

## **Developing an Online Tool for Delivering Research Results: An Update to the Oregon Department of Transportation's Crash Reduction Factor Database**

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## ABSTRACT

Oftentimes, the challenge in disseminating research results to the practitioner is to package and present the results in a manner that is accessible and easy to use, while still providing the depth, guidance, and necessary information. In most cases, final research reports are made available in printed form and online, however, for some applications converting the report to a more interactive online report (tool) can produce results that are easier for the user to access. This is particularly true in this age of information overload and as practitioners find themselves needing to “do more with less.” This paper describes how research results from an update to the Oregon Department of Transportation’s crash reduction factor (CRF) database were incorporated into an online tool. The paper describes the methodology for cataloging a total of 94 crash countermeasures, reviewing the literature, and the development of the interactive online tool. The tool allows users to search based on key parameters for the countermeasure(s) most appropriate to a particular highway safety improvement project and to directly access pertinent citations from the literature review database. A case study is used to describe how a traffic safety professional might use this online tool in practice.

## INTRODUCTION

Oftentimes, the challenge in disseminating research results to the practitioner is to package and present the results in a manner that is accessible and easy to use, while still providing the depth, guidance, and necessary information. In most cases, final research reports are made available in printed form and online, however, for some applications converting the report to a more interactive online report (tool) can produce results that are easier for the user to access. This is particularly true in this age of information overload and as practitioners find themselves needing to “do more with less.” The research results described in this paper from a project to update the Oregon Department of Transportation (ODOT)’s crash reduction factors (CRFs) are used to estimate the safety effects of various engineering treatments, was conducted with an online delivery method envisioned. Planners, engineers and safety professionals who wish to use research results will be interested in quickly finding the countermeasure(s) that best match the safety problem that they have identified at a specific location. The final report for the completed research project is approximately 180 pages (1) and is organized by research quality and type of improvement. If, for example, users are interested in finding countermeasures that apply to an urban intersection, they will be required to sort through the majority of the report. While all of the information is available, an interactive online tool can be more productive and present more detailed information the user. Further, the interactive nature of a web-based format can provide links to related countermeasures, detailed information, original sources, photographs and graphical examples. The content can also be continuously updated in the online version.

Developing a transportation system that balances safety, mobility, and efficiency is a primary objective of most transportation agencies. In spite of these objectives, there are still unacceptably high numbers of traffic-related fatalities and injuries on U.S. highways—upwards of 42,000 fatalities and almost 3 million injuries are reported per year (2). Every state has a highway safety improvement program, many of which were implemented with federal guidance following the passage of the Highway Safety Act of 1966. Typical state approaches to highway safety improvement include the following steps (3):

- Identification of hazardous roadway locations using crash records;
- Detailed engineering studies of selected hazardous locations to identify problems;
- Identification of potential countermeasures;
- Assessment of the costs and benefits of potential countermeasures;
- Implementation of countermeasures with the highest net benefits; and
- Assessment of countermeasure effectiveness following implementation.

Identification and implementation of safety improvements (countermeasures) are keys to safety improvement planning. Benefits of safety projects are usually measured as reductions in the severity or frequency of crashes. Estimates of the safety effectiveness of countermeasure are often called crash (accident) reduction factors (CRFs). CRFs are usually based on research that examines the effects of particular countermeasures on crash frequency and severity. These empirical results are then used by transportation agencies to forecast prospective crash reductions which are converted to dollar values for use in safety cost-benefit analysis. CRFs are used by many states, including Oregon, as a tool to evaluate the cost-benefit relationships between various roadway improvements and their effectiveness in reducing the number and/or severity of crashes. Although a need was recognized for a comprehensive national inventory of CRFs nearly 30 years ago (4), responsibility for their development has, until recently, remained with individual states. Most states compiled their lists from the literature or evaluations of their own projects and existing research. Considerable variation still exists between states in the countermeasures

employed and the quality and sources of research used to determine CRFs (4). Fortunately, cataloging countermeasures and documenting their effectiveness have become a major focus in transportation research and planning in recent years. The American Association of State Highway and Transportation Officials (AASHTO) Strategic Highway Safety Plan (SHSP) and the Federal Highway Administration (FHWA)'s adoption of the "Vital Few" approach, along with work toward developing a Highway Safety Manual, have motivated these efforts.

