TORT LIABILITY RISK PRIORITIZATION THROUGH THE USE OF 
FAULT TREE ANALYSIS

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ABSTRACT

Tort liability for transportation agencies has become a growing issue across the country over the last 3 decades and consumes an increasing portion of agencies’ already tight budgets. There is a need for a tort liability risk prioritization strategy that will allow for agencies to address the factors that lead to tort actions in an efficient and effective approach reducing the resources consumed and improving unsafe conditions. This paper develops a risk prioritization strategy based on fault tree analysis that utilizes data from a state Department of Transportation, to demonstrate an application as a case study. The case study shows that the risk prioritization strategy can provide both qualitative and quantitative results which 1) identify risks qualitatively, 2) evaluate risks quantitatively, and 3) identify and prioritize countermeasures. In addition, this paper demonstrates a method to quantitatively validate the fault tree which utilizes basic event probabilities calculated from state agency collected data. The probabilities of the fault tree cut sets are mapped to the specific claim types which allow for the occurrence of actual claims to be compared to the calculated probabilities. The validation did support the assumption that the percentage of claims increases with increasing cut set probabilities.
INTRODUCTION

Across the country, tort liability for transportation agencies has become a growing issue over the last 3 decades as states have lost their sovereign immunity. Most transportation agencies have experienced a rapid and significant increase in monetary losses from tort liability suits (1) and AASHTO estimated in 1991 that annual payments made by individual states in settlements or judgments for highway tort-related incidents were between $135 million and $345 million (2). From 2007-2010, the South Carolina Department of Transportation spent on average over $4 million annually on handling and settling claims and lawsuits (3). This is a concern because money spent on tort lawsuits and compensating crash victims is money that is unavailable for improving the state highway system.

Managing tort liability risks is a complicated and challenging process that has been addressed across the country at state transportation agencies through the implementation of many types of risk management strategies. Based on a tort liability survey of state agencies with 20 responses, only 4 states were found to use previous claims and lawsuit locations as a way to identify conditions that lead to claims or lawsuits (3). In addition, few states were found to analyze past claims and lawsuits to identify events or conditions that lead to tort actions against the agency. An opportunity exists in managing the risk of future claims and lawsuits by analyzing these types of past events and improving roadway elements that serve as or are perceived to be causal factors to claims or lawsuits.

The objective of this paper is to develop and demonstrate a risk prioritization strategy that can identify and quantify the probability of events that lead to tort actions and prioritize the events in order to identify the most effective countermeasures. This risk prioritization strategy will provide an effective method for agencies to identify and reduce the probability of events that lead to tort actions through the use of fault tree analysis.

Reducing or eliminating the probability of events that lead to tort actions will reduce the tort liability of agencies and improve safety by identifying conditions or events that lead to property damage and personal injury. By reducing the tort liability of agencies, these agencies can reduce direct and indirect costs associated with the handling and settlement of these tort actions which allows for more resources to be spent on the agencies primary tasks of maintaining and managing the infrastructure system.

This paper utilizes data from the South Carolina Department of Transportation, to demonstrate an application of the strategy as a case study. Other transportation studies that utilize fault tree analysis will be reviewed along with strategies to address highway risk management. The results of this paper show that the risk prioritization strategy provides both qualitative and quantitative results which lead to the identification of the riskiest causal factors of tort claims and allows for the identification of appropriate countermeasures.

BACKGROUND

This section summarizes transportation studies that utilize fault tree analysis and work related to the risk management of highways by public agencies.
2.1 Fault Tree Analysis

Fault Tree Analysis (FTA) is a common tool used for risk analysis (4). FTA has been traditionally applied to physical systems such as machines and their related processes and FTA has been used effectively in transportation related applications such as safety. However, FTA has not been implemented in risk management research involving tort liability.

In 1995, Kuzminski et al. utilized FTA to analyze automobile accidents in order to identify vehicle designs features that lead to accidents (5). The study showed that fault tree can be effective in analyzing accidents and identifying the related causal factors. Garber et al. used FTA to identify and quantify the occurrence of driver and roadway causal factors that lead to accidents on multi-lane highways in Virginia in order to recommend safety countermeasures (6). In addition, generalized linear models were used to calculate the crash rates based on various designs and operational characteristics as well as crash severities.

