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A Safety Improvement Program for Rural Unpaved Roads

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A SAFETY IMPROVEMENT PROGRAM FOR RURAL UNPAVED ROADS

by

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ABSTRACT

This paper presents a prototype safety improvement program (SIP), which was developed specifically for unpaved roads. The combination of high mileage, low traffic volume, and limited budgets make it difficult for local agencies to adopt traditional safety improvement programs. The SIP for unpaved roads presented here is economically and procedurally appropriate for local road agencies. It provides a systematic means of prioritizing road sections for safety analysis and identifying safety improvement needs. One of the many unique features of the program is its "partnering" approach to involving public road users in the safety improvement process. Results of case studies that validate the procedure are included.

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Executive Summary

Introduction

Implementing safety improvements on low volume rural (LVR) unpaved roads is a continuous challenge for local road agencies. Traditionally, local governments have not had resources to implement all safety improvements needed on unpaved roads. This is still true. A recent nationwide survey revealed the condition of mileage maintained by counties is cause for concern. The survey indicated that 37.5 percent of the mileage had limited failures and was in barely adequate, or worse, condition. On average, 25 percent of the mileage did not meet the barely adequate condition rating [1].

Several issues compound safety analysis and improvement programs for unpaved roads. Current safety improvement programs rely heavily on the analysis of crash data to help identify roadway safety needs. However, the suitability of relying on this type of analysis for low volume roads has been questioned [5,36,40,41,42]. Another major issue involves road standards. Current funding policies often require low volume unpaved roads to conform to the same standards as those recommended for higher volume roads. By some accounts this conformance has stunted road improvement progress and increased project costs as much as 200 percent [13]. When making improvements on low volume unpaved roads, local agencies often desire to make smaller, more affordable, incremental improvements while working toward a final design. However, it is difficult to secure outside funding for improvements that do not meet all standards. This often results in local agencies doing nothing [5,13,18]. Policies to encourage incremental improvements, and programs to structure such improvements, are needed by unpaved road agencies.

Safety improvement programs for unpaved roads must be accommodated within the limited budgets of local road agencies. Low traffic volumes on unpaved roads make it difficult for road agencies to justify the cost of improvements. A 1979 LVR study conducted by John Glennon examined safety performance by evaluating the impact of crash costs. When considering a road carrying 50 vehicles per day, and given a realistic goal of a 25 percent reduction in crashes due to safety improvements, only safety improvements costing less than $166 per mile per year were justified (cost figures in 1979 dollars) [5].

Literature Review

The state of the art in safety improvement programs was researched to identify options currently available to local agencies. The Federal Highway Administration in the publication, *Highway Safety Improvement Program* (HSIP), recommends that specific safety related programs should be carried out by state and local highway agencies in an organized, systematic manner [26]. However, many of the procedures recommended to successfully maintain the HSIP require a large amount of resources and professional expertise. At this time, few rural local agencies are utilizing the HSIP guidelines simply because the procedures are beyond their means.

Safety management systems and safety audits also are designed more toward state agencies and their greater resources. However, there are important concepts that each of these full scale road safety programs can offer to local unpaved road safety improvement programs. Most importantly, a systematic safety improvement program is needed.

Methodology

A focus group of transportation professionals was used to assist in defining critical characteristics and developing the safety analysis procedure for unpaved roads. Focus group members were from the Federal Highway Administration, Wyoming Department of Transportation, Wyoming Association of County Engineers and Road Superintendents, Wyoming County Commissioners Association, and regional universities. A modified Delphi survey procedure was used for group interaction. The Delphi methodology involves a questionnaire in which the respondent is asked for input or answers to questions based on their own judgment and professional knowledge. Common Delphi characteristics are feedback to the respondents, an iterative process of multiple rounds of questionnaires, anonymous response, and self confidence ratings. The Delphi is often used in situations where there are no hard facts or data available. The results of a Delphi Survey present a selection of expert information and opinion that is then used in solving a problem.

A crash data analysis was conducted to gain supplementary information for the unpaved road SIP. Typically, crashes on low volume roads are randomly dispersed throughout the road network. As a result, the identification of crash trends is difficult, if not impossible. In this research, the feasibility of using unpaved road traffic counts and user data to enhance the crash data analysis was studied. Traffic counts were taken and comparisons of crash rates and other statistics between paved and unpaved roads were made.

Analysis and Results

The major findings of this research are presented in three sections. The first discusses the value of crash and user data. The second, presents the recommended SIP procedures. The final section provides a case study evaluation of the recommended procedures

Unpaved Road Crash and User Data Analysis

In this research, exposure data consisting of traffic counts and user information were collected and analyzed. The findings are as follows:

1. The injury crash rate on Wyoming unpaved road sections was 3.03 per million vehicle miles of travel (MVMT). This is more than five times as high as the injury crash rate for all roads in Wyoming (0.55 crashes per MVMT).
2. In-state drivers from non-local counties had a significantly higher ($\alpha = 0.05$) proportional crash involvement rate than either local or out-of-state drivers. They constituted about 32 percent of the drivers on unpaved roads but were involved in 52 percent of the crashes.
3. The crash locations did not identify a large portion of the safety needs on the case study roads. Still, the analysis helped to ensure that crash based needs were not overlooked.

Unpaved Road Safety Improvement Program

The initial pilot Delphi survey examined issues for an unpaved road safety improvement program. Each of the representative focus subgroups responded to the survey. There was also strong agreement among the respondents. Overall, the survey proved to be an effective tool in formulating policy issues for unpaved roads. Important findings from the survey included:

1) Output from the safety improvement program should be in the form of a group index versus an item by item prioritization.
2) The safety analysis should be conducted on a section by section basis.
3) Incremental improvements should be encouraged on local LVR unpaved roads. A change in policy and practice concerning incremental improvements to unpaved roads is needed.
4) Crash data should be included in the safety improvement program to check for high frequency crash locations and to identify the circumstances of crashes.
5) Roadway classification by traffic volume and user expectation was recommended.

The next step of this research project used the initial Delphi findings to develop a prototype safety improvement program. The focus group provided additional input through a second Delphi survey. The recommended SIP is a systematic process consisting of five steps including:

1. system-wide prioritization of unpaved road sections,
2. identification of safety improvements on prioritized road sections,
3. prioritization of safety improvements,

4. scheduling and implementing safety improvements, and
5. program evaluation and update.

The focus presented here is on the first two steps.

System-wide Prioritization of Unpaved Roads

It is generally accepted that local road agencies do not have adequate resources to simultaneously address safety improvements on all their unpaved roads. Therefore, the first step of the SIP is to prioritize unpaved roads on a system-wide basis. The goal of the prioritization process is to identify roads with the largest potential safety benefit. Some degree of professional judgment is required during this process to eliminate the need for costly and time consuming formal road inventory and data collection procedures.

A local agency's network of unpaved roads is first divided into road sections. Sections begin and end at natural break points, such as major intersections. Each section receives a primary rating factor determined by traffic volume and user types. The primary rating factor is then modified up or down by using adjustment factors. The final adjusted rating factors are used to prioritize the road sections for further safety analysis.

The rating concept for both the primary rating and adjustment factors is based upon a relative evaluation of unpaved road sections in each local jurisdiction. A detailed data collection effort is not proposed. Instead, each element is subjectively rated as either high or low, relative to other unpaved road sections in the jurisdiction. If uncertain, the element is rated as average.

The matrix format shown in Table 4.8 simplifies selection of a primary rating factor. For this matrix, local users are defined as motorists who use the road on a regular basis. They are familiar with short term changes that occur in the road's characteristics.

Table 4.8. Unpaved Road Primary Rating Factors

User Types (Users consist mainly of)	**Traffic Volume** (based on subjective evaluation)		
	Low	**Average**	**High**
Local	A	B	C
Local + Recreation	B	C	D
Local + Recreation + Tourist	C	D	E

Recreational users are defined as non-local, in-state motorists who use the road on an infrequent basis. Some are probably first-time users. Recreational users are generally not familiar with the present condition of the road, but may use expectations previously developed on similar unpaved roads. These users are often driving sport utility or recreational vehicles and may be pulling trailers. Tourists are defined as out-of-state users who are not familiar with the road's present condition. Often they are first-time users and are not generally familiar with unpaved roads in the state. They may also be driving sport utility or recreational vehicles.

Each level of rating in the matrix is represented by an alpha character. An "A" road section is evaluated last since the users are primarily local and the road has low traffic volume. This rating scheme hierarchy is similar to the "Level of Service" ratings used in the *Highway Capacity Manual* (HCM) [48]. Unpaved road sections rated "E" are the first to be evaluated for safety improvement needs.

The adjustment factors in Table 4.9 account for elements that also are important to stratifying the road sections. Operating speed has a potential influence on crash rates

Table 4.9, Rating Adjustment Factors for Unpaved Roads

Element	Levels of Ranking (based on subjective evaluation)	Rating Adjustment Factor
Operating Speed	High and/or Large Variation in Speed	Move down 1 Class
	Average	Neutral
	Low	Move up 1 Class
Heavy Vehicles	High (Logging, Mining, Agriculture, etc.)	Move down 1 Class
	Average	Neutral
	Low	Move up 1 Class
Terrain	Mountainous	Move down 1 Class
	Rolling	Neutral
	Level	Move up 1 Class

and severity. Large variability in operating speed indicates conditions are present, which potentially violate driver expectancy. An example is a relatively low speed curve at the end of a higher speed tangent. Generally, high operating speeds also increase the severity of crashes. Therefore, road sections with a high variability in speed and/or relatively high operating speeds need special consideration. A high percentage of heavy vehicles also influence safety. Heavy vehicles are often wide, large, and moving at different speeds than passenger cars. They tend to disrupt normal traffic operation and often create additional safety problems such as severe rutting and dust. A high percentage of heavy vehicles usually occurs when commercial operations such as logging, mining, or oil fields are nearby. Road sections used for these purposes also need special consideration. Likewise, the immediate terrain influences safety on road sections. Roads in mountainous terrain often have steep side slopes, drop-offs and poorer sight distances. Many times these roads have no shoulders or clear zones. Rolling and level terrain present decreasing hazard potentials.

Each road section is checked for the presence of rating adjustment elements listed in Table 4.9. The primary rating factor is then adjusted up or down accordingly. If road sections have seasonal fluctuations for any of the rating elements present, the worst conditions should be used to evaluate the road.

The adjustment factors shown in Table 4.9 represent one possible scheme. As presented, all of the rating factors have equal weight. Several focus group members indicated a need to develop variable weighting schemes for the adjustment factors.

Identification of Safety Improvements on Road Sections

The second step in the SIP is to identify specific safety improvement needs. It is assumed that readily identifiable safety needs exist on local unpaved roads. Through a partnership with local road users who are directly concerned with safety on "their" particular roads, input is gained concerning needed safety improvements. The approach evaluated was to use a mail-out safety survey of local road users to assist in identifying safety improvement needs. This procedure is economical for the limited budgets of local unpaved road agencies. Potential user groups to receive the safety needs survey typically include:

- property owners and residents (residential, agricultural, summer homes, and cabins),
- route drivers (school bus, mail carriers, parcel delivery service),
- sheriff's deputies and emergency personnel, and
- road and bridge personnel.

There are several distinct advantages of involving local road users in the safety needs survey procedure. First, regular users are familiar with areas of the road that present problems for them. They drive the roads often and under various conditions. People who live near the road also may be aware of accidents that occur and are never reported. Second, the local property owner is continuously observing the road condition and may have good maintenance and safety ideas, which should not be overlooked [41]. Third, by involving road users and opening a line of communication, road agencies demonstrate that they genuinely are concerned with safety conditions on local roads. By including local road users in the safety survey process, the agency gains not only information, but also fosters "partnership" ties to the community. With a general increasing demand in the accountability of government road agencies, public involvement on road projects is critical [49]. The National Association of County Engineers recommends gaining public support for local roadway safety improvement programs to ensure overall success [41]. Fourth, it is potentially an accurate and cost effective method of identifying safety needs [39].

Nine out of 10 focus group members agreed with the concept of involving road users in the identification of safety needs. Comments included:

- Town meeting or public input meeting also could be utilized.
- Looks good.
- Good idea.
- Communication is needed for information (exchange) and to eliminate confrontation.
- Only for input. Final decisions need to be left to professionals.
- We have too much of that right now. In many cases it becomes extremely political.

Often property owners feel that their roads deserve more attention and that the local agency is not adequately attending to their unpaved road maintenance needs. They also are probably unaware of the limited budgets and manpower of local agencies. Partnering is a potential means of making the public aware of such limitations and winning their political support.

Prioritization of Safety Improvements

A standardized procedure for prioritizing improvements must be developed. Several questions in the second round Delphi survey addressed the policy issue of how to prioritize safety improvements. Several focus group members did not feel it was acceptable for improvements to be made only to the highest priority roads. The following are typical of the nine comments received:

- There may be a time when small repairs could be done on roads with a lower priority while waiting on materials or weather or other reasons on a higher priority road.
- I feel benefit/cost has to be considered. We may be able to save two lives for an expenditure of $100 on a low priority road, or one life for $1,000 on a high priority road. For this reason, I think some flexibility should remain for the safety coordinator.

- I am in favor of prioritizing road sections, but I think it is unreasonable to put aside smaller, less expensive repairs while focusing on a larger problem.

Several issues must be considered in the prioritization procedure. First, a safety program must be started with a sound basic procedure. A systematic procedure of safety improvement that is not data or resource intensive is proposed. Second, until higher priority roads are surveyed and safety needs identified, addressing needs on lower priority roads is difficult. Third, determining all safety improvements needed for all road sections is beyond the resources of most agencies.

Scheduling and Implementing Safety Improvements

The next step is to schedule and implement the safety improvements. A number of considerations must be made. Funding for safety specific improvements, as well as routine maintenance and special projects is often included in the total roadway budget. Funding for the safety improvements must have flexibility to allow for outside influences such as emergency repairs, unexpected weather trends, special events, unexpected changes in use, and other unforeseen circumstances.

Scheduled safety improvements should maximize the benefit/cost ratio. As in the other parts of the SIP, professional judgment is needed to avoid many of the in-depth procedures developed for high volume paved roads.

Program Evaluation and Update

The final step in the SIP is to conduct an evaluation of the program's effectiveness. This is important and necessary to ensure long term success. A dynamic program is needed to accommodate changes, which occur in unpaved road networks.

Safety Improvement Program Case Study

After developing the safety improvement program, a case study that evaluated the proposed procedures was conducted in Albany County, Wy. The case study tested the road prioritization and safety needs identification procedures.

After discussions with the Albany County Road and Bridge Superintendent, four unpaved road sections were selected. These four road sections received a large number of citizen complaints and each had unique roadway and user elements. Road users were identified and a mail-out survey was conducted. Respondents included land owners, residents, and county road and bridge employees. Sheriff's deputies and UPS drivers also were surveyed on a county-wide basis. In total, 55 user surveys were returned. Using the SIP procedures and the road user surveys, an analysis of each road section was completed. A safety audit based on engineering principles also was completed for each road section. It evaluated the accuracy and usefulness of the user surveys.

The case study successfully demonstrated the feasibility of key procedures in the safety improvement program. The road prioritization process indicated that of the four road sections analyzed, one was high priority ("E" rating), two were secondary ("D" ratings), and one was low priority ("A" rating).