Currently, there are many relevant safety-related research efforts underway at the state, national, and international levels. One example is National Cooperative Highway Research Program (NCHRP) Project 17-25, "Crash Reduction Factors for Traffic Engineering and ITS Improvements," whose objective was to "develop reliable CRFs for traffic engineering, operations, and ITS improvements (5)." The results of this study were used extensively in the project described in this paper. Another effort cataloging knowledge of the safety effects of countermeasures is the Highway Safety Manual (HSM). The HSM will be a comprehensive source for safety knowledge in much the same way as the Highway Capacity Manual (HCM) is for traffic operations. The HSM is being developed by the Task Force for the Development of the HSM, a committee of the Transportation Research Board. Yet another effort, Safety Analyst, is a software package under development by FHWA in partnership with thirteen state Departments of Transportation (DOTs) will "provide state-of-the-art analytical tools for use in the decision-making process to identify and manage a system-wide program of site-specific improvements to enhance highway safety by cost-effective means" (6). The tool will include methods for network screening, countermeasure selection, and cost-benefit analysis. Finally, there are numerous guidebooks and manuals available that comprise a "toolbox" for practitioners. One example is the series of guidebooks produced as part of the AASHTO initiative to implement the SHSP, listing countermeasures by crash type and evaluating each based on the extent of their application and studies of effectiveness (7-14). The need for reliable CRFs has clearly been recognized.

The updated ODOT database will improve the ability of department staff to select the best safety improvement and in the long run, enhance project development. The two objectives of the research were to 1) to document important aspects of the CRFs so engineers will be better informed when selecting the appropriate countermeasures and 2) to clearly document the methodology and sources to enable easy updating of the database in the future. With so much new research in the safety area being performed, a printed report will soon be out of date. The advantage of a well-designed database is that this new research can be easily incorporated as it is published. The following sections describe how the crash reduction factors database was developed, how the research results were converted to an online tool, and a case study demonstrating how the tool can be used by engineers and planners at ODOT as well as at other transportation agencies.

## DEVELOPING THE CRASH REDUCTION FACTORS

CRFs are expressed in the expected percent reduction in crashes after implementation (negative CRFs imply crash increases). Alternatively, expected changes in safety can be expressed with accident or crash modification factors (AMF or CMF). AMFs are increasingly becoming the standard manner in which safety effectiveness is reported in the literature and in recent federally supported research. An AMF of 1.00 implies no safety effect, while an AMF greater than 1.00 represents an increase in crashes and less than one a decrease. The relationship between AMFs and CRFs is by the formula ( $CRF = 1 - AMF$ ). Given that ODOT, on whose behalf this research was performed, has historically used CRFs, this paper uses this terminology.

ODOT has relied on its current collection of countermeasures since the early 1990s. The CRF database contained approximately 70 total countermeasures divided into categories that often did not clearly relate to particular situations or crash types. One criticism of the database was that documentation for each countermeasure was not apparent for professionals to make judgments about the applicability or validity of the particular countermeasure. Given the uncertainty inherent in estimating the safety effects of various treatments, it was thought that providing more information about the methods, study approach, and statistical reliability of analyses used to develop a CRF would be valuable. In essence, the main objective of this research was to compile and present countermeasures in a way that would make it less cumbersome for ODOT engineers and planners to search for countermeasures applicable to a given situation, as well as giving them a greater degree of confidence in the recommended CRFs.

Using ODOT's existing CRF analysis tool as a point of departure, an effort was made to expand the CRF database by including potential CRFs from existing public agency catalogs (Kentucky, South Dakota, Ohio, Southeastern Michigan Council of Governments) and a substantial body of literature (6-22). The new expanded CRF database was briefly reviewed by the technical advisory committee (TAC) developed for this research project, ODOT research staff, ODOT engineers, several academics and other practitioners. Several countermeasures unlikely to be used in Oregon were ultimately removed from the database at the suggestion of the TAC. The remaining countermeasures became the focus of a comprehensive literature review.