Not all studies utilize fault trees quantitatively when analyzing accidents. Li et al. utilized FTA for a study on tire blowouts and resulting accidents (7). Instead of identifying probabilities, FTA was used to qualitatively describe accidents caused by blowouts. FTA allowed the basic events that lead to accidents due to blowouts to be identified and two countermeasures to be recommended. This demonstrates how FTA can be used for specific accident types where identifying the small number of basic events that lead to the accident can allow for effective countermeasures to be identified.

FTA has been utilized in transportation safety research for analyzing vehicle designs, specific accident types and accidents along specific roadway classifications. These studies successfully utilized FTA which resulted in the identification and prioritization of causal factors and corresponding countermeasures. Despite the successful utilization of FTA in transportation safety studies, it has not been utilized in studies of risk management or tort liability as proposed in this research.

2.2 Highway Risk Management

Government entities are exposed to various degrees and types of risks which result in a wide range of tort liability risk management strategies. These include legal strategies when handling tort actions or making process changes to improve the handling of tort actions. In this study, highway risk management refers to the attempt by entities responsible for roadways to manage or mitigate their tort liability or risk by addressing tort action causal factors.

An unsuccessful attempt of risk identification was demonstrated in 1981 when Iowa DOT’s tort liability was studied and the claims data were analyzed using multiple regression analysis (8). The analysis tested two dependent variables by county: total number of claims filed and claims per capita. This regression analysis did not identify any correlations greater than .31 for the independent variables: county population, county geographic location, miles of roadway by type, number of licensed attorneys, VMT, and total value of claims filed (8).

Several strategies of risk evaluation are discussed by Demetsky and Yu who conducted a survey as part of an assessment of tort liability procedures and objectives for transportation agencies across the country (9). They found that 3 out of 25 responding states used a mathematical formula to prioritize identified hazards on the roadway while the remaining states simply used the degree of hazard for prioritization (9). The Iowa DOT used a rating system based on the accident rate, number of accidents, and financial damages while the Colorado DOT
used a hazard index based on VMT, the number of fatalities, injuries, and property damage only accidents (9). While these prioritization equations are based on the causes of claims, they do not consider the cost of countermeasures which is an important factor in risk management.

Texas uses a complex safety improvement index to select the most cost effective countermeasure to identified risks. This index incorporates a benefit cost ratio based on the cost of increased maintenance or the cost of the improvement project and the savings from reduced accidents (9). This prioritization addresses the cost considerations for risk management. However, it is more appropriate for analyzing individual locations for improvement or specific hazard types.

While states have addressed risk identification, risk evaluation, and countermeasure development and selection utilizing various methods, the strategy in this study can be used to accomplish all of these steps. This capability of the strategy is due to the use of fault trees which have not been previously utilized in risk management or tort liability studies of transportation entities. The strategy can be implemented in stages in order to provide increasingly detailed and analytical results as well as reduce resources required by DOTs for development and implementation. In addition, once this strategy has been implemented, it can be continually updated with the most recent data with minimal effort to continue to obtain timely results.

3.0 METHOD

As the previous section explained, fault trees have been used effectively in safety analyses and can provide similar results for risk management while addressing several common steps in a risk management program.

This section details the proposed risk prioritization strategy for tort liability analyses, outlined in Figure 1, through a case study of a state DOT.

3.1 Data Collection

The data available related to the events that lead to claims and lawsuits have a large impact on the scope and level of detail the strategy can provide. This will become apparent during the construction of the fault tree and identification of the probability of basic events that make up the tree.

**FIGURE 1 Risk Prioritization Strategy.**
Details on claims and lawsuits are initially needed to identify and understand the events that lead to claims and lawsuits. This is vital to the accurate construction of the fault tree. In addition to the claim and lawsuit data, other resources from an agency can be used in order to gain a more detailed or even professional understanding of some or all of the events that lead to claims and lawsuits. These include interviews with agency personnel that are familiar with handling or reviewing tort claims and lawsuits, tort management staff such as lawyers, claims handlers, or investigators and safety engineers that are frequently involved in the defense of lawsuits.

