changing input variables. PLANSAFE is designed for scenario testing and sketch planning. PLANSAFE responds to significant regional land use or transportation network changes, and does not reflect site-specific changes such as a new turn lane or access management. Unlike HSM Predictive, PLANSAFE is not intended to provide a direct causal connection between particular investments and safety results; it does not explain why outcomes will occur. PLANSAFE does not directly address pedestrian or bicyclist safety.

Implementation

PLANSAFE is a stand-alone software tool that uses GIS for most of the data preparation. Developed in NCHRP 8-44 (1) and (2), the current phase of the project intends to create a more user-friendly interface and address a wider variety of conditions. The revised software and report is not publically available at this time, and using the original software requires a high level of effort to implement. Staff would need to be specifically trained to produce consistent results if PLANSAFE were to be used on a daily basis. Public implementation examples of PLANSAFE are limited to the NCHRP reports and small case studies.

Strengths and Weaknesses for Development Review

PLANSAFE does not provide analysis at the level of individual intersections or roadways, and thus would not be an appropriate tool for typical development reviews.

Table 6: PLANSAFE TSSPM Evaluation

	Strengths	Weaknesses
Evaluate Baseline Safety Performance	• Planning-level analysis and regional scale means predictive analysis can be run for a full region without site-level details. • Flexible focus crash types. • Incorporates observed crash data. • Accounts for exposure and RTM.	• Does not create inherent performance threshold. • Results at the Block Group/TAZ level, not at the facility level. • Software and SPFs are not currently in active or open development.
Determine Safety Impact of Development	• Quantifies the estimated changes in safety using development and growth. • Integration with travel demand models allows for fast analysis of many growth/land use scenarios. • Provides quantitative evaluations of existing and future conditions. • Results are in units of crash frequency.	• Does not create inherent performance threshold. • Results at the Block Group/TAZ level, not at the facility level. • Does not establish cause and effect. • Small changes in traffic volume will have very little noticeable impact on results.
Identify and Evaluate Countermeasures	• Quantifies estimated impact of countermeasures on safety. • Comprehensive coverage is good for behavioral and systemic countermeasures.	• Not intended to evaluate site-specific engineering countermeasures. • Results at the Block Group/TAZ level, not at the facility level.
Implement on a Daily Basis	• Does not require site-level details.	• Software is not user-friendly, is currently unsupported.

Risk-Based Analysis - ODOT's Bicycle and Pedestrian Safety Implementation Plan

Risk-based analysis evaluates sites based on the presence of various traits associated with crashes.

Safety Performance Measure Summary

Risk-based analysis attempts to overcome the limitations of crash data by profiling roadways based on the expected risk of traveling on the roadway. Risk-based analysis is popular for proactively analyzing pedestrian and bicycle safety, since these modes exhibit crashes that often are too infrequent or geographically dispersed for traditional methods.

Risk is evaluated on a relative scale (higher to lower risk, not quantified to a likelihood of collision) based on the presence of risk factors, and used to identify higher-risk corridors that could be priority locations for targeted or systemic countermeasure application. There is no clear threshold for a high risk score.

Risk factors are identified based on a system-wide evaluation of bicycle and pedestrian (or other target type) crashes, relating the presence of the risk factors to a history of crashes. This TSSPM is proactive because it may identify locations for safety improvements that do not have a history of crashes.

Implementation

ODOT's Oregon Pedestrian and Bicycle Safety Implementation Plan used a risk-based analysis method as a supplement to traditional crash frequency and severity analysis when identifying potential project corridors. Due to limited or inconsistent data, the risk-based screening method was only applied to ODOT facilities in urban areas. A Clackamas County implementation could use these risk factors and scores directly, or could develop local versions that are tailored to county crash history and available roadway data. The results of a risk-based analysis depend heavily on the relative weights given to each risk factor, which is usually decided by consulting the project management team and stakeholder groups. The ODOT study identified the following risk factors and weightings, where more points indicate higher risk:

Table 28 Pedestrian Risk Factor Scoring Criteria

Risk Factor	PMT Relative Weight	Risk Factor Scores
Proximity to Signal	1	• 1 point if at least 1 signal is located on the segment or within 100' of the segment
Proximity to Transit Stop	2	• 1 point for segments with 1 transit stop located on the segment or within 100' of the segment; • 2 points for 2 or more transit stops
Pedestrian Activated Beacons or Flashers	2	• 1 point subtracted (rewarded) for the presence of an enhanced midblock crossing
Posted Speed Limit	3	• 2 points for posted speed limit of 35 or 40 mph; • 4 points for posted speed limits above 40 mph
Undivided, 4-lane Segment Characteristic	3	• 2 points if segment is an undivided 4-lane segment
Number of Non-Severe Injuries and Pedestrian Involved but Not Injured in Crashes	4	• 2 points if a non-severe injury or pedestrian-involved crash was reported on the segment or within 100'; • 1 additional point for each additional injury or pedestrian involved
AADT	4	• 2 points for AADT between 12,000 and 18,000; • 4 points awarded for AADT above 18,000[1]
Number of Severe Injuries Resulting from Pedestrian-Involved Crashes	5	• 4 points awarded if a severe injurywas reported; • 2 additional points awarded for each additional severe injury
Number of Fatalities Resulting from Pedestrian-Involved Crashes	5	• 4 points awarded if a fatality was reported