It is well documented in the literature that many safety analyses from the past were of poor quality. Most of these studies did not account for some rather common problems with crash data or trends. Readers are referred to

Shen and Gan (23) and Hauer (24, 25) for further discussion of issues such as regression to the mean, crash migration, and other contributing factors. As part of the critical literature review, each research study for each of the countermeasures was evaluated on a Likert scale for quality and thoroughness (with 1 representing lowest quality and 5 representing highest quality). This was based on the type of study, the extent of the research, data validity, and the quality of the citations. Based on these reviews, countermeasures were categorized into three classes: 1) Countermeasures with Robust Research; 2) Countermeasures with Limited Research; and 3) Countermeasures with Discussion Only. To be classified as “*Countermeasures with Robust Research*,” it was determined that well-designed, reliable research results were available, and the safety effects of the treatment have been quantified. For “*Countermeasures with Limited Research*,” this meant that there were only limited research results available and for which safety effects have been only partially quantified. In this category, CRFs were provided but discussions of the limitations and concerns are also clearly presented. In the online tool (and in Table 1) categories 1 and 2 are displayed as “*Results with Suggested Crash Reduction Factors*” for the research quality. For “*Countermeasures with Discussion Only*” the literature review found that no estimates of crash countermeasure effectiveness were provided. However, many of these countermeasures are generally considered good design practice and rather than not include them, the decision was made to categorize them in this manner. For this category, no CRFs are given (only qualitative text discussion). The method used in this review and classifying of countermeasures is synergistic with the methodologies used in NCHRP 17-25 but was developed independently. As this project proceeded, the decision was made to follow the results of NCHRP 17-25 for consistency for ODOT. As a result, the classification of a total of 20 countermeasures with robust research matches NCHRP 17-25 exactly in terms of estimated safety effectiveness and name.

To further characterize each countermeasure, descriptive variables were defined. These additional variables are shown in Table 1. “Character” refers to whether the countermeasure is applicable in an urban or rural setting (or both). “Roadway type” describes whether the countermeasure is applied over roadway segments or at intersections. The “type of improvement” category is the general category of work. The variables “crash type” and “other cause factor” allow multiple selections for each countermeasure, while the others are single variables. These are defined generally for each countermeasure (i.e. the countermeasure has some effect on the crash type and cause factor, whether or not this rigorously defined in the reviewed literature). This exercise, while helpful for including in the printed report, was primarily performed to add useful search capabilities to the online database.

## DEVELOPING THE ONLINE WEB TOOL

An online tool was envisioned from the first phases of this research. To facilitate easy transfer of the research results to an online tool, a relational database in Microsoft Access was created at the beginning of the project to capture the pertinent information. There are three primary tables—countermeasures, research, and sources. There are also a number of lookup tables for various variables. The main table of countermeasures contains the categorization data described shown in Table 1 along with a text description. The data captured in the countermeasure table is shown in the upper part of Figure 1. The research table documents the results of the literature review for each study, including any CRFs that were identified by each study. One of the primary objectives of the research update was to thoroughly document which studies were reviewed for each countermeasure. A database record was created for each study that had been reviewed to develop a particular CRF. In this manner, it would be apparent to the safety professional (the ultimate user of this tool) which specific studies had been reviewed. Because studies can relate to multiple countermeasures it is not surprising that there is some duplication of the studies reviewed. A separate code is used to identify the record that presents the final recommended countermeasures. If a particular countermeasure has CRFs for different crash types, there are also separate records. One study reviewed for the countermeasure shown in Figure 1 is shown in the subform “qry\_researchform” shown in lower half of Figure 1. The final table, sources, contains the publication reference data for each of the studies. A macro was written in order to export the data in text format to be formatted for the final printed report and the database for the online tool.

The online CRF database is provided through an interactive website (the site is temporarily located at <http://its.pdx.edu/CRF/CRFweb/>, but plans are in place to move the site to an official ODOT location in the near future). The web site is coded in PHP connected to a MySQL database. The text files generated from the Access database are imported into the MySQL. (It would have been possible use MySQL for the entire application but the budget was not available to develop the customized entry screens needed). The homepage, a screenshot of which is shown in Figure 2A, is query page which enables broad queries of the database. For example, as shown in Figure 2A, the query parameters are set to urban, any countermeasure type, all other crash causes, intersection, and rear-end crashes. Upon submitting the query, 12 countermeasures that meet the criteria are displayed (as shown in Figure 2B). By clicking on each countermeasure, the analyst can see a summary page that lists the specific countermeasure, a sample photograph of the countermeasure in place, the corresponding crash reduction factors, applicable use criteria, a brief discussion of the countermeasure, and citations of the references used to determine the

countermeasure's CRFs. Figure 2C shows the information displayed for countermeasures with suggested CRFs. Figure 2D shows the information displayed for those countermeasures identified with discussion only. Both pages include a small photograph (with a linked full-size image) of the countermeasure. Note that the information presented in Figure 2C is identical to that shown in Figure 1 from the Access database.