Crash data and other related data was used to improve the understanding of reported incidents that lead to claims. Conveniently, these incidents are included in state crash databases with in-depth details filled out by law enforcement that have received specific training and carry an expert understanding of the events that contribute to crashes, and thus lead to tort actions. Matching the crash data to the respective claim or lawsuit provides extensive details on the events leading to a tort action.

The case study conducted an extensive review of damage claims against the DOT and conducted multiple interviews and meetings with DOT officials in order to understand all levels of the tort claims process. The review of claims data was conducted using records from the Claims Office which handles tort actions against the department. Interviews were conducted with engineers that initially review claims and state safety engineers that are called upon during the defense of the DOT. Technicians responsible for investigating claims were also interviewed as was the DOT attorney responsible for approving and disapproving the outcome of all claims. This provided an adequate understanding of the various events that lead to tort actions against the DOT.

The data used for analysis consisted of 3000 claims and represented approximately 3 years of data. These data were provided in an electronic format and consisted of over 40 data fields for each claim. However, several critical data fields in the hardcopy files of the claims were not recorded in the electronic database so these fields were extracted from the hardcopy files and added to the electronic database. Extracting this data manually resulted in over 90% of the hardcopy files for claims being reviewed which allowed for a comprehensive understanding of the claims that is necessary to build the fault tree.

### 3.2 Build Fault Tree

Once the causal events and their relationships were understood from the review of data and discussions with experts, the fault trees were built. The fault tree modeling hierarchy numerically describes factors causing tort actions through the concept of Boolean-algebra (AND, OR). The Fault Tree Handbook was followed to ensure the construction of a valid tree (4). Several types of software exist that can be used for or are exclusively for building fault trees and fault tree analysis. This study utilized Isograph Faultree+ software to build the fault trees and perform the quantitative analyses on the tree (10).

Before the tree was built, the scope of the project was set in order to control the size of the tree since including the events that lead to every tort action would result in an unmanageable tree. The claims data classified the claims by cause type so types that consisted of more than 6 claims over the 3 year study period were included in the fault tree resulting in approximately 90% of the claims in the database being represented. With the scope set, the fault trees began to be built with selection of the top level event.
The top level event of the fault tree was “claim filed against the department”. Since it was crucial to identify the common “perceived” defects in the roadway by users, in addition to safety related conditions, this top level event needed to include claims that were not caused by an actual defect, notwithstanding the perception of one by the claimant. Depending upon agency policies, denied claims can be caused by an actual or perceived defect so these tort actions needed to be included in the analysis. In addition, claims in which the DOT are not liable still require significant indirect costs to process and have been shown to exceed payouts for claims in which the DOT are found liable (3).

After the top level event, the tree was broken down into branches in accordance with the Fault Tree Handbook. Events in each branch continued to be broken down until one of the following limiting conditions was reached: 1) Further knowledge of the event was unavailable. 2) Further breakdown was outside the scope of the project. 3) The event could not be broken down any further. Once each branch meets one of the 3 conditions, the fault tree was complete. An example from the fault tree of the conditions being met: 1) debris fell from unknown vehicle, 2) inadequate, improper, or no evasive action taken.

Undeveloped events could be broken down further, but due to the scope of the research and additional data required to devise probabilities at lower levels, the branches were not continued. For example, “inadequate or inappropriate or no evasive action taken” was represented as an undeveloped event since it could be broken down further; however, since the research was not concerned with driving behavior, but rather the existence of defects and their relationship with claims, the branch of the tree was not continued.

3.3 Calculate Probabilities

Once the trees were built, the probabilities of the occurrence of basic events were calculated. This was a critical step in identifying the countermeasure effects on the overall probability of a tort action being filed. Developing these probabilities was a challenging task due to the diverse types of events. Data relating to these events occurrence were difficult to obtain, lacked sufficient detail, and even did not exist.