The user safety survey accurately matched most of the specific needs identified in the safety audit. A major advantage was that users were able to identify additional safety needs based on their familiarity with the roadway environment and their knowledge of crashes, which were not officially reported. Users also identified weather-related conditions, which primarily affect safety and were not identified by the safety audit procedure. However, the local respondents did not provide more detailed safety needs such as flattening steep slopes and improving positive guidance.

Summary

Implementing traditional SIPs on unpaved road networks often is beyond the economic means of local road agencies. As a result, many of these agencies do not have safety improvement programs. The primary objective of this research was to develop and test a suitable SIP for local unpaved roads. A literature review of current SIPs found no models available specifically for unpaved roads. A focus group consisting of unpaved road experts and professionals was formed. Input from the focus group was gained through the use of a modified Delphi procedure. Additional input was gained from a crash and user data study.

Using input from the focus group the following five-step program was developed:

1. system-wide prioritization of unpaved roads,
2. identification of safety improvements on individual road sections,
3. prioritization of safety improvements,

4. scheduling and implementing safety improvements, and
5. program evaluation and update process.

The recommended program is simple to use and cost effective. A primary assessment of candidate unpaved road sections using traffic volume and types of users is recommended. Modification factors account for high speed and speed variations, high percentage of heavy vehicles, and terrain type.

Conclusions

The following conclusions were made from this research project.

1. Many local road agencies do not have a safety improvement program for unpaved roads.
2. Development of a safety improvement program for unpaved roads must recognize limited local funding.
3. The case study demonstrated that crash data and road user assessments are useful in identifying safety needs for unpaved roads.
4. Changing current policy and practice to prioritize unpaved roads for evaluating safety needs is recommended.

Recommendations

This section presents recommendations for additional research concerning safety improvements on unpaved roads.

1. Further research is needed to establish "weights" for adjustment factors used in the road prioritization process. As developed and demonstrated in this project, all rating factors were weighted equally.
2. Safety benefit tables must be developed for safety improvements on unpaved roads. This will greatly enhance the local safety coordinators' ability to prioritize safety improvements. Such tables should reflect the benefits obtainable from incremental safety improvements to elements such as road cross section geometry, alignment, road surface condition, cattleguards, etc.
3. Studies to determine if the absence of washboard road surfaces improve safety are recommended. Each of the road user groups surveyed ranked washboard surfaces as a high priority safety improvement. WYDOT crash reports also mentioned washboard surfaces. One Albany County deputy stated, "Washboard roads need more attention. I have investigated numerous roll-overs due to loss of control on these roads."
4. After the prototype SIP is out of its development stage, it is recommended that field tests of the procedures be conducted by several local agencies.
5. It is recommended that local agencies adopt, on a regional basis, uniform policies concerning safety improvement programs. Hopefully, by adopting uniform policies, favorable legal precedence will be established.

Chapter 1

INTRODUCTION

Implementing safety improvements on low volume rural (LVR) unpaved roads is a continuous challenge for local road agencies. The purpose of this research was to design and test a prototype safety improvement program (SIP) for use by local unpaved road agencies. The development goal for the unpaved road SIP was to facilitate the identification and prioritization of safety improvements for unpaved rural roads. The objectives were two-fold. First, the procedure needed utility at the local agency level, i.e. low cost. Local agencies simply do not have adequate funding to complete formal, in-depth engineering studies on all roads under their jurisdictions. Second, the procedure had to be reliable in the field and credible in a court of law.

Traditionally, local governments have not had resources for safety improvements on low volume unpaved roads. This is still true. A recent nationwide survey revealed the condition of county roads is cause for concern. The survey indicated that 38 percent of the mileage had limited failures and was in barely adequate, or worse, condition. On average, 25 percent of the mileage did not meet the barely adequate condition rating [1].

Increasing tort settlements associated with the non-compliance of accepted roadway safety guidelines also compound the problem [2]. Most often cited functions for negligence in tort cases against government road agencies are maintenance (65 percen), operations (17 percent), and design (10 percent) [3]. In the years from 1978 to 1990 lawsuits more than doubled for 50 percent of the states, 18 percent of the counties, and 12 percent of the cities [3].

A traffic study completed as part of this research confirms the need for improved safety on unpaved roads. The study results indicated that the number of injury crashes per vehicle mile traveled on Wyoming unpaved roads is five to six times as high as on the state's paved road network. Unfortunately, decreases in federal and state transportation funding at the local level and increases in vehicle miles traveled on unpaved roads are anticipated. A safety improvement program that specifically addresses the safe maintenance and operation of unpaved roads is needed to help reduce negligence claims against local road agencies.

Currently local road agencies are responsible for the maintenance of more than 1.4 million miles of LVR unpaved roads in the United States. This is about 36 percent of all public roadway mileage. More than 60 percent of this mileage carries fewer than 50 vehicles per day, and more than 99 percent carries fewer than 500 vehicles per day [4]. These low traffic volumes make it difficult for road agencies to justify costly improvements. A 1979 LVR study conducted by John C. Glennon examined safety performance by evaluating the impact of crash costs. Results showed that the average annual cost of crashes on LVR roads ranged from $665 per mile for a road carrying 50 vehicles per day to $3,570 per mile for a road carrying 400 vehicles per day. When considering a road carrying 50 vehicles per day, and given a realistic goal of a 25 percent reduction in crashes due to safety improvements, only safety improvements costing less than $166 per mile per year were justified (cost figures in 1979 dollars) [5]. This example illustrates that safety improvements that are justified by a reduction in crashes must be extremely low cost. Unfortunately, SIPs developed for higher volume paved roads rely on costly and time consuming formal engineering studies. Engineering studies typically involve extensive data collection, roadway inventories, and analysis procedures. For low volume unpaved road agencies these activities often are cost prohibitive.

The U.S. Department of Transportation (DOT) recently developed a Highway Safety Action Plan in response to regulatory changes made by National Highway System (NHS) legislation. One of the objectives of this plan is to aggressively promote and support the development of Safety Management Systems (SMS) in all states [6]. Significantly, a federal-state partnership is evolving. However, a full scale SMS at the local level is unlikely due to limited local budgets. An alternative systematic procedure is needed for local agencies.

This research develops and evaluates an approach that accommodates local agency needs. A focus group of transportation experts and professionals with interests in local unpaved roads was established. A modified Delphi survey technique was developed and used to obtain the focus group's input. Utilizing the group's input, and a statistical analysis of crash and user data, a prototype safety improvement program for unpaved roads was developed. Critical elements of the SIP were tested to establish their feasibility.

Contained in Chapter 2 is a literature review of road safety programs and related information for unpaved roads. Chapter 3 presents an overview of the methodology used for this project. Chapter 4 includes the results and findings of the project and Chapter 5, the project summary, conclusions, and recommendations for future research are presented.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews pertinent highway safety-related programs developed to date. The Federal Highway Administration (FHWA) has many publications that are available for transportation agencies as guides when establishing safety programs. Some of these publications address a broad range of roads. Others are more specific to certain road classifications. A large number of the procedures outlined require resources and expertise, which is not available to many local road agencies.

The literature concerning local LVR roads generally carries a theme of differentiation between the needs of LVRs and those designed to carry higher traffic volumes. In 1975 a Transportation Research Board (TRB) conference emphasized that low volume roads are unique. A summary of the conference states, "Engineers must design low volume roads from a point of view different from that used in the design of high volume roads...A primary concern is that techniques should be developed for designing low volume facilities with a minimum of effort and, certainly, in most cases with the use of most meager data." The need to concentrate on the matter of economics was repeatedly stressed [7].

Although it is well-recognized among transportation officials that low volume unpaved roads have unique needs, literature and guidelines specifically concerning safety on unpaved roads are limited. Safety guidelines for unpaved roads often are included with those for paved roads. Unpaved road management systems have been developed to address the general maintenance and surface conditions for unpaved roads [8, 9, 10]. However, safety issues specific to unpaved roads are usually ancillary to maintenance, if mentioned at all. The level of interest in safety for unpaved roads is now growing. This is partially due to current trends in tort liability.

The number of tort liability cases are increasing [3]. In 1982, 36 state highway departments had more than $6.8 billion of claims pending against them [11]. The trend of filing suit against transportation agencies has resulted in either the loss of insurance policies, or extreme increases in insurance premiums for local agencies [3].

2.2 Local Road Agency Statistics

Local government agencies currently are responsible for the maintenance of more than 2.9 million miles of roadways. This is about 75 percent of the total U.S. public roadway mileage (see Table 2.1). As indicated in Chapter 1, unpaved roads constitute about 36 percent of the nation's road mileage. In local jurisdictions 1.4 million miles are unpaved. More than 99 percent carry fewer than 500 vehicles per day and more than 60 percent carry fewer than 50 vehicles per day [4].

Table 2.1, Jurisdictional Control of U.S. Roads and Streets [12]

Jurisdiction	Rural Mileage	Percent	Urban Mileage	Percent	Total Mileage	Percent
Federal	179,561	5.8	1,292	0.2	180,853	4.6
State	692,414	22.3	107,058	13.3	799,472	20.5
Local	2,229,668	71.9	694,728	86.5	2,924,396	74.9
Total	3,101,643	100.0	803,078	100.0	3,904,721	100.0

More than 2,900 of the 3,050 counties in the U.S. have direct responsibility for managing road systems. Counties range in area from a few hundred to several thousand square miles. Their road systems range from several hundred to several thousand miles in length. Traffic counts vary from a handful of vehicles per day to thousands. There also are large variations in nearly all other factors directly related to the management of county roadways including: terrain, geological conditions, drainage conditions, number and size of bridges, environmental concerns, socioeconomic factors, and budgets, to list a few [13].

In 1992 the fatality rate on local rural roads was four deaths per 100 million vehicle miles traveled. This is compared to 1.75 deaths per 100 million vehicle miles for all roads. The fatality rate on local rural roads was higher than on any other roadway system [14].

In 1993 about 103 billion vehicle miles of travel occurred on local rural roads. This is about 11.6 percent of the total travel on all U.S. rural roads. Travel on local rural roads increased 27 percent between 1983 and 1993 [12]. If this trend continues, by 2003 travel on rural local roads will increase to 131 billion vehicle miles. An increase in the frequency of vehicle crashes will follow.

2.3 Local Low Volume Road Dilemmas

The word "dilemma" has been used many times in describing management and safety concerns for LVR roads [1, 5, 15, 16, 17]. At the local level, several key concerns greatly influence LVR policies. The largest concern for many road agencies is the severe economic or financial constraints placed on them. In 1975 Oglesby described the low volume "dilemma" as being one of many choices, many judgment calls, and severe cost constraints. Safety requirements, grade and alignment criteria, and many other features of low volume roads are unique [17].

Another common dilemma faced by local road agencies concerns road standards. Most unpaved roads were constructed long before current national safety and design standards were drafted. John Glennon writes [5]:

> "When considering safety on LVR roads, the highway agencies have been faced with a dilemma. On one hand, the agencies were inclined or required by funding sources to provide the same high-type design and operational features as on the primary highway system. On the other hand, the cost of providing such features often conflicted with the agency's philosophy of economic expediency. Because so few dollars had to be spent over so many miles, LVR roads have historically been designed and operated at minimal cost. Safety was seldom a primary consideration."

Current policy often requires low volume unpaved roads to conform to the same standards as are recommended for high volume roads. By some accounts this conformance has stunted road improvement progress and increased project costs as much as 200 percent [13]. When making improvements on low volume unpaved roads, local agencies often want to make small, more affordable, incremental improvements while working toward a final design. However, securing funding for an incremental upgrade is difficult and this is primarily due to liability issues. As tort cases become more prevalent, fewer funding agencies are willing to approve projects that do not bring all design elements of a road section up to current standards. Ivey and Griffin referred to this philosophy as the "Do All Syndrome" (DAS). The DAS requires that if one element of the roadway is brought up to "standards," then all elements are brought up to "standards." This philosophy often results in local agencies doing nothing [5,13,18].

The following example is offered to illustrate local agency "standards" dilemma: A county maintained 16-foot-wide earth surface road recently has seen an increase from 10 vehicles to 50 vehicles per day due to a new residential development. The road users are beginning to complain about dust and mud. The road manager has calculated that adding a gravel surface course to reduce the road's overall maintenance cost and improve serviceability is justified. The manager's calculations also show it is not economical to upgrade the road to an 18-foot traveled way with 2-foot graded shoulders as recommended in AASHTO's A Policy on Geometric Design of Highways and Streets (the Greenbook) [19]. However, to qualify for state funding support, this agency is required to bring the roadway section up to accepted guidelines and standards in all design areas.

A natural reaction of local officials to situations like these is to campaign for lower standards. Existing standards are needed however, and current guidelines represent the state of the art. The Greenbook is updated periodically to reflect the most current data and research available. Lowering standards is simply not a reasonable solution.

Another aspect of the safety upgrade dilemma is the associated problem of creating roadway inconsistencies. Inconsistencies in the roadway violate drivers' expectations. In a recent paper, Stanley Polanis stated, "crashes are usually the product of bad decisions, and engineers create, operate, and maintain the environment within which these decisions are made" [20]. The present need is to consider more than just the accepted safety guidelines. Looking at the overall roadway environment, and how drivers interact with it, also is necessary [21].

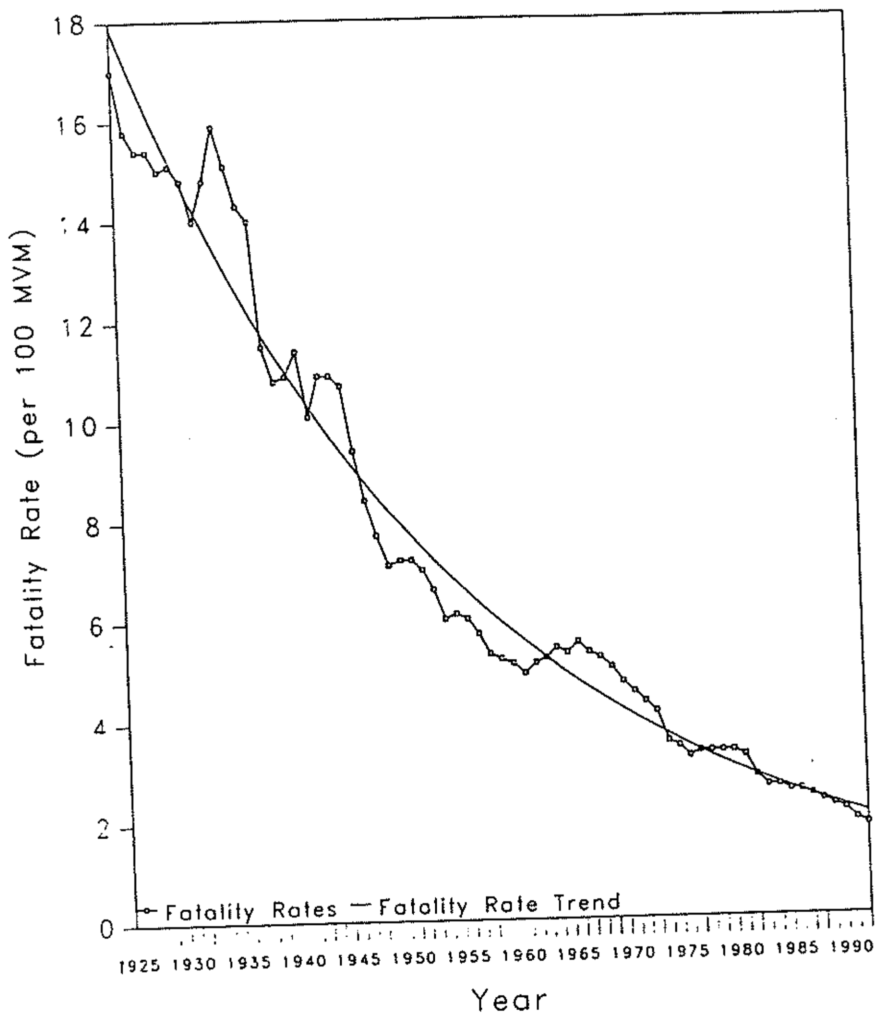
It has been well documented that drivers operate their vehicles on a section of road based on expectations [22,23,27]. Some expectations are developed over time with experience (a priori), and some are developed over the section of road just traveled (ad hoc) [24]. On unpaved roads there is often a wide variety of service or maintenance levels that a driver encounters from one road to the next. Many unpaved roads have a smooth, wide, well maintained surface with wide shoulders. Others have little more than two or three wheel ruts with a washboard surface. Driver expectations vary depending on the user type. Familiar users generally know what to expect along the roadway. Unfamiliar users usually do not. When unfamiliar drivers turn onto an unpaved road, their expectations for that road are developed as they travel. As long as the roadway is consistent they soon adjust their behavior to match the limitations of the road. These ad hoc experiences give drivers some idea of what to expect around the next curve or over the next hill. If inconsistencies are present, the driver may be taken by surprise and react in an unfavorable manner. When considering this issue, should an isolated section of a rural unpaved low volume road be upgraded to current standards when this may in turn, create an inconsistency in the overall roadway? Will fixing a high crash location by bringing it up to acceptable standards effectively shift the problem to the next section of road? Both of these outcomes are probable [42].