As one can see, a wide variety of queries and investigations can be performed within this interactive website. This will allow the analyst to "brainstorm" about a range of potential solutions, and investigate trade-offs and perform some degree of optimization through the design process. Full citations for the references are provided and if further information or the original study is desired it can easily be found. A complete library of the literature was developed and is part of the project files. On-line links to full text documents or summaries have not been provided at this time, but is a feature that could easily be added. The online database can easily be updated as more current research becomes available. As a useful and accessible tool, the website should have a longer life than the printed report. To demonstrate its usefulness, a case study is presented.

## USING THE ONLINE TOOL

A case study is presented that describes how the crash reduction factors and the interactive query-based website will be useful to ODOT engineers and planners, as well as to staff of other agencies in Oregon. The case study is presented as if the safety professional is documenting a preliminary safety investigation and considering alternative design features. This case study does not imply that a detailed engineering field investigation or engineering judgment can be replaced by this online tool. The intersection of highway OR-8 (designated SW Tualatin-Valley Highway at this location) and SW Murray Boulevard has been one of the highest crash locations in the City of Beaverton, Oregon for several years. In 2003, ODOT assigned this intersection a Safety Priority Index System (SPIS) rating of 86.31 (out of a maximum score of 100). Murray Blvd. is owned and managed by Washington County. The intersection is located within the City of Beaverton, and this overlap of three jurisdictions poses a unique challenge to the operation of the intersection. An aerial photograph is shown in Figure 3. The average daily traffic (ADT) volume is approximately 42,000 entering vehicles (2003 data). Tualatin-Valley Highway runs east and west; Murray Blvd. runs north and south. The land use on each quadrant is:

- NW: ARCO gas station with an AM-PM mini-mart
- NE: Shell gas station
- SE: Toyota dealership
- SW: 5-acre lawn which is part of a 43-acre property with a Catholic convent and school owned by the Sisters of St. Mary of Oregon

Approximately 25 feet directly south of and parallel to Tualatin-Valley Highway are railroad tracks owned and operated by Western & Pacific Railroad. Trains run several times a day and the gated crossing has a deleterious effect on intersection capacity when in operation. Tualatin-Valley Highway is a seven-lane facility: three lanes of travel with a left-hand turn lane in each direction. Two of the three lanes in each travel direction are through lanes only; the curbside lane in each direction allows vehicles to turn right as well. Murray Blvd is a five-lane facility: two travel lanes and a left-hand turn lane in each direction. The left-hand lane in each direction permits only through movements, while the right-hand lane allows vehicles to travel through the intersection or to turn right. Murray has a designated, separated, right-hand only turn lane for vehicles turning right onto westbound Tualatin-Valley Highway. A low concrete median (approximately 6 inches high) is in place on Tualatin-Valley Highway east of the intersection and extends approximately 400 feet back. This median is covered by reflectors and prevents turns into and out of the Shell gas station. Sight distance and visibility on all approaches appear to be very good and adequate for the posted speeds: 40 mph on Murray Blvd., 45 mph on Tualatin-Valley Highway. Lane markings are in generally good condition. There is also a bus pullout area on southbound Murray Blvd., immediately south of the intersection and the railroad tracks. Both gas stations allow driveway access close to the intersection.

A review of the collision data found a total of 234 crashes during the 5-year study period, 2000-2004. Nearly 50% of the total crashes were turning crashes. An additional 35% were turning-related crashes and the remaining crashes were sideswipe, angle, and other. The primary driver errors were related to the crash type (following too closely or speed too fast for conditions (40%), not yielding right-of-way (30%) and other improper driving (14%). There were 3 serious injury crashes. Weather and environmental factors appear consistent with other urban intersections in the area. A collision diagram was created for the intersection and is shown in Figure 4. The collision diagram highlights a number of crash problem locations. Based on the crash data, site geometry, and site the safety problems at this location appear to be 1) rear-end crashes; 2) driveway turning conflicts; and 3) crashes near one bus stop.

With this information, the safety professional could then begin using the online tool to explore potential countermeasures. They might begin with the query shown in Figure 2A—the parameters are set to urban, intersection, rear-end crashes. The tool returns 12 countermeasures with a CRF and 8 with discussion only. Two of the 12 countermeasures with CRFs (lengthen the yellow change interval to Institute of Transportation Engineers

guidelines and add right turn lane on major approach) appear worthy of further investigation. The remaining countermeasures with suggested CRFs do not apply since the intersection has turn lanes on all approaches, sight distance is adequate, and red-light running is not a known problem. A number of countermeasures with discussion text only suggest additional items for the safety professional to consider such as driveway closures, signal head visibility, and potential timing improvements. The analyst could also explore other the results of other queries such as turning-related countermeasures, operations, or other parameters.