For the case study, devising probabilities of basic events required a number of data types due to the wide range of events that could lead to a claim against the DOT. A majority of the probabilities utilized maintenance data which allowed for work requests, work orders, and work quantities to be identified. Other data types included the state crash database, claims database, maintenance records, request logs, and expert opinions from employees in the maintenance and safety offices.

An example of the calculation of the probability of the basic event “broken curb” is detailed using a DOT sponsored Maintenance Assessment Program (MAP) to evaluate the condition of state roadways across the state. The MAP is conducted by engineers that randomly select 2/10 mile segments of roadway to evaluate in order to identify the occurrence of common maintenance defects. The length of broken curb is one maintenance criteria of the MAP and is used to calculate the probability of occurrence. The probability is calculated:

\[
P = \frac{\text{Length of broken curb}}{\text{Total length of curb}}
\]

where P is the probability of a broken curb.
The data from these sources are provided in annual data sets, mostly for 3 years, so in order to account for yearly variations in the basic event probabilities, a 3 year average was calculated along with the standard deviation. This allowed for the basic event probabilities to be represented as normal distributions rather than point values in the fault tree. The fault tree software also allowed for basic event probabilities to be represented as normal distributions when analyzing the tree.

The basic event probabilities were categorized based on the developers’ confidence in the accuracy of the probability considering the data available and assumptions made for each probability. The event probabilities were categorized into one of the following confidence categories: certain, less certain, or uncertain. This categorization will be used to help validate the probabilities in the fault tree.

3.4 Risk

Since risk is a measure of the frequency and severity of an undesired event, both measures of a tort claim were considered in the analysis. Therefore, the probabilities of the minimum cut sets, which were mapped to the respective claim type they represent, were combined with the severity of the claim type. This was achieved through a claims risk index defined by:

\[
\text{Claim Risk} = (\text{Probability of Claim Type}) \times (\text{Average Cost of Claim Type}).
\]

This equation was used to calculate the claim risk for each claim type. The claim type risks were then compared to identify the riskiest claim based on the analysis.

3.5 Identify Minimum Cut Set

Once the fault trees were developed, the minimum cut sets were identified. Minimum cut sets are the minimum combinations of basic events that all must occur in order for a claim or lawsuit to be filed. These cut sets can be identified manually using a simple set of rules or by fault tree software. These cut sets allow for basic events to be identified and targeted with countermeasures to reduce the probabilities of their occurrence, in order to reduce the probability a claim is filed.

With the probabilities estimated, the probability that each minimum cut set leads to a claim was calculated through the use of Boolean-algebra and the fault tree software. The probability for each minimum cut set was used to rank the sets in order to identify the riskiest combinations of events that lead to a claim or lawsuit. These rankings of combinations of events allow for agencies to conduct risk prioritization and identify the effects that countermeasures targeted to individual cut sets may have on the probability of a claim being filed.

3.6 Rank and Evaluation

Once the probabilities for the minimum cut sets were developed, they could be ranked. This allows the DOT to develop a prioritized list of risks unique to the agency. The riskiest minimum cut sets can then be evaluated. The basic events that make up each minimum cut set can be evaluated in order to identify countermeasures that would reduce the occurrence of those basic events and thus reduce the probability of a tort action being filed. These countermeasures might be maintenance related, safety measures or policy type measures. Consulting with specific divisions such as maintenance in the DOT to obtain ideas for countermeasures or review countermeasures will utilize expertise in the development of the most effective list of countermeasures.
3.7 Validation

The developed fault trees were validated both qualitatively, considering the structure and relationships between events in the fault tree, and quantitatively, considering the event probabilities. The fault tree was developed based on the events that lead to the actual claims received by the SCDOT and was qualitatively validated by mapping the actual claims to the fault tree as well as by the SCDOT Claims Attorney/Manager experienced in the handling and understanding of the claims. The claims were mapped to the fault tree and represented by cut sets by identifying each combination of basic events that lead to the specific claim type.