Another unpaved road dilemma concerns the use of spot safety improvements such as delineation of curves. The uncertainty is that if one road is improved with curve delineation, should all similar roads also receive delineators? If an improvement such as this is made, is liability exposure increased on other roads not receiving delineation? If the curves were delineated and the tangent roadway approaches were not delineated, is liability exposure also increased? The current trend in the U.S. legal system demands that these very real concerns be noted. Obviously, safety improvements of any kind should not increase liability exposure. Neither should safety improvements or treatments on one road be used against an agency on another road. Recognition of real world safety objectives is needed.

2.4 History of Highway Safety Improvement Programs

In 1965 a program to identify hazardous locations and provide funds for improvements began. The next year, guidelines for a safety improvement program began with the Highway Safety Act of 1966. A national concern focused on the rapid increase of highway fatality rates observed during the early 1960s (see Figure 2.1).

Figure 2.1, U.S. Motor Vehicle Traffic Fatality Rates 1952-1992 [14]



In 1967 AASHTO published a guideline to assist transportation agencies in establishing and maintaining mandated safety programs. In 1973 Congress passed another Highway Safety Act making federal funding available for specific safety programs such as: pavement marking demonstration programs, rail/highway crossings, high hazard locations, elimination of roadside obstacles, and safer roads demonstration projects [25]. As a result of the increase in highway safety programs in the 1960s and early 1970s the crash and fatality rates began to decrease. A continued emphasis on highway safety through the late 1970s and early 1980s led to the development of a systematic process. Among the objectives were the efficient use and allocation of available resources and the improvement of techniques for data collection, analysis and evaluation [26].

Throughout the 1980s, crash and fatality rates continued to decline as a result of the 20-year emphasis on transportation safety. In 1991 Congress again accentuated their interest in transportation safety by passing the Intermodal Surface Transportation and Efficiency Act (ISTEA). One of the ISTEA mandates called for the development of Safety Management Systems (SMS) in each state transportation department.

Another development that occurred throughout the 1980s was a notable increase in the number of tort cases filed against transportation agencies. With the increase in litigation came a renewed interest in reducing traffic crashes. This led to the development of risk management programs and safety audit procedures. Risk management programs not only aimed to reduce the number of crashes, but targeted specific areas where the probability of law suits arising from a crash were higher than normal. Safety audits apply a systematic approach to evaluating highway construction projects and existing facilities with the primary purpose of identifying needed safety improvements. Safety audits currently are being used in Australia and the United Kingdom.

2.4.1 The Highway Safety Act of 1966

The Highway Safety Act of 1966 set requirements for states to develop and maintain safety programs through 16 Highway Safety Program Standards. The standards called for a coordinated approach among all levels of government to increase roadway safety. Three additional standards later were adopted, resulting in 19 standards (see Table 2.2).

Table 2.2, Highway Safety Standards [26].

No.	Standard
1	Planning and Administration
2	Periodic Motor Vehicle Inspection
3	Motor Vehicle Registration
4	Motorcycle Safety
5	Driver Education
6	Driver Licensing
7	Codes and Laws
8	Traffic Courts
9	Alcohol in Relation to Highway Safety
10	Identification and Surveillance of Crash Locations
11	Traffic Records
12	Emergency Medical Services
13	Highway Design, Construction, and Maintenance
14	Traffic Engineering Services (Traffic Control Devices)
15	Pedestrian Safety
16	Police Traffic Services
17	Debris Hazard Control and Clean-up
18	Pupil Transportation Safety
19	Crash Reporting and Investigation

The Federal Highway Administration's office of Highway Safety administered the four highway-related safety standards, sometimes referred to as the "Three-Plus Standards."

These standards are [27]:

Standard 10, Identification and Surveillance of Crash Locations

Standard 13, Highway Design, Construction, and Maintenance

Standard 14, Traffic Engineering Services

Standard 15, Pedestrian Safety (the "plus" in the Three-plus standards)

The Three-Plus Standards placed many requirements on state and local transportation agencies. Standard 10, "Identification and Surveillance of Crash Locations," required the development of a program to identify and maintain surveillance at locations having high crash rates. Measures were then required to improve safety performance at these locations. The FHWA required periodic evaluations of each state's program.

Standard 13, "Highway Design, Construction, and Maintenance," required the development of a program relating to safety feature design for all construction. Roadway design elements specifically targeted were sight distance, horizontal and vertical curvature, spacing of decision points, lane widths, expressway lighting, surface treatments, rail/highway grade crossings, and clear zone treatments.

Standard 14, "Traffic Engineering Services," required the application of modern traffic engineering principles and uniform standards to reduce the likelihood and severity of traffic crashes. A plan was required to ensure appropriate traffic engineering skills were available to local jurisdictions. Provisions for upgrading the skills of traffic engineers, maintenance personnel, and technicians also were required. Each state was to develop a program to inventory and maintain traffic control devices according to Federal Standards.

Standard 15, "Pedestrian safety," required the development of programs to specifically address pedestrian/motor vehicle crashes. Programs included preparing and maintaining a data base for these types of crashes, initiating safe school route handbooks, familiarizing drivers with pedestrian problems, conducting engineering studies at high hazard locations, and training and educating the general public about pedestrian safety.

2.4.2 Highway Safety Improvement Program

In 1979 the FHWA required the development and implementation of a comprehensive Highway Safety Improvement Program (HSIP) in each state [27]. This policy required three standard components for an effective Highway Safety Improvement Program:

- Planning
- Implementation
- Evaluation

Each component was in turn made up of defined processes and subprocesses (see Table 2.3). Following each subprocess in Table 2.3 is a number in parenthesis, which refers to the number of individual procedures suggested to attain that sub-process. Overall, the structure recommended was quite complex and was composed of three components, six processes, and 14 subprocesses. There were 64 recommended procedures to use. Some procedures were left undefined, such as those in the evaluation component. At the time, a

Table 2.3, Outline of HSIP Structure

I. PLANNING COMPONENT

Process 1: Collect and Maintain Data
- Subprocess 1: Define the Highway Location Reference System (5)
- Subprocess 2: Collect and Maintain Crash Data (3)
- Subprocess 3: Collect and Maintain Traffic Data (5)
- Subprocess 4: Collect and Maintain Highway Data (4)

Process 2: Identify Hazardous Locations and Elements (7)

Process 3: Conduct Engineering Studies
- Subprocess 1: Collect and Analyze Data at Identified Hazardous Locations (24)
- Subprocess 2: Develop Candidate Countermeasures (3)
- Subprocess 3: Develop Projects (5)

Process 4: Establish Project Priorities (4)

II. IMPLEMENTATION COMPONENT

Process 1: Schedule and Implement Safety Improvement Projects
- Subprocess 1: Schedule Projects (4)
- Subprocess 2: Design and Construct Projects
- Subprocess 3: Conduct Operational Review

III. EVALUATION COMPONENT

Process 1: Determine the Effect of Highway Safety Improvements
- Subprocess 1: Perform Non-Crash-Based Project Evaluation
- Subprocess 2: Perform Crash-Based Project Evaluation
- Subprocess 3: Perform Program Evaluation
- Subprocess 4: Perform Administrative Evaluation

13-minute slide/tape overview was available from FHWA to assist state and local agencies in understanding just the program structure.

Overall the HSIP represents an exhaustive safety program. Most of the procedures recommended require financing, personnel, and expertise not available at local unpaved road agencies. Not surprisingly, small local agencies have not adopted the HSIP as developed.

2.5 Safety Management Systems

In 1991, ISTEA legislation required six management systems be developed by state transportation agencies. One of these was a safety management system (SMS). Safety management systems assist decision makers in selecting cost effective safety countermeasures. The SMS process focuses on [25]:

1. Identifying hazards, setting priorities, and developing a program to correct hazardous highway locations and features;
2. Maintaining and upgrading the safety of highways, highway features, and highway hardware;
3. Ensuring routine and timely inclusion of safety concerns in the development of all highway projects; and
4. Identifying special safety needs of commercial motor vehicles in the planning, design, construction, and operation of the highway system.

The ISTEA legislation also stressed the importance of building partnerships between transportation agencies and the general public. Creating a means for public input to transportation decision making was mandated.

A good safety management system should strive for total accident reduction, not just reactive remedial measures. Breaking the chain of self-evaluation and encouraging outside input is recommended to help create the most effective management systems. In all cases, some form of safety check or audit of the design of new facilities and of existing highways is warranted [28]. Again, the requirements of ISTEA did not consider the limited resources of local government.

2.6 Risk Management Programs

The present trend in American society is for plaintiffs to bring suit against a government agency (or an individual employed by an agency) if they feel they have been wronged. The National Association of County Engineers (NACE) state in their risk minimization program that a law suit is likely if the following conditions exist for any given crash [29]:

1. A potentially dangerous roadway defect.
2. The defect was the proximate (legal) cause of the crash.
3. The responsible agency had notice (actual or constructive) of the alleged defect and no action had been taken to correct it.

Since there is no way to completely eliminate liability or prevent law suits, the next best thing is to reduce liability exposure. Risk management programs strengthen known weaknesses in an agency's safety program and target high risk locations. The primary goals of a risk management program are the minimization of highway crashes, crash severity, crash potential, lawsuits stemming from crashes, and agency losses from lawsuits [3]. NACE lists the following items as the most frequent causes of lawsuits against county road agencies: malfunctioning traffic signals, sign defects, roadside hazards, guidance, guardrail, shoulder maintenance, road surface maintenance, geometrics of the road and intersections, snow and ice control, and removal of highway debris. A risk management program is essentially a preventative maintenance program that systematically addresses high frequency items like those listed above. Good record keeping, routine inspections, employee training and education, provisions for emergency maintenance, crash record reviews, design and operational reviews, and proper insurance coverage should all be included in an effective risk management system [3,29].

An example of a risk management program developed in Michigan is presented next. Safety improvements are targeted based on the analysis of past crash experience and risk assessment. A recommended policy is to contest even nuisance lawsuits, simply to prove to the plaintiffs' attorneys that there is no "easy money" available. Instituting programs such as a well-documented record-keeping system, and an effective defect identification and surveillance system, are recommended to help minimize potential losses from lawsuits [30].

The Michigan program consists of four major elements: crash reduction, loss reduction, defect surveillance, and public relations. In addition, there are three identifiable processes that are part of the overall risk management system: risk identification, resource allocation, and risk management evaluation.

The analysis procedure utilizes risk factors to prioritize safety improvements for an agency's road network. It is suggested that risk factors be calculated in one of two ways. If sufficient historical crash and law suit data are available for the potential crash site in question, the risk factors are calculated using statistical probabilities. This is usually accomplished using a Poisson Distribution. If sufficient data are not available risk factors are calculated based on weighting schemes, expected crash frequencies, and roadway defects. Defects are included in the calculation to account for locations where no crashes have occurred, yet there is a risk that they might occur in the future. The weighting factors are developed based on these assumptions:

- The higher the severity of a traffic crash, the higher the chance of being sued.
- The higher the severity of a traffic crash, the higher the amount of judgment or settlement.
- The higher the severity of a defect, the higher the probability of a traffic crash and lawsuit.

Risk management programs, like the HSIP, involve many complex and detailed procedures. Some of the procedures are appropriate for local unpaved road agencies and some are beyond their means. Like with the HSIP, many local agencies have not adopted risk management systems due to the lack of resources.

2.7 Road Safety Audits

A road safety audit has been defined as a formal examination of an existing or future road or traffic project, or any project that interacts with road users, in which an independent, qualified examiner looks at the project's accident potential and safety performance. The objectives of road safety audits are to identify potential safety problems for road users and others affected by a road project, and to ensure that measures to eliminate or reduce the problems are considered [31]. In the particular case of examining existing roads, assessment should be carried out on a regular basis [32].

In Australia and the United Kingdom, formal road safety audits currently are being implemented on paved highway systems. One distinction of a formal safety audit is that an individual or team of "auditors" review each highway project with the primary purpose of identifying potential safety problems. This is in contrast to many procedures where safety is an additional responsibility of the design or maintenance personnel. Also, safety audits are aimed at crash prevention rather than crash reduction.

Benefits from a formal safety audit are expected to be increased safety to the motoring public and decreased liability for the road agency. Comments on current programs have included:

- It is obvious that the process of a road safety audit can play a vital part in achieving safer roads [31].
- Highway authorities that fail to adopt safety audits or comparable processes run a higher risk that legal liability will be imposed when crashes occur [33].

In Britain, three-person teams are used during the feasibility and layout design stage of new projects. The team typically consists of a road safety specialist with experience in crash investigation and expertise in safety engineering principles and practice; a highway design engineer; and a person with previous experience in safety audits who is able to generate discussion and assist in the procedure. At the pre-opening or in-service stages, the inclusion of the police and an engineer who has responsibility for the maintenance of the road and its traffic control devices are desirable [31].

In general, the audit team is either internal or external. Internal teams are familiar with the projects or existing roads, but may find it difficult to say that problems exist on their own roads. Conversely, external teams are less familiar with the roadways, but are not hesitant to point out any deficiencies that exist. The concept of safety audits is not limited to transportation facilities. The Occupational Safety and Health Administration (OSHA) recently has begun to encourage businesses to integrate safety audits into their safety and health programs [34].

Austroads, the Australian national association of road transport and traffic authorities, examined the benefits and costs of a national approach to safety audit in 1992. The Austroads project estimated that road safety audits, when fully instituted nationally, have the potential to reduce annual casualty accidents by up to 3 percent. This amounts to a saving of up to $275 million per year (Australian dollars) [35].