Following a more through review of the potential CRFs suggested by the on-line tool (i.e. verifying signal timing, checking visibility, and examining platooning patterns) the analyst could use the suggested CRFs in a benefit-cost analysis of the alternatives. For those recommendations without a CRF, the safety professional may want to pursue additional information about the countermeasure, either using the studies suggested or searching for more recent research results. While not apparent in this example, the online search tool may suggest a countermeasure that would not have been included by the less experienced safety professional. For example, a search of rural countermeasures for head-on collisions returns expected suggestions such as barriers and centerline rumble strips but also countermeasures to reduce run-off-road events, since many head-on crashes are related to road departures. As this tool continues to develop, it can be customized rather easily.

## CONCLUSIONS

The objective of this research was to compile the best available data for development of a comprehensive crash countermeasures database containing their respective crash reduction factors for ODOT to use in its transportation safety planning and engineering. While a traditional final report was prepared, an online tool was also created to easily search the report and encourage dissemination of the results. The tool allows the safety professional easy access to the documentation behind countermeasures. The decision to disseminate the research with an online tool in the first phases of the project helped in developing a robust tool. All of research that was used to develop the CRFs was carefully documented and is provided to the user as part of the tool. In the case of CRFs, the inherent uncertainty involved in forecasting safety effects, the transparency of the CRF list is important. Certainly, most research results do not lend themselves to such an interactive tool but when appropriate, it can increase the transferability of the research results.

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**LIST OF FIGURES AND TABLES**

TABLE 1 Countermeasure Categorization.

FIGURE 1 Screen Capture of Sample CRF Access Database Entry Form.

FIGURE 2 Sample CRF Website Screen Captures.

FIGURE 3 Intersection of Tualatin-Valley Highway and Murray Blvd, Beaverton, Oregon.

FIGURE 4 Collision diagram, Tualatin-Valley Highway and Murray Blvd, Beaverton, Oregon, 2000-2004.

**TABLE 1 Countermeasure Categorization.**

<b>Research Quality</b>	<b>Type of Improvement</b>	<b>Crash Type</b>	<b>Other Cause Factors</b>
Results with Suggested Crash Reduction Factors	Design improvement	Pedestrian	Driver Inattention
Results with Discussion Only	Markings or signs	Angle	Excessive Speed
<b>Character</b>	Operations/ITS	Head-On	Weather
	Pedestrian	Rear-End	Visibility
Urban	Railroad crossing	Sideswipe-Meeting	Turning Volumes
Rural	Roadside improvement	Sideswipe-Overtaking	Geometry
<b>Roadway Type</b>	Traffic calming	Turning	Congestion
	Intersection	Parking Maneuver	Access Management
	Segment	Non-Collision	
		Fixed Object	

**frm\_countermeasures**

id: 130, crf\_cat: 1, crash\_type1: Turning, ac\_factor1: Turning Volumes, crash\_type2: Angle, ac\_factor2: Geometry, crash\_type3: Rear-End, crash\_type4: Sideswipe-Over, crash\_type5: , crash\_type6: .

description: Add Right-Turn Lane on Major Road, Signalized Intersection

main\_cat: Intersection

crs\_cat: Design Improvement

urb: U

summary: Providing right-turn lanes at signalized intersections can reduce collisions between right-turning and following through vehicles, particularly on high-volume and high-speed roads. However, it is important to note that the installation of right-turn lanes at signalized intersections carries the potential to create other safety and/or operational problems: such as vehicles in right-turn lanes blocking cross-street driver's line of sight, and decreased distance to roadside objects if installation of right-turn lanes was accomplished by shoulder re-stripping. Sufficient guidance through the intersection is an important consideration with exclusive right-turn lanes. In some instances, channelization may be desirable. In addition, raised islands can serve as a refuge for pedestrians, an important consideration when right-turn lanes result in increased crossing distances and pedestrian exposure to traffic. These CRFs apply to one approach.