With the claim types mapped to the minimum cut sets, the probabilities of the cut sets were compared to the actual percentage of all claims each claim type represents. Quantitatively, the fault tree was validated by comparing the cut set probabilities that represent each claim type with the percentage of all claims that the respective claim type represents based on the actual state claims data. The relationship between the two probabilities was comparable because they were based on the occurrence of the same events.

The claim type cut set was the combination of basic events that each claim type was mapped to in the fault tree. The events were classified as “certain” or “less certain” by the confidence in the estimated basic event probabilities that made up the cut sets which was based on the DOT data utilized and assumptions made to calculate the probabilities. This comparison was made to see if a pattern exists between the “certain” or “less certain” probabilities’ relationship with the claim type’s percentage of all claims. Theoretically, as the probability of the cut set increases, the percentage of all claims the claim type represents would increase.

4.0 ANALYSIS OF RESULTS

The research team has developed a prioritization strategy utilizing fault trees which is detailed in this section. The strategy has been applied to a state DOT as a case study to demonstrate its ability to identify and rank events based on risks that lead to tort actions. Validation of the fault tree is also discussed in this section.

4.1 Risk Prioritization Strategy

The results of the fault tree development are outlined in this section along with the ranked minimum cut sets based on probability. The fault tree for claims is shown in Figure 2 and Figure 3. The fault trees represent the events that lead to a set of claim types that make up 90% of all claims. The top event is a claim filed against the department. On the second level, personal injury claims are represented in the trip/fall branch while property damage is represented by branches for vehicle damage, utility damage and damage caused by landscape work. The tree is broken down into 22 basic events, and 5 undeveloped events on 7 levels. Figure 2 shows the event “vehicle claim” which symbolizes a transfer gate in the tree. This simply means the tree is continued in Figure 3 from that event which is the vehicle branch of the tree. This branch represents events that lead to claims filed due to damage or injury to or from a vehicle.

The minimal cut sets were identified as the minimal combinations of events that lead to a claim being filed. The top 10 most probable cut sets are identified and ranked in order of probability in Table 1. The cut sets allow for basic events to be identified and targeted with countermeasures to reduce the probabilities of their occurrence, in order to reduce the probability of a claim. The probabilities of the cut sets in Table 1 represent the potential reduction in the probability of a claim being filed, if a countermeasure or multiple countermeasures are used to
reduce or eliminate the probability of one of the basic events that make up the cut set. The most
probable cut sets are outlined in Table 1 with further descriptions of the basic events that make
up the cut sets and possible countermeasures.

The probabilities in Table 1 represent the unit less probability that the series of events
that makeup the cut set will occur. The probabilities are not normalized and are utilized in order
to relatively compare cut sets.

In order to account for the variability in the probabilities, distributions were used to
describe the basic events as well as the top level event. 10,000 simulations run using the Monte
Carlo method produced a probability distribution for the top level event. The basic events that
make up the top ranked cut sets were examined in order to identify appropriate countermeasures.
Figure 4 shows the most probable cut set, “utility damage due to mowing”. As shown in the
Figure, an event representing the utility filing a claim is included in the tree. An expert opinion
from an assistant state maintenance engineer was used to identify this probability. An effective
counter measure to reduce claims could be delineating these utility pedestals with posts, so that
mowers can identify them when mowing in tall grass. This counter measure targets the basic
event “utility is in the mow path”. The cut set has a high probability of leading to a claim, due to
the amount of mowing conducted in the area of these utility pedestals - the right of way. In
addition, tall grass can easily hide these green colored pedestals from view. The event “utility
owner files a claim” is included in the tree to represent the probability that a utility owner files a
claim against the DOT if damage occurs. An expert opinion from the state maintenance office
identified this probability, which can vary depending on the owner of the utility. An evaluation
similar to this can be conducted for each of the 10 most probable cut sets in order to identify
countermeasures to reduce the probability of the cut set from occurring.

Figure 5 shows the claim risk calculated based on the probability of the cut set and the
average severity (cost) of the claim type. No claim type listed has zero risk despite the fact that
there may be no paid claims of that type. Zero risk claims are not represented because the
average indirect cost of claims is considered and results in every claim filed having a cost.