The Safety Audit procedure Australia has adopted employs in-depth check lists. The items on the check list cover safety deficiencies that commonly are found in the roadway environment. The list is comprehensive and exhaustive. The amount of man-hours required to carry out the procedure make it impractical for direct adoption by local agencies.

2.8 Summary of Literature Review

The Highway Safety Improvement Program examined in this chapter represents a thorough and exhaustive outline of management procedures. The Federal Highway Administration in their publication, Highway Safety Improvement Program, recommend that the specific safety related programs should be carried out by state and local highway agencies in an organized, systematic manner. However, many of the procedures recommended to successfully maintain the HSIP require a large amount of resources and professional expertise. At this time, few rural local agencies are utilizing the HSIP guidelines simply because the procedures are beyond their means.

The suitability of using crash rate analysis, such as those recommended by HSIP, to identify road hazards on rural and low volume roads also must be questioned. A rural crash study completed at the University of Wyoming in 1992 found that "...an analysis based on the existing data is of little or no use in determining major crash contributing factors. Thus, using this type of analysis would not provide enough information to decrease the overall crash rate." The same study showed that when appropriate "exposure" data were included, useful crash factor combinations were determined [36].

Safety management systems, like the HSIP, are designed more toward state agencies and their greater resources. Road safety audits also have been developed, but are beyond the economic means of most local agencies. However, there are important concepts that each of the full scale road safety programs offer to unpaved road safety improvement programs. Most importantly, the very existence of a systematic SIP will almost surely reduce liability risk for local agencies. On the other hand, if an agency has done nothing toward implementing a safety program, negligence may be easy to prove.

Practical safety improvement programs designed specifically for unpaved roads were not found during the literature review. Certain elements of the safety improvement programs presented in this chapter are feasible for unpaved roads. However, the level of detail recommended in the procedures is probably not achievable by most local agencies due to limited resources.

Chapter 3

METHODOLOGY

The main goal of this research was to develop a prototype safety improvement program (SIP) for rural unpaved low volume local roads. The methods used to achieve this goal are presented in this chapter. To begin, a focus group made up of transportation professionals who have special interests in safety and maintenance on unpaved roads was established. A modified Delphi survey procedure was used to gather input from the focus group. Through the Delphi surveys, the focus group provided necessary input to define critical characteristics for low volume unpaved roads and develop a prototype SIP. In addition, crash records, traffic counts, and user data for selected unpaved roads were studied to supplement the input of the focus group. The prototype SIP was then developed and key components were evaluated on selected county roads in southern Wyoming.

3.1 Crash Data Analysis

A crash data analysis was conducted to gain supplementary information for the unpaved road SIP. A 39-month time period from 1992 to 1995 was selected based on the known accuracy of WYDOT crash records for this period. Crash records for three Albany county unpaved roads were examined in conjunction with user data. Wyoming unpaved road crash records from five counties were examined and compared to crashes on paved roads. Crash records were obtained from the WYDOT crash data base, Wyoming Accident Records System (WARS). This data base is capable of providing information from 151 different data fields covering vehicle, driver, and roadway elements. For this project 28 data fields were examined. A list of these fields is presented in Appendix A.

Crash data analysis is a recommended procedure for almost all highway safety programs [18, 26, 27, 29, 37, 38, 39]. However, the extent of crash data usefulness on low volume roads has been questioned [18, 36, 40, 41, 42]. Since crash frequency is a direct function of traffic volumes, low volume roadways typically have few crashes despite the fact that they may be extremely hazardous. Often crashes on low volume roads are dispersed randomly throughout the road network. As the result of low numbers of crashes and random dispersion, the identification of crash trends is difficult, if not impossible. A hazardous location is one that presents a risk to the driver in terms of either a high probability of crash occurrence or a high crash severity. This risk is not necessarily reflected in past crash records for unpaved roads [42].

In this research, the feasibility of using unpaved road traffic counts and user data to enhance the crash data analysis was studied. Employees of the Albany County Road and Bridge Department collected user data while doing routine road maintenance during September and October of 1995. This was accomplished by making 149 roadside observations. Vehicle registration information was recorded by state and county. Vehicle types were classified as either pick-up, car, sport utility, truck, or other.

Twenty-one day traffic counts were taken during this same time period, with automatic traffic counters placed at key locations. Comparisons of crash rates and other safety parameters between paved and unpaved roads were then made.

3.1.1 Principal Evaluations

Crash statistics are often used to provide a means of quantifying and examining roadway safety concerns. Three principal evaluations are commonly made:

1. Crash occurrence,
2. Crash involvement, and
3. Crash severity.

Crash occurrence is generally described in terms of the types and numbers of crashes that occur, often as a rate based upon population or vehicle miles of travel (VMT). Involvement statistics often concentrate on the categories of vehicles and drivers involved in crashes. Severity is generally expressed as the number of deaths, and/or injuries [43]. By calculating the rate instead of the frequency of crashes, it is possible to compare different sections of roadway or make before and after comparisons when changes are made to a single roadway. If crash severity is included, rates are often broken down to reflect the costs of injury and fatal crashes. Common crash categories include fatality crashes, injury crashes, and property-damage-only (PDO) crashes [37].

3.1.2 <u>Z-Test on Two Proportions</u>

In the crash and user data analysis portion of this research, statistical tests on two proportions were made. The testing determined if two different proportions were statistically equal. The hypothesis for these tests is stated as:

Ho: $p_1 = p_2$ (Proportion 1 = Proportion 2)
Ha: $p_1 \neq p_2$ (Proportion 1 ≠ Proportion 2)

For testing with large n the normal-curve approximation to the binomial probability is preferred. The parameters μ and σ^2 are approximated by $\mu = np_0$, and $\sigma^2 = np_0q_0$, where p_0 = x/n and $q_0 = 1 - p_0$. These estimates are quite accurate as long as np_0 and nq_0 are both greater than 5. For testing two proportions, the *z-value* test statistic for the standard normal variable is reduced to:

$$z = \frac{\hat{p}_1 - \hat{p}_2}{\sqrt{\hat{p}\hat{q}\left[(1/n_1) + (1/n_2)\right]}}$$

Where:

The pooled estimate of the proportion $\hat{p}$ is given by: $\hat{p} = \dfrac{x_1 + x_2}{n_1 + n_2}$,

$$\hat{q} = 1 - \hat{p},$$

$$\hat{p}_1 = \frac{x_1}{n_1}, \text{ and}$$

$$\hat{p}_2 = \frac{x_2}{n_2}.$$

The critical regions for the appropriate alternative hypothesis are set up based on a one-sided or two-sided test. For the data analysis completed here, the two-sided alternative hypothesis, Ha: $p1 \neq p2$, at the $\alpha = 0.05$ level of significance was used. The critical region was then given by: $z_{CR} < -z_{\alpha/2}$ and $z_{CR} > z_{\alpha/2}$ [44].

3.1.3 Crash Rates

Injury crash rates were calculated for unpaved county roads using the standard formula [46]:

$$RSEC = \frac{1{,}000{,}000 \times A}{365 \times T \times V \times L}$$

Where:

$RSEC$ = Crash Rate for the Section

(crashes per million vehicle miles of travel)

A = Number of Crashes Reported

T = Time frame of analysis, in years

V = Estimated Average Daily Traffic

L = Length of Road Section, miles

3.2 Safety Improvement Program Focus Group

Developing a working focus group of transportation professionals was a key element to the success of this research. The focus group members provided input for the proposed safety improvement program based on professional experience. To ensure diversity in the group, members of the focus group were from various areas of the Rocky

Mountain region, and various subgroups in the transportation profession. The focus group members consisted of well-recognized transportation experts and professionals from the Federal Highway Administration, Wyoming Department of Transportation, Wyoming Association of County Engineers and Road Superintendents, Wyoming County Commissioners Association, and regional universities.

3.3 Delphi Survey Technique

A written survey method was adopted as the means for focus group input and interaction. The survey employed modified Delphi techniques. The Delphi survey is a hybrid combination of a polling procedure and an inquiry survey. The general methodology involves a questionnaire where the respondent is asked for input or answers to questions based on their own judgment and professional knowledge.

A Delphi survey is a method for structuring a group communication so the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem. Four characteristics of a Delphi are [45]:

1. The exercise involves a group.
2. The goal of the exercise is information; i.e., the exercise is an inquiry.
3. The information being sought is uncertain in the minds of the group.
4. Some type of preformulated systematic procedure is followed in obtaining the group input.

More specific characteristics are, feedback to the respondents, an iterative process of multiple rounds of questionnaires, and anonymous response. Usually the administrators of the survey will produce the first round of questions and when the responses are received, any comments or questions from the panel are incorporated into the next round. In this manner the panelists have the opportunity to re-think and refine their answers, and hopefully, as a group, reach an agreement. An important feature of the Delphi is that members of the response group remain anonymous to each other and preferably to the design and evaluation team. This allows the members to answer with their true feelings without social pressures that are present in a face-to-face committee.

The Delphi is often used in situations where there are no hard facts or data available. In these situations there is no alternative to expert opinion. It also is used in virtually any area where experts are found and in many areas where well-informed stakeholders are available. There are two fundamental assumptions that are made with a Delphi survey. First, in situations where complete information or adequate theories are not available, it is assumed that expert judgment can be used as a substitute for direct knowledge. Second, in a wide variety of situations of uncertainty, a group judgment (made by experts) is preferable to the judgment of a single expert [45]. These assumptions reflect the underlying Delphi philosophy.

The Delphi results rarely are a finished solution. Delphi results present a selection of expert information and opinion that is then used in solving a problem.

In the next chapter these methodologies are applied in the development of a safety improvement program for unpaved roads. Initial analysis of accident data is followed with the Delphi survey results. An evaluation of road user input into the identification of safety needs complements the proposed unpaved road SIP.

Chapter 4

ANALYSIS AND RESULTS

The development of the prototype safety improvement program for use by local agencies was undertaken in two stages. First, critical safety issues for local LVR unpaved roads were identified using focus group input supplemented with a crash and user data analysis. Second, the prototype safety improvement program was then developed using these critical issues as input. For both stages, a modified Delphi survey technique was utilized to gain input from the focus group. Presented in this chapter are the crash and user data analysis, results of the pilot Delphi surveys, the prototype safety improvement program, and results from the case study.

4.1 Unpaved Road Crash and User Data Analysis

Wyoming DOT crash records show that 44 crashes were reported on Albany county unpaved roads during the 39-month study period, which was suggested by WYDOT. Of these 44 crashes, 34 involved single vehicles and 10 involved two vehicles. Thirty-four people were injured. Twenty (45 percent) of the reported crashes were injury crashes, however no fatal crashes were reported on Albany County unpaved roads during the study period.

On examination of the crash data, the percentage of injury crashes reported on unpaved roads appeared considerably higher than the percentage of injury crashes reported on the Wyoming road network as a whole (45 percent versus 26 percent). This was attributed to the under-reporting of property damage only (PDO) crashes on unpaved roads. The extent of under-reporting of crashes varied by crash type, driver age, location, time, and other variables. Analysts making comparisons across such variables either assume under-reporting is constant, or that under-reporting is negligible in the scope of the study. If these assumptions are not acceptable, the under-reporting should be corrected [46]. For this study, only injury crashes were included. It was assumed that injury crashes were under-reported at the same level for unpaved roads as for paved roads. Comparisons between unpaved and paved roads were then made.

4.1.1 Albany County Unpaved Road Injury Crash Rate

Four unpaved road sections in Albany County, Wyoming were selected for crash data analysis. These same road sections also were used for the SIP case study. Table 4.1 contains the crash rate results for the four sections examined. The injury crash rate on these four county road sections averages 3.03 crashes per million vehicle miles of travel (VMT). The average injury crash rate on all Wyoming roadways was 0.55 crashes per million VMT [47]. The injury crash rate on the three unpaved roads was almost six times higher than on all Wyoming roads (significant difference at the $\alpha = 0.05$ level). The variability in crash rates may help to identify county roads that should receive priority attention when safety improvements are considered.

Table 4.1, Wyoming Injury Crash Rates for Selected Unpaved Road Sections vs. all Roads

Roadway Section or System	Number of Injury Crashes	Daily No. Veh. (Sept. 1995)	Road Section Length (miles)	Number of Days in Study (3 yr. 3 mo.)	VMT (Vehicle Miles Traveled)	**Injury Crash Rate per 1,000,000 VMT**
Albany Co. #234 (0-1.6 miles)	2	158	1.6	1186	299,821	**6.67**
Albany Co. #234 (1.6-10 miles)	1	35	8.4	1186	348,684	**2.87**
Albany Co. #47 (0 - 8 miles)	3	108	8	1186	1,024,704	**2.93**
Albany Co. #61 (0-15 miles)	3	73	15	1186	1,298,670	**2.31**
Four Albany Co. Sections Combined	9				2,971,879	**3.03**
1992-1993 All Wyoming	7121				12,969,000,000	**0.55**

A study also was completed to determine if driver familiarity with the roadway was a factor. Road user data were obtained from 149 roadside observations and were used in conjunction with 31 WYDOT unpaved road crash records. Drivers' familiarity was inferred by the proximity of their home to the road crash site. For the field observations it was assumed that the location of a driver's residence coincided with the location where the vehicle was registered. It also was assumed that a driver in a vehicle with an Albany county registration was less than 25 miles from home, a driver in a Wyoming vehicle from other than Albany county was more than 25 miles from home, and that a driver in an out-of-state vehicle was from out of state. For the crash records, WYDOT indicates a driver's home proximity to a crash site as either less than 25 miles, more than 25 miles, or out of state. Proportional comparison results are presented in Table 4.2.

Table 4.2, Drivers Proximity to Home

Albany County Wyoming	Drivers' Proximity to Home		
	Less than 25 Miles	**More than 25 Miles**	**Out of State**
Proportion on Road (p_1)	63/149 (42%)	48/149 (32%)	38/149 (26%)
Proportion Involved in Crashes (p_2)	10/31 (32%)	16/31 (52%)	5/31 (16%)
Ho: $p_1 = p_2$ @Alpha = 0.05	Accept Ho	Reject Ho	Accept Ho

Local drivers and out-of-state drivers showed a lower percentage involvement in reported crashes, but this difference statistically was not significant. In-state drivers who live in other counties had a significantly higher proportionate involvement rate.

4.1.2 The Roadway Environment

Roadway elements are routinely noted on Wyoming crash reports. For this investigation, the six roadway fields listed in Table 4.3 were retrieved from the WYDOT crash data base for the 44 reported crashes occurring on Albany county unpaved roads during the study period.

Of the 44 crashes only four listed contributing roadway elements. One T-intersection, one driveway, and two cattleguards were reported as contributing factors. In the investigating officers' written descriptions, "washboard" and "loose gravel" also

Table 4.3, WARS Data Fields For Roadway Elements

1. Contributing Roadway Element
2. Surface Type (gravel, dirt, etc.)
3. Road Conditions (wet, dry, icy, etc.)
4. Road Alignment (straight and level, curved and downgrade, etc.)
5. Traffic Control Devices (stop sign, warning sign, etc.)
6. Adverse Road Conditions (bridge out, etc.)

were mentioned. These comments were not included in the WARS crash data base. Unfortunately, this is the type of information that road agency personnel need when conducting safety studies.