qy\_researchform

id: 130, title: Harwood, D.W., K.M. Bauer, I.B. Potts, D.J. Torbic, K.R. Richard, E.R. Kohman Rabbani, E. Hauer, and L. Elefteriadou, Safety Effectiveness of Intersection Left- and Right-Turn Lanes. 2002, Federal Highway Administration, McLean, Va.

study\_type: Empirical Before-After, study\_quality: 5

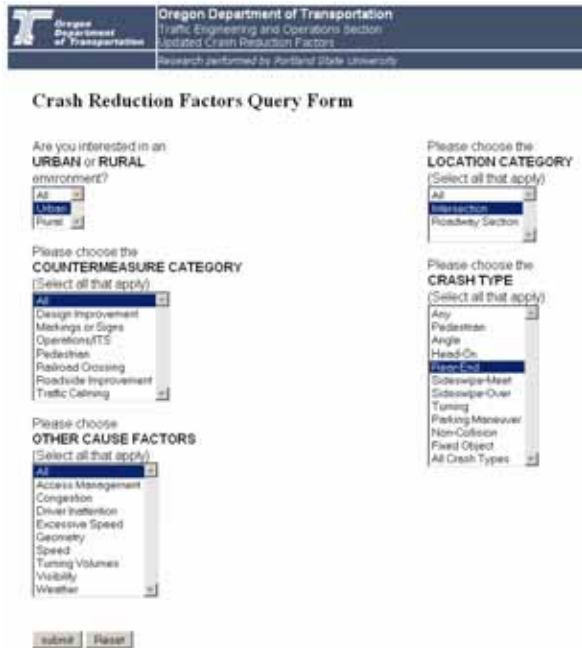
notes: This report presents the results of a comprehensive before-after evaluation of the safety effects of providing left- and right-turn lanes for at-grade intersections. Geometric design, traffic control, traffic volume, and crash data were gathered for 200 improved intersections and 300 similar intersections that were not improved during the study period. An observational before-after evaluation of these projects was performed using several evaluation approaches: the yoked comparison (or matched-pair) approach, the comparison group approach, and the Empirical Bayes approach. The research concluded that the Empirical Bayes method provided the most accurate and reliable results. This study found reductions of 4% for all crashes when adding right turn lanes at signalized 4 leg intersections, and reductions of 9% for fatal and injury crashes.

crash\_type1: , urb:  fat\_min: , inj\_min: , crf\_min: , pdo\_min: .

Record: 1 of 3

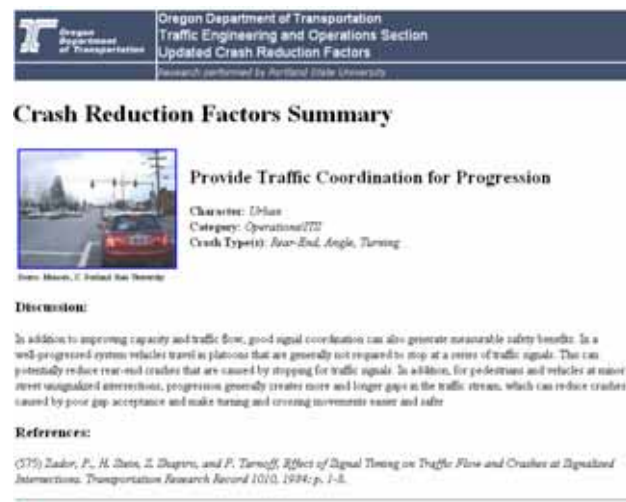
Record: 5 of 94

FIGURE 1 Screen Capture of Sample CRF Access Database Entry Form.