4.2 Validation

Figure 6 shows the percentage of all claims that each claim type represents versus the
estimated probability of the claim type cut set. Theoretically, as the probability of the cut set
increases, the percentage of all claims the claim type represents will increase. However, the
dashed circle around “water on the road” highlights one claim type that does not increase as a
percentage of the total claims as the probability of the respective cut sets increase relative to the
other cut sets. This claim type is classified as “less certain”. While this could be evidence that
the calculated probability is not as accurate as the author assumed, another explanation is that the
probability that a claim is filed given a cut set occurred could vary considerably between claim
types. The fault tree for this research assumes the probability a claim is filed given a cut set
occurs is equal for groups of similar events. For example, the “surface defect” cut set has a
relatively large probability and also makes up a large percentage of the claims filed as expected.
However, the “mowing” cut set also has a high probability but represents a lower percentage of
claims. This variation could be due to the fact that there is a large probability that a claim is filed
when a surface defect causes damage while there is a low probability that a claim is filed when
damage occurs from a mower. The probability a claim is filed given a cut set occurs is not a
probability that SCDOT could try to mitigate because they do not have control of the decisions
by the property owner and it would also be ethically questionable for SCDOT to try to reduce
that probability. However, more data on this probability is needed at an individual claim type
level to be more certain on the validation of the fault tree.

TABLE 1 Ranked Cut Sets

<table>
<thead>
<tr>
<th>Rank</th>
<th>Basic Events That Make Up Cut Set</th>
<th>Cut Set</th>
<th>Probability</th>
<th>Countermeasure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Utility in path of mowing, utility company files a claim</td>
<td>Utility damage by mower</td>
<td>1.03E-04</td>
<td>Delineate above ground utilities</td>
</tr>
<tr>
<td>2</td>
<td>Debris of unknown origin in the road, inappropriate/improper or no evasive action, vehicle owner files a claim</td>
<td>Vehicle damage from unknown road debris</td>
<td>8.92E-05</td>
<td>Frequent inspection and efforts to increase debris reports and response</td>
</tr>
<tr>
<td>3</td>
<td>Equipment throws debris, property owner files claim</td>
<td>Landscaping work damages property</td>
<td>5.14E-05</td>
<td>Greater care of operation or use of equipment with more control near property</td>
</tr>
<tr>
<td>4</td>
<td>Surface defect in the road, inappropriate/improper or no evasive action, vehicle owner files a claim</td>
<td>Vehicle damage due to surface defect</td>
<td>1.84E-05</td>
<td>Increased maintenance efforts for surface repairs and improved response to requests</td>
</tr>
<tr>
<td>5</td>
<td>Rutting or insufficient slope holds water, inappropriate/improper or no evasive action, vehicle owner files a claim</td>
<td>Vehicle damage due to water on road with</td>
<td>1.52E-05</td>
<td>Resurface road segment, milling surface level</td>
</tr>
<tr>
<td>6</td>
<td>Utility in path of ditch work, utility company files a claim</td>
<td>Utility damage due to ditch work</td>
<td>1.33E-05</td>
<td>Locate utilities before ditch work, ensure utilities are buried at proper depth</td>
</tr>
<tr>
<td>7</td>
<td>Vehicle damage due to mh, cb, di, defect, inappropriate/improper or no evasive action taken, vehicle owner files claim</td>
<td>Vehicle damage due to raised or broken mh, cb, di</td>
<td>6.63E-06</td>
<td>Increase inspections of structures, improve response to maintenance requests</td>
</tr>
<tr>
<td>8</td>
<td>Broken edge/low shoulder, inappropriate/improper or no evasive action, vehicle owner files claim</td>
<td>Vehicle damage due to broken edge and low shoulder</td>
<td>4.85E-06</td>
<td>Increase road edge maintenance, improve response to maintenance requests</td>
</tr>
<tr>
<td>9</td>
<td>Broken curb, inappropriate/improper or no evasive action, vehicle owner files claim</td>
<td>Vehicle damage due to broken curb</td>
<td>2.92E-06</td>
<td>Delineate vulnerable curbs, increase inspections and maintenance of damaged curbs</td>
</tr>
<tr>
<td>10</td>
<td>High shoulder, excessive water on road causes lost control, inappropriate/improper or no evasive action, vehicle owner files claim</td>
<td>Vehicle damage due to water on road from high shoulder</td>
<td>2.51E-06</td>
<td>Increase shoulder maintenance/grading, rain inspections</td>
</tr>
</tbody>
</table>
FIGURE 2 Claims Fault Tree Showing Top Level.
FIGURE 3 Claims Fault Tree Showing Vehicle Branch.
Tupper, Chowdhury, and Sharp