Road conditions reported for all crashes occurring in Wyoming were compared with conditions for crashes occurring on unpaved roads in five Wyoming Counties. (see Table 4.4). For unpaved roads, most crashes occur during dry conditions (80 percent). This probably reflects that dry conditions occur most often.

Table 4.4, Roadway Conditions for All Wyoming Crashes [47] vs. Wyoming Unpaved Road Crashes

Road Condition	**Percentage of Crashes on Wyoming Roads**	
	All Crashes (paved and unpaved)	Crashes on Unpaved Roads
Dry	67	80
Muddy	<1	7
Wet	6	6
Icy	20	2
Snowy	5	5

WYDOT crash records contain eight data fields for road alignment. Four hundred and three unpaved road crashes occurring in five Wyoming counties were examined for alignment data (see Table 4.5).

Table 4.5, Alignment Type for Unpaved Road Crashes in Wyoming

Straight and Level	29%	Curved and Level	16%
Straight with Downgrade	13%	Curved with Downgrade	27%
Straight with Upgrade	3%	Curved with Upgrade	7%
Straight on a Hillcrest	2%	Curved on a Hillcrest	3%

The largest percentages of crashes occurred in September and October; on Fridays, Saturdays, and Sundays; and during the afternoon hours of noon to 9 p.m. The "First Harmful Event" data field showed "Overturned" (50 percent), "Collision Between Motor Vehicles" (23 percent), and "Collision With Various Objects (27 percent). The "Collision Type" data field refers only to motor vehicle - motor vehicle collisions and showed "Sideswipe" (50 percent), "Head On" (40 percent), and "Angle" (10 percent). The contributing factor data field for 483 crashes showed "Unknown" (46 percent), "Inattentive Driver" (12 percent), "Unsafe Speed" (22 percent), "Alcohol-Related" (7 percent), and "Driver Distraction or Inexperience" (2 percent).

There was no significant difference between the proportion of alcohol-related crashes on paved versus unpaved roads in Wyoming at the $\alpha = 0.05$ level. In fact, the two proportions were almost identical (see Table 4.6).

Table 4.6, Alcohol Related Crashes for All Wyoming Roads vs. Unpaved Wyoming Roads

Alcohol Related Crashes	Proportion	Percent
All Wyoming Roads [47]	1023/14227 (x_1/n_1)	7.19
Unpaved Wyoming Roads	35/483 (x_2/n_2)	7.25

A crash location pin map was constructed to evaluate the Albany County unpaved road system for possible high frequency crash locations (commonly called black spots). Crashes were found to be widely and randomly dispersed except for one cluster of three crashes on a short section of roadway. It was found there had been a series of curves in this section and the road had recently been realigned to improve safety. This indicates the value of evaluating unpaved road systems for black spots. However, accident crash data alone only have limited application in identifying safety needs on individual low volume unpaved road sections.

4.2 Safety Issues for an Unpaved Road Safety Improvement Program

The first round Delphi survey examined safety issues. Each of the nine questions was structured with background information and a rating scale for respondents' self-evaluation of confidence. Ten surveys were returned, representing a 62 percent return rate. The survey questions and summary results are included as Appendix B. The major findings of the survey are outlined below.

The focus group agreed that output from a safety improvement program for unpaved roads should be in the form of a severity group index. It was recommended that the ranking or grouping of roadway safety deficiencies be conducted on a road section-by-section basis. It was generally agreed that further detail, such as item-by-item rankings, would require too much detail and be too labor intensive for local agencies to maintain. Several respondents noted that a provision for "weighing" the cost of safety improvements should be included in the final program.

The focus group estimated that the typical unpaved road agency has approximately 280 man hours (or seven weeks) per year to devote to an SIP. In contrast, the HSIP procedures presented in Chapter 2 would require at least one full-time, highly trained employee, on a year around basis. The estimates also emphasize the need for a relatively simple, cost effective, SIP for local road agencies.

Focus group respondents generally agreed that the expense of a safety audit procedure would have to be recaptured in benefits other than monetary ones. Reduced liability and improved safety were two of the more substantial benefits noted. Other benefits included the possible reduction in maintenance activities or insurance premiums. Several respondents implied that if a safety improvement program prevented the loss of a tort liability case, it would more than pay for itself.

One of the more important findings of the first round survey was that incremental improvements to unpaved roadways, while working toward accepted standards, should be encouraged. Current policy and practice often discourage incremental roadway improvements. The focus group strongly agreed on this issue with nine out of 10 respondents indicating that incremental improvements should be made. Of these nine respondents, seven were highly confident in their answers. The 10th respondent remained neutral on this question. Many supportive comments were offered for incremental improvements. The following are typical of those comments:

- I strongly feel that any improvement is better than doing nothing at all.
- If we improve spots (high accident locations) these may provide inconsistencies in the road -- violating driver expectancy -- so the "improvements" may in fact decrease safety.

- Incremental improvements can have a positive benefit/cost ratio, but they should be part of a comprehensive safety plan. It should not be used on a site-by-site basis without consideration of long term plans.
- A step at a time helps the final outcome of the system.
- Not everything can be addressed, but doing something is better than doing nothing. We need to focus on doing the best we can with the resources that we have.

When asked about the use of historical crash data in the proposed safety improvement program, nine out of 10 respondents indicated crash data should be included. Of these respondents, eight were confident or highly confident in their answers. The focus group indicated that accident data should be used with care due to the random nature of crashes on unpaved roads. It was recommended that only crashes associated with roadway parameters be included. The main focus of using crash data would be to identify common roadway factors involved in crashes. Also, locations with multiple crashes (black spots) should be evaluated to see if any roadway deficiencies exist.

Another important focus group recommendation was that classification schemes would benefit the safety improvement program. Classification by traffic volumes and driver expectancy were rated highest. Other important classifications were based on user types (which also indirectly addresses driver expectancy), access to the road (number of driveways and intersections), and surface types (gravel, earth, primitive). It was pointed out that well defined classification schemes would help make the procedure uniform between agencies. This, in turn, would help establish the procedure's legal credibility.

The last section of the survey asked the focus group to rate the importance of various elements associated with unpaved road safety. Contained in Table 4.7 are the ranking of safety elements in descending order. Comments from the focus group indicated that the most important elements are those that deal with keeping the vehicle on the road.

Table 4.7, Ranking of Safety Elements for Unpaved Roads

Rank	Safety Related Element
1	Road Surface Width, Signage
2	Consistency, Sight Distance, Surface Condition
3	Horizontal Curves, Operating Speed, Large Trucks
4	Bridges, Railroad Crossings, Vertical Curves
5	Foreslope
6	Clear Zone, Pedestrians, Bicycles
7	Culverts
8	Cattle Guards, Dust Condition, Grades, Guardrails, Superelevation, Recreational Vehicles
9	Environmental Conditions, Livestock, Wildlife, Local v. Tourist User
10	Access Type, Links Higher Road Types
11	Lighting
12	Backslope

4.3 Summary of First Round Delphi Survey

The primary purpose of the initial Delphi survey was to examine issues for an unpaved road safety improvement program. The secondary purpose was to develop, test, and refine the Delphi survey methodology. Overall, the results of the first round Delphi survey were extremely promising. There was strong agreement among the respondents.

The survey proved to be an effective tool in formulating policy procedures for local LVR unpaved roads. Important findings from the survey included:

1. Output from the safety improvement program should be in the form of a group index versus an item-by-item prioritization.
2. The safety analysis should be conducted on a section-by-section basis.
3. Incremental improvements should be encouraged on local LVR unpaved roads. A change in policy and practice concerning incremental improvements to unpaved roads is needed.
4. Crash data should be included in the safety improvement program to check for high frequency crash locations and to identify the processes by which crashes are occurring.
5. Roadway classification by traffic volume and user expectation was recommended.

The next step of this research project was to use these findings to develop a prototype safety improvement program. The prototype was presented to the focus group again using a Delphi survey.

4.4 Development of the Prototype Unpaved Road Safety Improvement Program

The second round survey also had a 62 percent return rate (10 surveys). There was again strong agreement in the focus group responses. The prototype SIP developed through the second round Delphi survey encourages systematic and uniform application. The prototype contains five separate steps:

1. system-wide prioritization of unpaved roads,
2. identification of safety improvements on individual road sections,
3. prioritization of safety improvements,

4. scheduling and implementing safety improvements, and
5. program evaluation and update process.

This research defined each of the five steps and developed procedures for carrying out the first two steps. The program represents suggested minimum analysis required to make safety improvement decisions for unpaved roads. Individual agencies will ultimately have the responsibility of identifying special situations, which require more rigorous engineering studies.

In this research the term "local safety coordinator" refers to the person at a local agency who is responsible for managing a SIP. In most cases this would be the county engineer, road superintendent, or other knowledgeable road agency employee.

4.4.1 System-wide Prioritization of Unpaved Roads

It is generally accepted that local road agencies do not have adequate resources to simultaneously address safety improvements on all of their unpaved roads. Therefore, the first step of the SIP is to prioritize unpaved roads on a system-wide basis. The goal of the prioritization process is to identify roads with the largest potential safety benefit. Some degree of professional judgment is required during this step to eliminate the need for costly and time consuming formal road inventory and data collection procedures.

A current map showing an agency's roads is useful for the prioritization procedure. First, road sections are identified that begin and end at natural break points, such as major intersections. Each unpaved road section receives a primary rating factor determined by traffic volume and user types. The primary rating factor is then modified by using adjustment factors. Adjustment factors account for other safety elements that should not be overlooked. The final adjusted rating factors are then used to prioritize the unpaved roads for further safety analysis.

The rating concept for both the primary rating and adjustment factor elements is based on a relative evaluation of unpaved road sections in each particular local jurisdiction. A detailed data collection effort is not proposed. Instead, each element is subjectively rated as either high or low, relative to other unpaved road sections in the jurisdiction. If the safety coordinator is uncertain of the high or low rating, the attribute is rated as average.

The matrix format shown in Table 4.8 simplifies selection of a primary rating factor. A local safety coordinator first ranks traffic volumes and user groups using personal knowledge. For this matrix, local users are defined as motorists who use the road on a regular basis. They are familiar with short term changes that occur in the road's characteristics. Recreational users are defined as non-local, in-state motorists who use the road on an infrequent basis. Some are probably first time users. Recreational users generally are not familiar with the present condition of the road. In-state drivers are probably familiar with similar roads and may use previously-developed expectations to navigate the road. These users often are driving sport utility or recreational vehicles and may be pulling trailers. Tourists are defined as out-of-state users who are not familiar with the road's present condition. Often they are first time users. They also may be driving sport utility or recreational vehicles.

Table 4.8 is entered at the corresponding levels and the primary rating factor determined. It is possible for this step of the procedure to be converted from subjective evaluation to objective evaluation by using actual volume and user-type data when available.

Each level of rating in the matrix is represented by an alpha character. An "A" road section will be evaluated last since the users primarily are local and the road has low traffic volume. Each subsequent alpha numeral represents a road section with greater need to be evaluated.

Table 4.8, Unpaved Road Primary Rating Factors

User Types (Users consist mainly of)	**Traffic Volume** (based on subjective evaluation)		
	Low	**Average**	**High**
Local	A	B	C
Local + Recreation	B	C	D
Local + Recreation + Tourist	C	D	E

The focus group was in general agreement with the primary rating procedure. Eight out of 10 respondents agreed with the selection of user types and traffic volumes to determine primary ratings. Some respondents preferred a fewer number of rating levels, such as "A, B, C." One respondent suggested that terrain (mountainous, rolling, level) should be used instead of user types. There also was discussion about types of users. User type recommendations included agricultural equipment and commercial users. These recommendations were incorporated into the following adjustment factor procedure.

The adjustment factors (Table 4.9) account for elements that also are important to stratifying the road sections. Operating speed has a potential influence on crash rates and severity. Large variability in operating speed indicates conditions are present that potentially violate driver expectancy. An example is a relatively low speed curve at the end of a higher speed tangent. High operating speeds generally also increase the severity of crashes. Therefore, road sections with a high variability in speed and/or relatively high operating speeds need special consideration. A high percentage of heavy vehicles also influence safety. Heavy vehicles often are wide, large, and moving at different speeds than passenger cars. They tend to disrupt normal traffic operation and often create additional safety problems, such as severe rutting and dust. A high percentage of heavy vehicles usually occurs when commercial operations such as logging, mining, oil fields, or agriculture are nearby. Road sections used for these purposes need special consideration. The immediate terrain influences safety on road sections. Roads in mountainous terrain often have steep side slopes, drop-offs, and poorer sight distances. These roads often have no shoulders or clear zones. Rolling and level terrain present decreasing hazard potentials.

Each road section is checked for the presence of rating adjustment elements. The primary rating factor is then adjusted up or down accordingly. If road sections have seasonal fluctuations for any of the rating elements present, the local road safety coordinator must decide under which conditions to evaluate the road.

The adjustment factors shown in Table 4.9 represent only one possible scheme. Several focus group members indicated a need to develop weighted adjustment factors.

Table 4.9, Rating Adjustment Factors for Unpaved Roads

Element	**Levels of Ranking** (based on subjective evaluation)	**Rating Adjustment Factor**
Operating Speed	High and/or Large Variation in Speed	Move down 1 Class
	Average	Neutral
	Low	Move up 1 Class
Heavy Vehicles	High (Logging, Mining, Agriculture, etc.)	Move down 1 Class
	Average	Neutral
	Low	Move up 1 Class
Terrain	Mountainous	Move down 1 Class
	Rolling	Neutral
	Level	Move up 1 Class

As presented, all of the rating factors have equal weight. Alternatives are to reduce the adjustment factor weights, or to limit the number of adjustments made to each road section. Additional input from the focus group is needed to establish a practical weighting system for the adjustment factors.

Using this procedure, the lowest priority rating attainable is an "A" road and the highest priority is an "E" road. This rating scheme hierarchy is similar to the "Level of Service" ratings used in the Highway Capacity Manual (HCM) [48]. Like the HCM, an "A" road represents a more desirable classification, and an "E" road represents a less desirable classification. Here, an "E" road would be the highest priority road in the safety improvement program.

The entire rating procedure takes only a few minutes for each road section. In this manner, all of the road sections in a local agency's jurisdiction are given a priority rating in a short time.

4.4.2 Safety Needs Identification Process

The second step in the SIP is to identify specific safety improvement needs on road sections. The identification process is carried out according to the system-wide prioritization (E road sections should be analyzed first). The approach evaluated was to use a mail-out safety survey of local road users to assist in collecting recommended safety improvement needs (see Appendix D). This type of procedure is economical for the limited budgets of local unpaved road agencies.

It is assumed that readily identifiable safety needs exist on local unpaved roads. Also evaluated was the hypothesis that formal engineering studies were not necessary to identify a large percentage of the safety problems present. Instead, through a partnership with local road users who are directly concerned with safety on "their" particular roads, input is gained concerning needed safety improvements.

There are several distinct advantages of involving local road users in the safety needs survey procedure. First, regular users are familiar with areas of the road that present problems for them. They drive the roads often, and under various conditions. People who live near the road also may be aware of accidents that occur, but are never reported. Second, the local property owner continuously is observing the road condition and may have good maintenance and safety ideas that should not be overlooked [41].