Table 29 Bicycle Risk Factor Scoring Criteria

Risk Factor	PMT Relative Weight	Risk Factor Scores
Proximity to Signal	1	• 1 point awarded if at least 1 signal is located on the segment or within 100' of the segment
Undivided, 4-lane Segment Characteristic	1	• 1 point awarded if the segment is an undivided 4-lane segment
Proximity to Transit Stop	1	• 1 point awarded for segments with 1 transit stop located on the segment or within 100' of the segment; • 2 points awarded for 2 or more transit stops
Lack of Bicycle Facility (Left side of road)	2	• 2 points awarded for the lack of a bicycle facility on the left side of the road
Lack of Bicycle Facility (Right side of road)	2	• 2 points awarded for the lack of a bicycle facility on the right side of the road
AADT	3	• 2 points awarded for AADT between 12,000 and 18,000; • 4 points awarded for AADT above 18,000
Posted Speed Limit	3	• 2 points awarded for a posted speed limit of 35 or 40 mph; • 4 points awarded for posted speed limits above 40 mph
Number of Driveways	4	• 2 points awarded for segments with 1 driveway; • 3 points for segments with 2 to 3 driveways; • 4 points for segments with 4 to 8 driveways; • 5 points for segments with more than 8 driveways
Number of Non-Severe Injuries and Bicyclists Involved but Not Injured	5	• 2 points for first occurrence • 1 additional point for each subsequent
Number of Severe Injuries Resulting from Bicyclist-Involved Crashes	6	• 4 points awarded if a severe injury was reported; • 2 additional points awarded for each additional severe injury
Number of Fatalities Resulting from Bicyclist Involved Crashes	6	• 4 points awarded if a fatality was reported

Level of effort to implement this TSSPM is initially high, but would be lower once the risk factors have been determined. Risk-based analysis is typically managed through a GIS system. Use on a daily basis would be easiest if all risk factor data was available in a unified roadway information database. Calculations are simple and could be performed in a spreadsheet or implemented within a database.

Strengths and Weaknesses for Development Review

Risk-based analysis is an innovative way to quantify safety performance for locations with sparse crash history. The value for development review would partially depend on the identified risk factors being traits that are partially within developers control, and on the fee methodology established.

Table 7: Risk-Based Analysis TSSPM Evaluation

	Strengths	Weaknesses
Evaluate Baseline Safety Performance	• Provides quantitative evaluations of existing and future conditions. • Simple to implement. • Universal applicability. • Considers areas with no observed crash history. • Stable results year to year. • Incorporates site-level details.	• Does not create inherent performance threshold. • Does not directly consider crash history. • Does not quantify results in terms of potential for crash reduction. • No national standards.
Determine Safety Impact of Development	• Quantifies the estimated changes in risk due to traffic volume changes and facility changes. • Can be used for future conditions. • Incorporates site-level details.	• Does not create inherent performance threshold. • Does not quantify results in terms of potential for crash reduction. • Does not establish cause and effect. • Small changes in traffic volume may not impact results.
Identify and Evaluate Countermeasures	• Quantifies estimated impact of countermeasures on risk. • Considers countermeasures that may not have well developed CMFs.	• Does not quantify results in terms of potential for crash reduction. • Does not establish cause and effect. • Limited number of countermeasures will impact the analysis.
Implement on a Daily Basis	• Medium level of effort to implement once initial analysis is completed. • Easy to communicate concept.	• High level of effort to create initial analysis. • Abstracted from actual safety outcomes

Implementation Recommendations

Clackamas County is well positioned to include quantitative safety analysis during the development review process. Safety is already included as a consideration in policy ranging from high-level visions and goals to day-to-day Transportation Impact Study (TIS) requirements. The framework described in this memorandum could likely be implemented through the Clackamas County Roadway Standards. Given the County's inclusive approach to safety and development, outreach to affected stakeholders is highly recommended.

The most useful addition to county documents would be the inclusion of defined safety performance measures, including performance standards and analysis methodology, similar to the v/c and LOS requirements that currently guide motor vehicle capacity analysis.

The Clackamas County Roadway Standards currently provide threshold crash rates that trigger the requirement for HSM analysis. However, these crash rates only trigger an analysis, and do not appear to set the target for mitigation actions. Additionally, these threshold crash rates are for crashes generally (all severities) and do not match the Transportation Safety Action Plan (TSAP) focus on high-severity crashes. Current threshold crash rates of 1.0 crashes per million entering vehicles for intersections and 5.0 crashes per million vehicle miles traveled for segments are set significantly higher than current county average crash rates, and thus if adopted as a target would not represent progress toward the TSAP goal of reduced crash fatalities and serious injuries.

Based on the evaluation presented in the previous section, we recommend an approach that applies a "layered" portfolio of critical crash rate, excess proportion of specific crash types, and HSM Predictive.

1. **Establish County Specific Safety Baseline.** We recommend that Clackamas County develop and regularly update information for site safety reference populations using county-wide crash data. The County should also provide a regularly updated list of approved Crash Modification Factors (CMFs) for use in the safety analysis process.
2. **Apply Critical Crash Rate Methodology.** The critical crash rate is recommended as the basic safety performance standard, and any intersection or segment exceeding its critical crash rate should be considered to be not meeting the safety performance standard. The all-severity crash rate and high-severity crash rate should both be considered. At sites that exceed either the all-severity or high-severity critical crash rate, excess proportion of specific crash types should be used to diagnose and document crash patterns considering collision type, injury severity, and TSAP emphasis areas.
3. **Identify Suitable Countermeasures To Address Impacts.** This information should be used to identify as conditions of approval proposed countermeasures sufficient to reduce crashes to below the critical crash rate.

County Engineering should retain the option to use HSM Predictive to provide more refined safety analysis and forecasting capabilities when professional judgement determines it would be appropriate.

As the County and developers become more familiar with the process, data, and tools involved, HSM Predictive can be considered for more frequent use in development review.