FIGURE 4 Cut Set "Utility Damaged by Mower".

FIGURE 5 Claim Risk Comparisons.
In Figure 6, it appears that as the probability of cut sets increase, the percentage of claims increases at a faster rate for the “certain” observations than the “less certain” observations. However, the near zero relationship of the “less certain” observations does not support the theoretical assumption that an increase in the probability of the cut sets leads to an increase in the percentage of all claims the claim type represents. “Certain” observations in Figure 6 with a high cut set probability but a low percentage of all claims could also represent potential risks to the department. SCDOT does not have control over the probability that a claim is filed given property damage occurs. If this probability is low but the probability for the cut set is high, there is a risk for an increase in the number of claims since the damage is occurring or is likely to occur. This is an example of how the department could be pro-active in its risk management using fault tree for risk analysis.

The validation of the fault tree compares the percentage of all claims each claim type represents to the respective cut set probabilities calculated from DOT data. This validation method demonstrates that with the use of various data to calculate the probability of basic events, quantitative validation of the fault tree with the use of actual claims data can be conducted. For this research more data is needed on an individual claim type basis on the probability a claim is filed given property damage occurs.
5.0 CONCLUSIONS

A strategy for tort liability risk prioritization is presented in order to aid agencies in reducing the number of tort actions filed against them and reduce unsafe conditions that lead to tort actions. The strategy is centered on the utilization of fault tree analysis which has been used effectively in the study of transportation safety but has not been utilized for highway risk management. The case study demonstrates that the proposed strategy allows agencies to 1) identify risks qualitatively, 2) evaluate and prioritize risks quantitatively, and 3) identify and select countermeasures. In addition to meeting three vital needs in a risk management program, this strategy can be developed in stages to reduce resources required for implementation and can be continually updated with minimal effort in order to incorporate recent data. The strategy also provides a high level and system wide analysis, which can be ideal for preliminary risk management programs versus strategies that rely on individual risk or site analyses.

The research team developed a fault tree made up of 22 basic events on 7 levels to represent the events that lead to a claim against the DOT. The basic event probabilities were then calculated based on data from the DOT including crash, maintenance, claims, and roadway data. The fault tree was used to identify the 10 riskiest cut sets and mowers damaging a utility were identified as the most probable combination of events that lead to a claim. The most probable cut set was evaluated and one countermeasure to delineate the utilities in the right of way where mowing takes place was identified.

The validation of the fault tree compares the percentage of claim types to the respective cut set probabilities calculated from DOT data. The validation did support the assumption that the percentage of claims increases with increasing cut set probabilities. This validation method demonstrates that with the use of various data to calculate the probability of basic events, quantitative validation of the fault tree with the use of actual claims data can be conducted.

This strategy can help reduce tort actions which decrease agency costs associated with processing and defending the tort actions while allowing resources to be utilized for their intended effort of maintaining, upgrading, and managing transportation infrastructure. Implementing this strategy will allow agencies to improve the safety of the infrastructure by reducing the probability of occurrence of unsafe conditions that lead to tort actions.

Future research related to this study includes more detailed and reliable accident data capture. With current accident and claims data it is difficult to identify a single cause of an accident especially when multiple vehicles are involved or if there is a high injury severity. Advanced vehicle monitoring systems such as the “black box” could significantly improve data used for determining probabilities of basic events identified in the fault trees which would improve the accuracy of the prioritization strategy.

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