Third, by involving road users, and opening a line of communication, road agencies demonstrate that they genuinely are concerned with safety conditions on local roads. By including local road users in the safety survey process, the agency gains not only information, but also fosters "partnership" ties to the community. With a general increasing demand in the accountability of government road agencies, public involvement on road projects is critical [49]. The National Association of County Engineers recommends gaining public support for local roadway safety improvement programs to ensure overall success [41]. Fourth, it is potentially an accurate and cost effective method of identifying safety needs [39].

Nine out of 10 focus group members agreed with the concept of involving road users in the identification of safety needs. Comments included:

- Town meeting or public input meeting could also be utilized.
- Looks Good.
- Good Idea.
- Communication is needed for information (exchange) and to eliminate confrontation.
- Only for input. Final decisions need to be left to professionals.
- We have too much of that right now. In many cases it becomes very political.

Often property owners feel that their roads deserve more attention and that the local agency is not adequately attending to their unpaved road maintenance needs. They also are probably unaware of the limited budgets and manpower of local agencies. Partnering is a potential means of making the public aware of such limitations, and winning their political support.

Potential user groups to receive the safety needs survey typically include:

- property owners and residents (residential, agricultural, summer homes and cabins),
- route drivers (school bus, mail carriers, parcel delivery service),
- sheriff's deputies and emergency personnel, and
- road and bridge personnel.

Local sheriff personnel investigate accidents and also patrol unpaved roads. Their input is needed. Close ties to law enforcement enhances notification of serious accidents. All serious accidents should be closely reviewed by the local safety coordinator for any possible connections to roadway features [41].

Road agency maintenance and office personnel also should be trained and encouraged to recognize potential safety needs on unpaved roads. As one focus group member pointed out, an added benefit of an SIP is its ability to identify maintenance problems at no extra cost. For example, recurring areas of washboarding are a safety concern and a maintenance problem. It may be possible to employ countermeasures such as chemical stabilization, which will improve safety and reduce maintenance at the same time.

After the user groups have been surveyed and safety improvement needs identified, the road agency's safety coordinator creates an improvement list for each road section. The safety coordinator has the task of assimilating all of the users' suggestions and determining those that are primary safety concerns.

The safety coordinator also includes safety improvements that have been identified through other means. Possible locations where roadway safety improvements typically are needed are gained from crash records, direct observations by road agency employees, operational problems, suggestions from other public officials, and complaints from the public. These sources provide low cost input for a safety needs survey. The safety improvement suggestions are recorded and merged with the user groups' to create the final safety improvement project list.

When asked to recommend a time schedule in which the safety needs identification process should be completed for all unpaved roads, the focus group did not reach a consensus. It is suggested here that the identification process be carried out beginning on the highest priority roads first. Each agency must establish an appropriate evaluation and re-evaluation time period. The time period selected should consider local factors such as available funding, rate of change of the roadway environment (including safety improvements made), and changes in the use of the roadway.

4.4.3 Prioritization of Safety Improvements

After the final safety improvement project list is completed, an agency's safety coordinator prioritizes the improvements. A standardized procedure for prioritizing improvements must be developed. Several questions in the second round Delphi survey addressed the policy issue of how to prioritize safety improvements. Several focus group members did not feel it was acceptable for improvements to be made only to the highest priority roads. The following are typical of the comments received:

- There may be a time when very small repairs could be done on roads with a lower priority while waiting on materials or weather or other reasons on a higher priority road.

- I feel benefit/cost has to be considered. We maybe able to save two lives for an expenditure of $100 on a low priority road, or one life for $1,000 on a high priority road. For this reason, I think some flexibility should remain for the safety coordinator.
- I am in favor of prioritizing road sections, but I think it is unreasonable to put aside smaller, less expensive repairs while focusing on a larger problem.
- There will need to be flexibility in the system because each county may have different goals and priorities, not to mention different conditions and users.

Several issues must be considered in the prioritization procedure. First, a safety program has to start with a sound basic procedure. A systematic procedure of safety improvement that is not data or resource intensive is proposed. Second, until higher priority roads are surveyed and safety needs identified, addressing needs on lower priority roads is difficult. Third, determining all safety improvements needed for all road sections is beyond the resources of most agencies.

4.4.4 Scheduling and Implementing Safety Improvements

The next step involves scheduling and implementing safety improvements. A number of considerations need to be made. Funding for safety specific improvements, as well as routine maintenance and special projects is often included in the total roadway budget. Funding for the safety improvements must have flexibility to allow for outside influences such as emergency repairs, unexpected weather trends, special events, unexpected changes in use and other unforeseen circumstances.

Safety improvements are scheduled to maximize the safety benefit per cost ratio. As in the other parts of the SIP, professional judgment is needed to avoid many of the in-depth, paved, high volume road procedures.

4.4.5 Program Evaluation and Update

The final step in the SIP is to conduct an evaluation of the program's effectiveness. This is important and necessary for long term success. A dynamic program is needed to accommodate changes that occur in unpaved road networks.

4.5 Evaluation of Proposed SIP Procedures

The final part of this research project tested the procedures for carrying out steps 1 and 2 of the unpaved road SIP. A pilot unpaved road user safety survey was designed and tested. Data gathered from this survey then was used to conduct a case study on four unpaved road sections.

4.5.1 Pilot Unpaved Road User Safety Survey

The feasibility of involving local road users in the safety improvement needs identification process was tested in Albany County Wyoming. Residents, land owners, and county road and bridge personnel were surveyed regarding four specific unpaved road sections. Albany County sheriff's deputies and UPS drivers were surveyed for all unpaved county roads. Names of property owners were obtained from the Albany County Clerk's Office. County road and bridge personnel identified additional residents along the road sections. A list of names also was supplied by property owners on the study roads who had formed a land owners special interest group. Sheriff's deputies and UPS drivers were contacted directly through their employers. Each individual was provided a survey form that was tailored to their user group. Each survey contained 18 questions.

The first block of questions established the users' background and their use of the road. Included were the number of years used, miles traveled per week, and purpose of travel on the road. The second block of questions asked users to rate smoothness, surface condition, and overall safety. The remainder of the survey was directed to specific safety issues. Respondents were asked to identify specific safety improvements as well as general improvements.

Each survey group also was asked to prioritize 13 unpaved road safety elements. The question stated, "Knowing that county budgets are limited and that all improvements can not be made at once, please rate the following items..." The results of their ranking are presented in Table 4.10. A complete listing of improvements suggested by respondents are included in Appendix E.

Table 4.10, Road User Safety Improvement Priority List

Priority	Roadway Element
1	Remove Washboarding
2	Add Gravel
3	Improve Curves Add Snow Fence
4	Add Warning Signs
5	Improve Cattleguards
6	Widen Roads
7	Add Delineation on Curves
8	Flatten Steep Shoulders
9	Improve Bridges and Culverts
10	Remove Roadside Objects
11	Improve Railroad Crossings
12	Add Guardrail

The number one element chosen by the user groups, "remove washboarding," probably indicates a ride smoothness concern. On the other hand, removing washboard surfaces to increase safety does have validity. When crash reports were examined for 13 crashes, which occurred on the Albany County case study roads, it was found that two specifically mentioned washboard surfaces as a contributing factor.

The survey also revealed that although the users were unhappy with the present condition of their roads, they still believed that most crashes were the fault of drivers. The responses ran 5 to 1 for placing the blame of crashes on the driver. On a related question, road users were asked if they thought that more warning signs would reduce the number of crashes. Here again, the majority felt that more signs would not reduce crashes. One respondent pointed out that due to vandalism, traffic signs are hard to keep in place on county roads.

All road survey recipients were asked to evaluate the relative safety of interstate highways, two-lane paved highways, and unpaved roads. Results indicated that most recipients believe unpaved roads are relatively safe. The crash rate analysis completed as part of this research showed the crash rate per vehicle miles traveled on unpaved roads is actually much higher than on other roads. Only the UPS drivers indicated a higher safety concern for unpaved roads.

4.5.2 Safety Improvement Program Case Study

The case study tested the proposed road prioritization and the safety needs identification procedures of the SIP. Fifty-five user surveys were returned for four unpaved road sections. These four road sections had received a large number of citizen complaints and were selected after discussions with the Albany County Road and Bridge Superintendent. Respondents included land owners, residents, and county road and bridge employees. Sheriff deputies, and UPS drivers did not provide responses to these specific road sections. A safety needs study based on engineering principles also was completed for each road section, which assisted in evaluating the accuracy and usefulness of the user surveys.

4.5.3 Fox Creek Road, No. 47

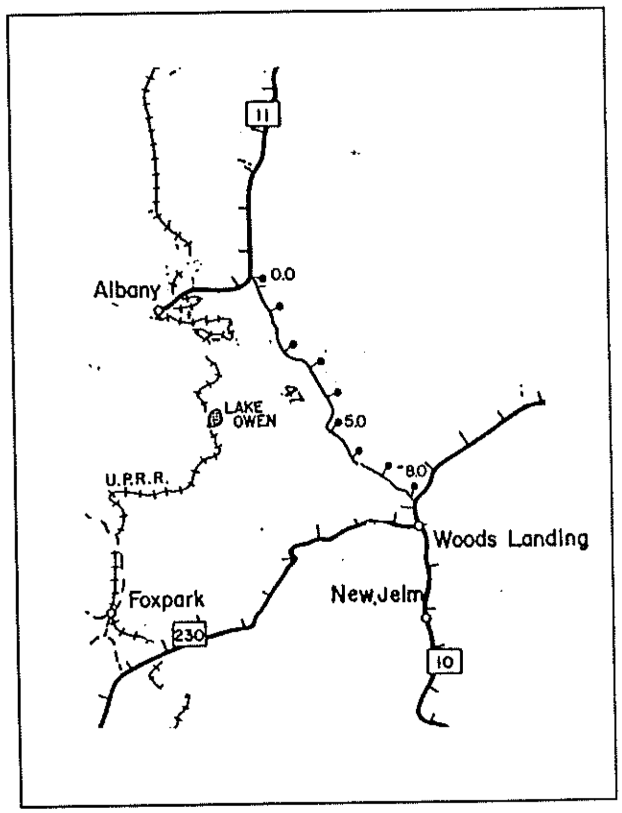
Albany County road No. 47 is an eight-mile-long section of earth and gravel road. It is located about 25 miles west of Laramie, Wy. and provides access to several Albany County residences, as well as to portions of the Medicine Bow National Forest. Fox Creek Road provides a direct route between two small recreational towns, Albany and Woods Landing (see Figure 4.1). The alignment varies from curves with poor sight distance, to straight rolling sections with good sight distance. Both ends of the road terminate at paved state highways. There are several cattleguards on the road section. Summary characteristics of the Fox Creek Road were:

- high traffic volume
- local + recreational users
- average and relatively consistent operating speed

- low number of heavy vehicles
- mountainous terrain

Using Table 4.8 and considering the traffic volume and user types, the primary rating factor was "D." Using Table 4.9 to rate the remaining elements it was found that: Average operating speed has a neutral effect. A low number of heavy vehicles adjusted the road to a "C" rating. The mountainous terrain moved the road down one rating, resulting in a final priority rating of "D."

Figure 4.1, Fox Creek Road, No. 47 [50]



The safety needs list created using input from the road user safety surveys was as follows:

- Add gravel to provide traction when wet (identified by eight respondents).
- Widen cattleguards (identified by six respondents).
- Improve sharp curves - increase sight distance (identified by five respondents).
- Remedy washboarding (identified by four respondents).
- Install snow fence (identified by four respondents).
- Install "slow" signs at each end (identified by one respondents).
- Remove large rocks from the clear zone (identified by one respondent).
- Widen entire road (identified by one respondent).

The engineering studies all were completed during daylight hours and good weather conditions. Traffic volumes and user types were considered. Safety needs identified for Fox Creek Road were:

- Widen cattleguards to roadway width or use positive guidance techniques to match the road surface width to each cattleguard.
- Eliminate abrupt changes in vertical alignment at cattle guards to reduce formation of washboard surfaces on approaches.
- On curves with poor sight distance: 1) Remove vegetation where possible to increase sight distance. 2) Widen road surface where sight distance can not be improved.
- Eliminate intermittent washboard surface.
- Round hinge point between road surface and shoulder.

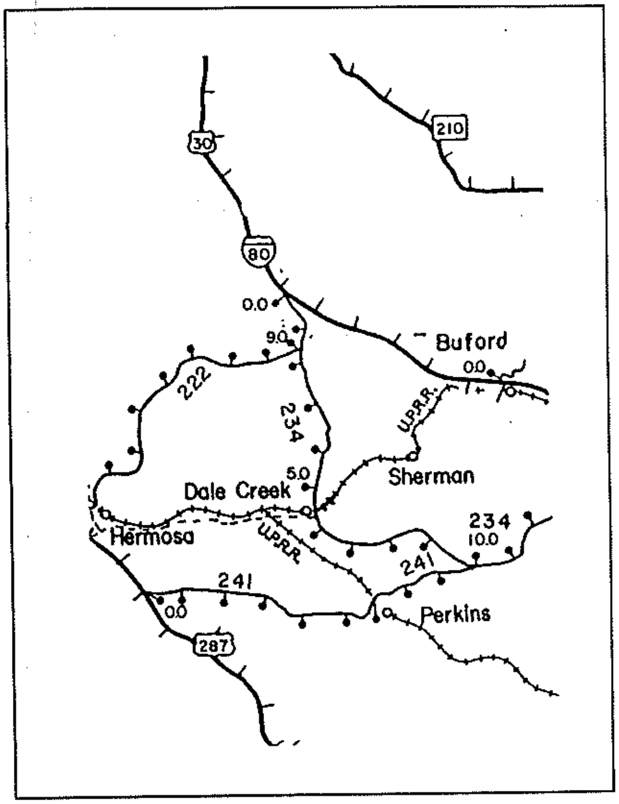
For this road section, the user safety needs survey identified most of the same elements as the engineering study. The safety survey list contains two additional weather-related elements, (add snow fence and add gravel to slick spots), which were not detected by the engineering study. A suggestion also was made to install "slow" signs at each end. The engineering study identified two additional elements: abrupt changes in vertical alignment at cattleguards and round shoulder hinge point. For this road section, the user safety needs survey was found to be accurate and useful.

4.5.4 Monument Road, No. 234, I-80 to Intersection with County Road No. 222

A 1.6 mile section of Albany County road 234 carries through traffic to several subdivisions, a few ranching operations, and is used by Union Pacific railroad maintenance vehicles. Monument Road also provides direct access to a state monument frequented by recreational and tourist visitors. The north end of the road section connects to Interstate 80, about 16 miles east of Laramie Wyoming (see Figure 4.2). The south end of the section terminates at County Road 222 near Ames Monument. Alignment varies from straight and level to curved and rolling. There are several cattleguards on the section. Characteristics of the road section were:

- high traffic volume
- local + recreational + tourist users
- high operating speed
- average number of heavy vehicles
- rolling terrain

Figure 4.2, Monument Road, No. 234 [50]



Using Table 4.8 and Table 4.9 to evaluate these elements, an "E" road priority rating was determined. Therefore, this road section had the highest priority in the SIP. The following safety needs list was made using input from the unpaved road user safety survey.

- <u>Remove washboarding and improve surface</u> (identified by 12 respondents).
- <u>Reduce and enforce</u> <u>speed limit</u> (identified by four respondents).
- <u>Remove unused cattleguard</u> (identified by one respondent).
- <u>Install snow fence</u> (identified by three respondents).