A - Query Dialog Screen

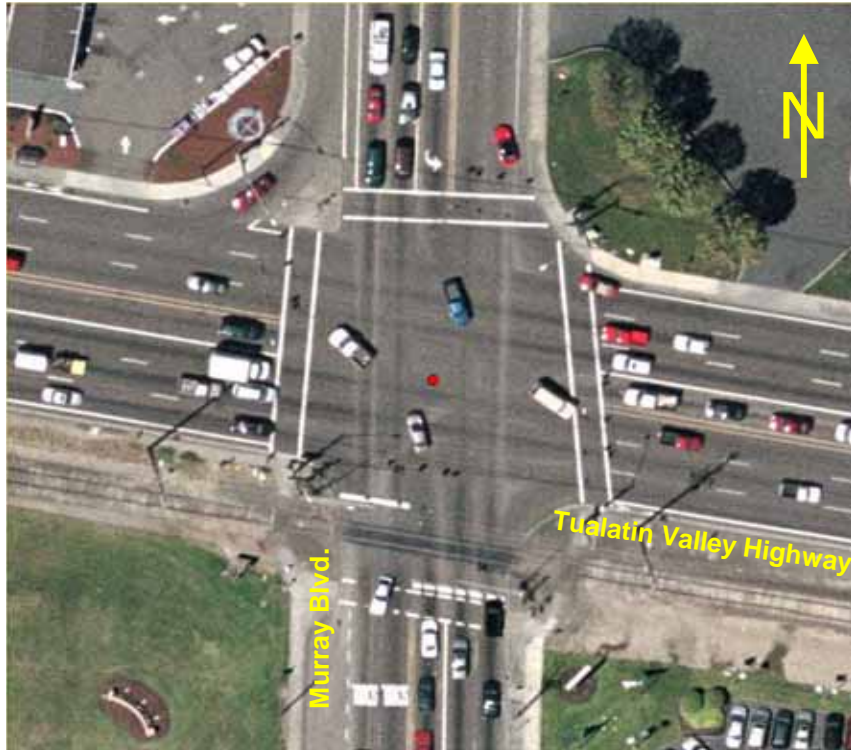
B -Results Page



C - CRF Summary (with CRF)

D -CRF Summary (with discussion only)

FIGURE 2 Sample CRF Website Screen Captures.



**FIGURE 3** Intersection of Tualatin-Valley Highway and Murray Blvd, Beaverton, Oregon.

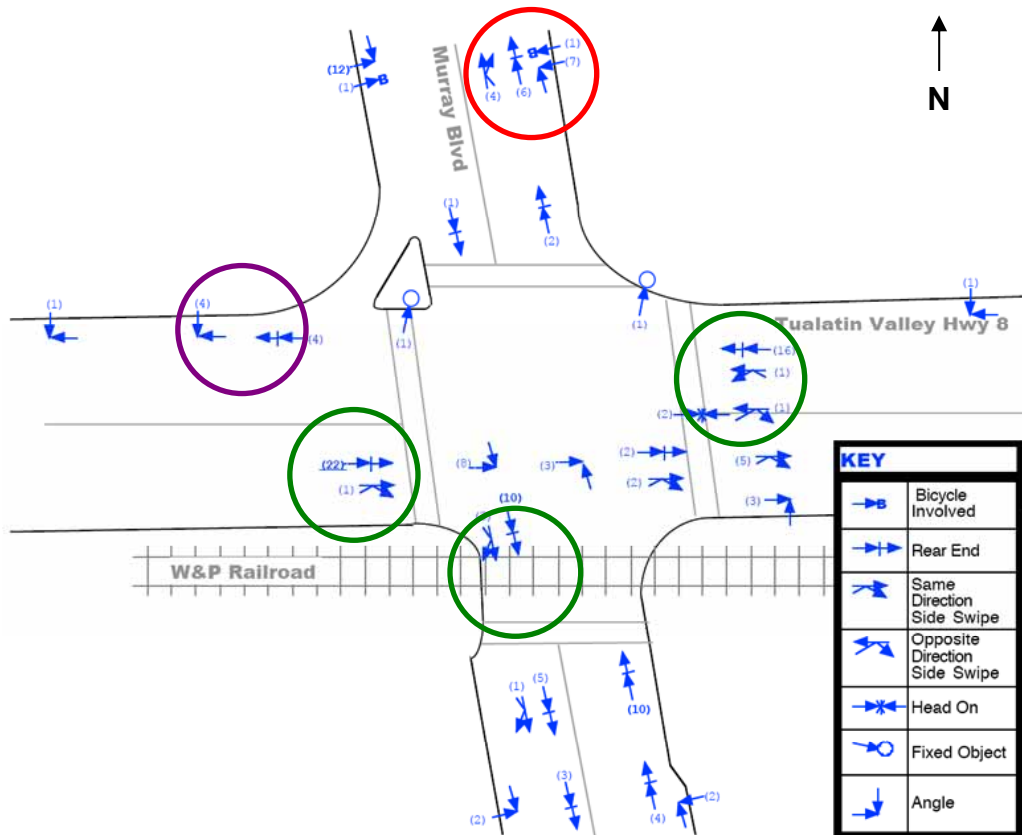


FIGURE 4 Collision diagram, Tualatin-Valley Highway and Murray Blvd, Beaverton, Oregon, 2000-2004.