The engineering study identified the following safety needs:

- Improve the surface transition (at the beginning) between the adjacent paved highway, the cattleguard, and the unpaved section. Vehicles leave the pavement, cross the cattleguard, and enter the unpaved section at a high rate of speed, necessitating a smooth transition (this is a previous accident location).

- Remove unused cattleguard (this is a previous accident location).
- Eliminate intermittent washboard surface.
- Round hinge point between road surface and shoulder.
- Eliminate abrupt changes in vertical alignment at cattle guards.

For this road section, the user survey and the engineering study identified most of the same needs. Again, the user survey identified a weather-related need, "snow fence." The engineering study identified an additional improvement need based on an accident location. The transition from the paved to unpaved section has the potential to violate unfamiliar drivers' expectations. In addition, the engineering study identified "round hinge point, and vertical alignment at cattleguards." For this road section the two needs identification procedures again overlapped, and both contained items not included in the other.

4.5.5 Monument Road, No. 234, Ames Monument to 10 Mile Marker

An 8.4 mile section of County road 234 provides access to several subdivisions, a few ranches, and also is used by Union Pacific railroad maintenance vehicles. The road section begins at its intersection with County road 222 and proceeds south to its intersection with County road 241 (see previous Figure 4.2). The road surface varies between decomposed granite and earth. The terrain is mostly rolling with a few level sections on the south end. Characteristics of this road section were:

- low traffic volume
- local users
- average operating speed
- rolling terrain
- low number of heavy vehicles

From Table 4.8, the primary rating factor was "A." From Table 4.9, the average operating speed and rolling terrain did not change the rating. A low number of heavy vehicles normally would move the rating factor up one class. However, this road already has the lowest priority rating possible, so its final priority rating remains at "A." In the SIP, this road section has a low priority for identifying and evaluating safety improvement needs. Initially, this road would not be evaluated based on the proposed procedure. However, users identified these improvement needs for this section:

- Remove washboarding and improve surface (identified by 12 respondents).
- Improve curve south of communications tower approximately 2 miles north of rail road crossing (identified by five respondents).
- Improve snow control (identified by four respondents).
- Add warning signs (identified by three respondents).
- Improve curve immediately south of rail road crossing (identified by one respondent as an accident site).
- Curve on hill south of Williams' house (identified by one respondent)

The engineering study identified the following needs:

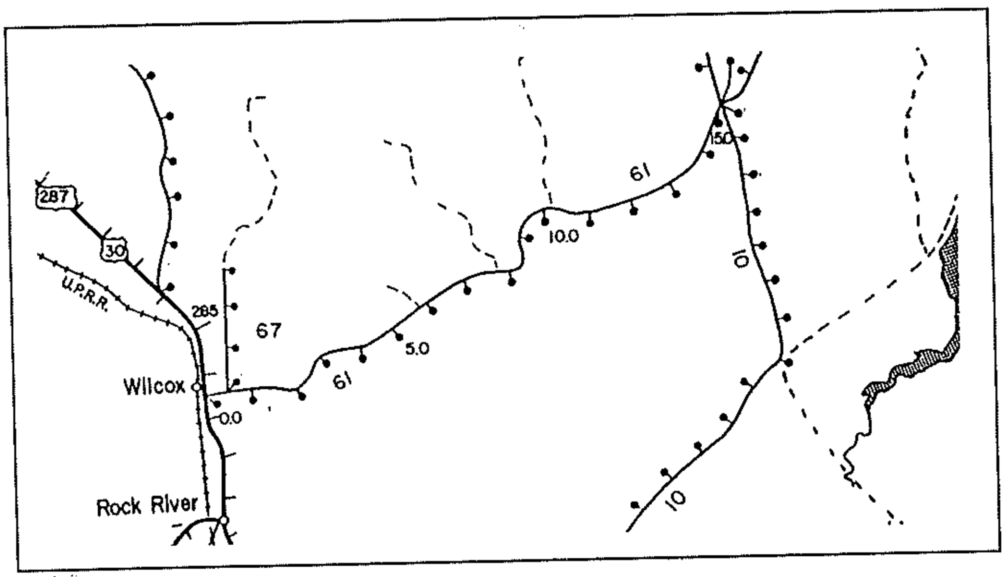
- Provide advanced warning for curve just south of Williams' Ranch. This curve is at the end of a relatively tangent section when traveling north. It combines a vertical and horizontal curve with poor sight distance. It has potential to violate unfamiliar drivers' expectations when traveling north.
- Improve alignment at curve south of communications tower (3.5 mile accident site)
- Eliminate intermittent washboard surface.
- Round hinge point between road surface and shoulder.
- Eliminate abrupt changes in vertical alignment at cattle guards.

Again the user group needs and the engineering needs overlap with some differences. The user safety survey identified two curves as accident locations in need of improvement. The engineering study identified one of these locations from crash records. The other curve was not identified in the engineering study. The engineering study identified one location that has a high potential to violate driver expectancy. One respondent also identified this location. The user safety needs survey identified most of the critical needs for this section.

4.5.6 Fetterman Road, No. 61, from U.S. 30 to 15 Mile Marker

Albany County Road 61 is located 42 miles north of Laramie Wyoming. The 15 mile section begins at U.S. 30 and proceeds to the east (see Figure 4.3). It

Figure 4.3, Fetterman Road, No. 61 [50]



provides access to a few residents in the first mile and several ranching operations along its length. It also carries through traffic for ranches in the northern part of the county and to parts of the Medicine Bow National Forest. During certain times of the year increased traffic from cattle trucks is common. The road surface varies from gravel to natural earth and the alignment is mostly straight. There is one relatively sharp 90° corner where vehicles have left the road in the past. Characteristics of the road section were:

- average traffic volume
- local + recreational users
- high and variable operating speed
- high number of heavy vehicles
- level terrain

From Table 4.8, the primary rating factor is "C." Using Table 4.9, the adjustment factors were determined. The high operating speed and high number of heavy vehicles each adjusted the primary rating down one classification. The level terrain adjusts the rating up one classification. Combined, the adjustment factors move the rating down one classification for a final rating of "D." The user identified needs list for this road section included:

- Improve sharp curve by Rock Creek (identified by four respondents).
- Add gravel (identified by five respondents).
- Add warning signs (identified by three respondents).
- Improve road surface (identified by three respondents).

The engineering study identified the following needs:

- Improve alignment, road surface, and/or provide advanced warning on curve located at Rock Creek. This is a relatively sharp 90° degree curve preceded in both directions by tangent sections. The curve is on a slight incline and the surface tends to washboard. This is an accident location that has the potential to violate drivers' expectations.
- Eliminate intermittent washboard surface.
- Round hinge point between road surface and shoulder.
- Eliminate abrupt changes in vertical alignment at cattleguards.

The user safety survey again identified most of the same needs as the engineering study. As for all sections tested, the users did not identify the shoulder hinge point or the vertical alignment at cattleguards. The users did identify the crash based location for the curve at Rock Creek.

The case study completed here demonstrates the feasibility of key procedures in the safety improvement program. The road prioritization process indicated that of the four road sections analyzed, one was high priority ("E" rating), two were secondary ("D" ratings), and one was low priority ("A" rating). These ratings encompass the upper and lower bounds of the rating scale. The procedure, as proposed, assigns equal weight to user types, traffic volumes, operating speed, heavy vehicles, and terrain. Using variable weighting of factors should be investigated as an alternative. The primary need is to develop a systematic, defensible procedure.

The safety survey forms proved to be a feasible means of gathering information from the road users. The surveys were structured using multiple choice, rating and ranking scales, short answers, and comment sections. The surveys elicited slightly more than a 50 percent return rate among the property owners (30 out of 58). This is generally considered a good return rate for mail-out surveys. The county-wide survey format used for the sheriff's deputies and UPS drivers was not as effective as the road specific survey used for the other recipients.

Overall, the road users were not satisfied with unpaved road characteristics such as smoothness and rideability. When asked for specific safety improvements, survey respondents were quite articulate. The following are typical examples of their responses:

- Bad curve coming out of section 7 south of tower should have curve sign and maybe slow sign. Had two or three wrecks in last few years.
- Quite a few people have missed the curve and hit the fence just south of the railroad tracks.
- Do something to improve the washboarding - it's hard to keep the car on the road.
- Clear brush before curves.
- Improve corner at cattleguard from section 18 to section 19. Corner shouldn't be so sharp. Would prevent accidents.

The user safety needs survey successfully matched most of the specific needs identified in the abbreviated engineering study. The users were able to identify additional safety needs based on their familiarity with the roadway environment, and their knowledge of unofficially reported crashes. Overall, the user identified needs were accurate. The following chapter contains the summary, conclusions, and recommendations for the unpaved road safety improvement program.

Chapter 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

This research addressed the need for a safety improvement program designed specifically for local LVR unpaved roads. Implementing traditional SIPs on unpaved road networks is often beyond the economic means of local road agencies. As a result, many of these agencies do not have safety improvement programs. The primary objective of this research was to develop and test a suitable SIP for local unpaved roads. A literature review of current SIPs found no models available specifically for unpaved roads. This necessitated complete development of the SIP structure. To meet this need in a justifiable manner, a focus group consisting of unpaved road experts and professionals was formed. Focus group members represented the Federal Highway Administration, Wyoming Department of Transportation, Wyoming Association of County Engineers and Road Superintendents, Wyoming County Commissioners Association, and regional universities. Input from the focus group was gained through the use of a modified Delphi procedure. Additional input was gained from a crash and user data study. Using this input, the following five step program was developed:

1. system-wide prioritization of unpaved roads,

2. identification of safety improvements on individual road sections,
3. prioritization of safety improvements,
4. scheduling and implementing safety improvements, and
5. program evaluation and update process.

The recommended program is simple to use and cost effective. A primary assessment of candidate unpaved road sections using traffic volume and types of users is recommended. Modification factors account for high speed and speed variations, high percentage of heavy vehicles, and terrain type.

5.2 Conclusions

The following conclusions are made for this research project.

1. Many local road agencies do not have a safety improvement program for unpaved roads.
2. Development of a safety improvement program for unpaved roads must recognize limited local funding.
3. The case study demonstrated that crash data and road user assessments are useful in identifying safety needs for unpaved roads.
4. Changing current policy and practice to prioritize unpaved roads for evaluating safety needs is recommended.

5.3 Recommendations

This section presents recommendations for additional research concerning safety improvements on unpaved roads.

1. Further research is needed to establish "weights" for adjustment factors used in the road prioritization process. As developed and demonstrated in this project, all rating factors were weighted equally.
2. Safety benefit tables must be developed for safety improvements on unpaved roads. This will greatly enhance the local safety coordinators' ability to prioritize safety improvements. Such tables should reflect the benefits obtainable from incremental safety improvements to elements such as road cross section geometry, alignment, road surface condition, cattleguards, etc.
3. Studies that determine if the absence of washboard road surfaces improve safety are recommended. Each of the road user groups surveyed ranked washboard surfaces as a high priority safety improvement. WYDOT crash reports also mentioned washboard surfaces. One Albany County deputy stated, "Washboard roads need more attention. I have investigated numerous roll-overs due to loss of control on these roads."
4. After the prototype SIP is out of its development stage, it is recommended that field tests of the procedures be conducted by several local agencies.

5. It is recommended that local agencies adopt, on a regional basis, uniform policies concerning safety improvement programs. Hopefully, by adopting uniform policies, favorable legal precedence will be established.

APPENDIX A

Wyoming Accident Reporting System Data Fields used in Analysis of Selected Wyoming Unpaved Roads

WARS Data Fields

	Field Name
1	County Road Number
2	Milepost Marker
3	Accident Report Number
4	Accident Date
5	Vehicle Body Type
6	Visual Obstructions Present
7	Driver's Activity Immediately Prior to Accident
8	Driver's Age
9	Driver's Sex
10	Driver's Proximity to Their Home
11	Driver's License State
12	Driver's License Status
13	Roadway Element Contributing to Accident
14	Accident Day of Week
15	Accident Time of Day
16	Number of Persons Injured
17	Number of Persons Killed
18	Was Accident Investigated at the Scene
19	Road Surface Type
20	Road Conditions (weather related)
21	Road Alignment
22	Traffic Control Devices Present
23	First Harmful Event
24	Adverse Road Conditions
25	Collision Type
26	First Contributing Factor
27	Speed Limit
28	Estimated Crash Speed

APPENDIX B

First Round Delphi Survey Questionnaire
and
Summary Results

NOTE: Survey Respondents' comments are typed in **ALL CAPS.**

Question #1

What is the desired output format for an unpaved road safety audit procedure?

The following four choices were ranked.

A) Priority ranking of safety defects, item by item.
B) Classification of safety defects by severity group index
C) Classification of safety defects by relative severity
D) Classification of safety defects by cost index

Question #1 Ranking Results

1. Severity Group Index
2. Relative Severity
3. Item by Item
4. Cost Index

Of the four choices, "B) **Classification of safety defects by severity group index**" was the overall favorable choice.

Respondents were generally confident to highly confident in their answers. Only two respondents were neutral in their confidence. The same results are obtained without including their responses. Therefore, respondents self-confidence is not considered an influencing factor for this question.

Several respondents indicated the need for combinations or variations of the four original schemes.

- "COST + SEVERITY OR SAFETY INDEX + ACCIDENT INVOLVEMENT
- USE A WEIGHTED AVERAGE THAT INCLUDES SAFETY DEFECTS, ADT, USES SCHOOL BUS ROUTE"

Comments:

◊ "IT MAY BE WORTH WHILE TO REVIEW SAFETY DEFECTS AND A WEIGHTED PRIORITY INDEX SIMULTANEOUSLY SO THAT A SERIOUS

DEFECT IS NOT OVERLOOKED BECAUSE OF A LOW TRAFFIC COUNT OR OTHER FACTORS.

◊ CLASSIFICATION BY COST INDEX SHOULD BE INCLUDED IN ALL METHODS. EXTREMELY COSTLY AND DANGEROUS SITUATIONS NEED TO BE IDENTIFIED AND THEN THE AGENCY NEEDS TO FIND WAY TO FUND THE FIX. HOWEVER, BY NOT FIXING A PROBLEM ONLY BECAUSE MONEY ISN'T AVAILABLE MAY BE A PROBLEM IN COURT.
◊ HOWEVER THE DEFECTS ARE PRIORITIZED THERE ARE MANY THINGS THAT CAN CHANGE THOSE PRIORITIES (BUDGET, WEATHER, PUBLIC COMPLAINTS, ETC.) WHAT I HAVE SEEN IS THAT PRIORITIES CAN CHANGE VERY QUICK.
◊ DEFECTS MAKES ME VERY NERVOUS! IS A ROAD WITH A SINGLE "DEFECT" A 'DEFECTIVE ROAD?' PLAINTIFFS LAWYERS WOULD LOVE THAT- ISN'T 'DEFICIENCIES', 'ACCIDENT POTENTIAL', OR 'HAZARD POTENTIAL' ---BETTER?
◊ THE OUTPUT FORMAT SHOULD BE A COMBINATION OF THE ABOVE OPTIONS. IT SHOULD BE A PRIORITY RANKING OF SAFETY DEFECTS BY SEVERITY GROUP AND COST INDEX. I ALSO BELIEVE THAT TRAFFIC VOLUME AND USER TYPE SHOULD BE CONSIDERED."

Comments on Individual Schemes (Respondents' comments are in ALL CAPS)

A) Priority ranking of safety defects, item by item. Each safety defect identified would be assigned an individual safety index number representing a composite of a variety of site specific measurements or indexes. (Please make any additions or comments anywhere on these pages as you work through the survey)

Advantages	Disadvantages
• Each safety defect would be prioritized with respect to all safety defects identified. • A prioritized list (by severity) would automatically be produced.	• The level of evaluation detail may be necessarily greater to produce a unique index number. This is a detail that must be addressed if this is your choice of preferred output. If the level of detail is not high enough, then effectively the procedure would be the one described next. If the level of detail is too high, then effectively the procedure is a comprehensive engineering study. • Few choices of which defects to address first could be made by the decision maker. If a high priority defect was skipped over, (for what ever reason,

- $ comes to mind), could this decision be called into question?
- By assigning an index number, it could be implied that some defects would be "severe." This may be undesirable in the liability sense.

◊ IT WOULD BE HARD TO KEEP UP WITH RANKINGS. AS ONE IS REPAIRED ANOTHER MAY COME ON LINE WITH DIFFERENT NEEDS, THEREFORE CHANGING YOUR NUMBERS CONSTANTLY.

◊ TOO MUCH DETAIL WOULD BE PRODUCED.

◊ THIS ASSUMES COSTS ARE NOT A FACTOR - COSTS ARE A BIG, BIG FACTOR!

◊ BIG PROBLEM - HOW TO ARRIVE AT A SAFETY INDEX # ; e.g. WHAT IS THE SAFETY INDEX OF A 15' WIDE ROAD? OF A STOP SIGN THAT VIOLATES DRIVER EXPECTANCY?

B) Classification of safety defects by severity group index. Safety defects would be grouped into one of several levels of severity (CONCERN). For example, groups consisting of A, B, C, D, E where "E" is a group of defects that should receive immediate attention (ARE OF IMMEDIATE CONCERN), and "A" is a group of defects that pose little risk to the public (CONCERN).

Advantages	Disadvantages
• Should make the classification procedure easier due to the limited number of index groups. Each group would cover a broader variety of defects than an individual indexing system, and therefor less detail should be required to facilitate classification. • Because defects within a group are not prioritized, the decision maker would have more lateral choice when picking which defects to address first. ◊ BY HAVING A GROUP INDEX THE TIME FACTOR WOULD BE KEPT TO A MINIMUM, AND WOULD BE EASIER TO COMPARE FROM ROAD TO ROAD. ◊ EASIER TO SELECT A THRU F RATHER THAN ASSIGNING A NUMBER AN NEEDING TO DECIDE BETWEEN, LET'S SAY 2.3 & 2.4, OR 8.2 & 8.4. THIS IS NOT THAT EXACT OF A SCIENCE. ◊ IT WOULD ELIMINATE HAVING TO CHANGE YOUR RANKING SYSTEM AS ONE DEFECT IS FINISHED AND ANOTHER IS PRESENTED	• Wouldn't tell the decision maker which defects within a group are the most severe. • May not provide adequate protection for the agency with respect to legal liability issues because of the broad groupings. For example, if a road manager chose an item to fix out of a group of 10 possible items, and then an accident occurred because of one of the other nine items that were not fixed, would the road manager still have protection in court? Would this system be better than nothing at all? ◊ NEED TO DISCUSS WITH ATTORNEYS, BUT THIS MAY BE DEFENSIBLE BY DISCRETIONARY FUNCTION.

C) Classification of safety defects by relative severity.

Advantages	Disadvantages
• Automatically produces a prioritized list (by severity) of safety defects • Doesn't necessarily imply that any of the defects are extremely dangerous. The road manager can see which of his defects should be addressed first, but doesn't self-incriminate the agency by saying any one particular defect is severe or poses an extreme threat to the public.	• Because of the relativity of the system when items are added or removed from the list, the whole system might have to be re-evaluated. • The logistics of the evaluation would be cumbersome. How could defects in locations all over a county be simultaneously evaluated? This approach may work better for section by section evaluation, where defects on each section are evaluated independently of defects on other sections. ◊ WOULD PUT MORE LIABILITY ON THE ROAD MANAGER.

D) Classification of safety defects by cost index

Advantages	Disadvantages
• Makes budgeting and selection of items within a budget very easy.	• Doesn't consider defect severity (threat to public safety) ◊ IF IT DOESN'T DO THIS, IS IT OF ANY SAFETY HELP?

<u>Question #2</u>

Should the ranking or grouping of roadway safety deficiencies be done on an item basis (agency wide), a roadway section by section basis, or on a item by section basis?

Discussion

A) If ranking is done on an item-by-item basis, then the prioritization output would be on a system-wide scale.
B) If grouping is on a section-by-section basis then each section would be compared to other sections, but specific items would not be automatically prioritized in the section.
C) If done on an item by section basis, the agency's roadway system would be broken into sections first and then safety defects in each section would be prioritized.

Question #2 Results

Respondents ranked the following four choices.

A) item by item, system-wide
B) section by section
C) item by section
D) other:

Ranking Results

1. section by section or item by section (tie)
2. item by item, system-wide
3. Kansas LVR System

Section by section and item by section tied as the most favorable response. Item by item was a close second. Together the two favorite responses indicate the road way should be analyzed by sections.

One respondent wrote in **"The Kansas LVR System."**

Similar ranking results were obtained when examining sub-groups of different self-confidence. Therefore, respondents self-confidence is not considered an influencing factor for this question.

Comments:

◊ "PROJECTS IDEALLY WOULD BE SCHEDULED BASED ON PRIORITY; NOT BASED ON POLITICAL INFLUENCE OR LOCATION.
◊ THIS MAY BEST DEPEND ON THE JURISDICTIONS' HISTORY OF SAFETY MANAGEMENT. HAVE THEY BEEN MAKING SECTION BY SECTION IMPROVEMENTS OR ITEM IMPROVEMENTS? THEY WOULD PROBABLY BE BEST SERVED TO CONTINUE THE SAME APPROACH AS IN THE PAST.
◊ IT SEEMS TO ME THAT WE MUST IDENTIFY THE DEFICIENCIES ON A SYSTEM-WIDE SCALE. I THINK THE TREND WILL BE THAT MOST SEVERE DEFICIENCIES ARE GROUPED, THUS IDENTIFYING SEVERE SECTIONS.
◊ THE KANSAS LOW VOLUME ROAD SYSTEM SHOULD WORK WELL"

Question #3

How many man-hours per quarter are available at a local agency for a safety audit procedure?

Question #3 Results

Respondent	1	2	3	4	5	6	7	8	9	10*	
Self-Confidence	4	2	1	3	1	5	2	5	2	5	Average
January, February, March	500	80	30	20	200	100	24	50	154	-	129
April, May, June	40	80	30	20	0	0	20	24	154	-	41
July, August, September	40	80	10	20	100	0	16	24	154	-	49
October, November, December	40	80	30	20	150	50	16	20	154	-	62
Yearly Total	620	320	100	80	450	150	76	118	616	-	281

*No estimate made. Not included in Average

Estimates vary widely between and within self-confidence groups. Therefore respondents self-confidence is not considered an influencing factor for this question.

This parameter depends heavily on agency size, etc.

Comments:

◊ "IDEALLY A FULL TIME PERSON COULD BE ASSIGNED TO SAFETY RELATED TASKS. HOWEVER, REALISTICALLY WE NEED TO BE CAREFUL THAT WE DON'T SPEND ALL OF OUR RESOURCES IDENTIFYING PROBLEMS AND THEN NOT BE ABLE TO ADDRESS THE PROBLEMS.

◊ I THINK ONE DAY PER MONTH WOULD BE REASONABLE WITH THE EXCEPTION OF THE SUMMER MONTHS AS MOST PROJECTS WOULD BE IN FULL SWING.

◊ AS THE MEN WORK EACH DAY, I KNOW THEY DEVOTE TIME TO SAFETY ISSUES. EXACT HOURS ARE HARD TO RELATE TO.

◊ THE AMOUNT OF TIME WOULD ALL BE GOVERNED BY WEATHER RELATED ACTIVITIES.

◊ THIS COULD BE BETTER IF THERE WERE TWO CATEGORIES, INITIAL AUDIT AND THEN FOLLOW-UPS. I THINK THE INITIAL AUDIT WILL TAKE CONSIDERABLY MORE TIME THAN A FOLLOW-UP.

◊ IN MY DISTRICT THE OPERATORS ARE RESPONSIBLE FOR HIS OWN AREA AND REPORTS THE PROBLEMS TO ME. THEN I PRIORITIZE THE PROBLEMS FROM THEIR REPORTS. EVERY SO OFTEN THE OPERATOR DRIVES HIS AREA TO CHECK FOR PROBLEMS THAT MAY HAVE COME UP SINCE HE HAD BLADED THE ROAD."

Question #4

Are there any immediate monetary benefits for a local agency that would offset the expense of implementing a safety audit procedure?

Question #4 Results

◊ "PROBABLY NO - SINCE 'THERE'S NO FREE LUNCH.' IF THERE ARE SOME ROAD INVENTORIES THAT ARE USUALLY REQUIRED, PERHAPS THEY CAN BE DONE DURING SAFETY AUDIT. SOMEONE FROM LOCAL AGENCIES SHOULD BE DRIVING ROADS REGULARLY -- MAYBE THIS PROCESS CAN BE INCLUDED AT LITTLE EXTRA COST.
◊ ONE COURT CASE WITH ASSESSED DAMAGES AGAINST AN AGENCY CAN OFFSET A LOT OF TIME SPENT ON THE AUDIT. HOWEVER, IMMEDIATE MONETARY BENEFITS SEEM UNLIKELY.
◊ THIS IS AN ACTIVITY THAT MAY RESULT IN AN INSURANCE DISCOUNT.
◊ SOME OF THE SAFETY DEFECTS ARE ALSO HIGH MAINTENANCE AREAS. THERE IS ALSO A SAVINGS FROM A LIABILITY STANDPOINT.
◊ EACH DEPARTMENT CAN BENEFIT FROM A SAFETY AUDIT PROCEDURE WITH TIME SPENT ON ACTIONS NOT REACTIONS.
◊ YES, SAFETY! WHENEVER SAFETY IS AN ISSUE I THINK KNOWING SAFETY PROBLEMS ARE BEING ADDRESSED WOULD OFFSET ANY MONETARY ISSUES, WITHIN REASON.
◊ INCREASED PUBLIC SAFETY -- LIABILITY ISSUES
◊ IF A REASONABLE PRIORITY SYSTEM BASED ON A SAFETY AUDIT CAN BE ESTABLISHED, AND THE LOCAL OFFICIALS AND THE PUBLIC WOULD SUPPORT THE SYSTEM THEN TIME SPENT JUSTIFYING PROJECTS AND SCHEDULES (is acceptable?)."

Question #5

Are incremental improvements of roadway defects, while working toward an accepted standard, better than no improvements at all?

Question #5 Results

Answers were indicated by means of the following rating scale. "1" indicated that incremental improvements should be made and "5" indicated that improvements should not be made unless standards are met.

Make Incremental Improvements 1 2 3 4 5 **No Incremental Improvements**

Respondent	1	2	3	4	5	6	7	8	9	10	
Self-confidence	1	1	4	3	1	1	1	3	1	1	Totals
Make Incremental Improvements **1**	x	x		x	x		x	x	x	x	8
2						x					1
Neutral **3**			x								1
4											
No Incremental Improvements **5**											

Nine out of 10 respondents indicate that incremental improvements should be made. Of these respondents, eight were highly confident of their answers.

Comments

◊ "I STRONGLY FEEL THAT ANY IMPROVEMENT IS BETTER THAN DOING NOTHING AT ALL.
◊ IF WE IMPROVE SPOTS (HIGH-ACCIDENT LOCATIONS) THESE MAY PROVIDE INCONSISTENCIES IN THE ROAD -- VIOLATING DRIVER EXPECTANCY -- SO THE 'IMPROVEMENTS' MAY IN FACT DECREASE SAFETY.
◊ INCREMENTAL STEPS APPEAR TO ME TO BE BETTER. SOME DEFECTS NEED ADDRESSING IMMEDIATELY, BUT UNLIMITED FUNDING IS NEVER AVAILABLE. REDUCING RISK SEEMS BETTER THAN JUST IGNORING IT.
◊ INCREMENTAL IMPROVEMENTS CAN HAVE A POSITIVE BENEFIT/COST (ratio), BUT THEY SHOULD BE PART OF A COMPREHENSIVE SAFETY PLAN. IT SHOULD NOT BE USED ON A SITE BY SITE BASIS WITHOUT CONSIDERATION OF LONG TERM PLANS.
◊ SOMETHING IS BETTER THAN NOTHING.

- ◊ A STEP AT A TIME HELPS THE FINAL OUTCOME OF THE SYSTEM.
- ◊ THIS WOULD BE A TOUGH ONE TO COMMIT TO AS I WOULD STRUGGLE WITH TWO ASPECTS; FINANCING, AND ROAD STANDARDS.
- ◊ NOT EVERYTHING CAN BE ADDRESSED BUT DOING SOMETHING IS BETTER THAN DOING NOTHING. WE NEED TO FOCUS ON DOING THE BEST WE CAN WITH THE RESOURCES THAT WE HAVE

Question #6

Which guidelines or standards should be the basis for the safety audit procedure? Please list standards or guidelines below which pertain to unpaved roads.

> AASHTO "Green Book"
> MUTCD, etc.

Question #6 Results

- ◊ "REVISE STANDARDS WHICH ADDRESS LOW VOLUME (ADT < 250) ROADS
- ◊ LOCAL ROAD & BRIDGE STANDARDS
- ◊ LOW VOLUME ROADS GUIDE
- ◊ NACE ACTION GUIDES
- ◊ BLM MANUAL, SECTION 9113
- ◊ ROADSIDE DESIGN GUIDE
- ◊ SAFETY EFFECTS OF CROSS-SECTION DESIGN FOR 2 LANE ROADS, FHWA/RD-87/008
- ◊ WYDOT - DESIGN GUIDE FOR COUNTY ROADS
- ◊ LOCAL LOW VOLUME ROADS & STREETS, ASCE, NOV. 1992
- ◊ KANSAS LVR HANDBOOK (MEETS MUTCD REQUIREMENTS)
- ◊ CONSIDER GEOMETRIC DESIGN FOR CANADIAN ROADS - CHAPTER H - LOW VOLUME ROADS"

Question #7

Should past accident data be incorporated into the safety audit procedure, or should the procedure be based on standards or rankings alone?

Question #7 Results

Answers were indicated by means of the following rating scale. "1" indicated the respondent was positively for including past accident data, and "5" indicated a vote for excluding past accident data

Include Accident Data 1 2 3 4 5 **Exclude Accident Data**

Respondent	1	2	3	4	5	6	7	8	9	10	
Self-confidence	1	1	2	4	1	2	3	2	1	1	Totals
Include Accident Data **1**	x	x	x		x				x		5
2						x	x	x		x	4
Neutral **3**				x							1
4											
Exclude Accident Data **5**											

Nine out of 10 respondents indicated accident data should be included. Of these respondents, all were confident or highly confident in their answer. One respondent was neutral.

No respondents indicated that accident data should be excluded from the audit procedure.

Comments:

◊ "(yes) BUT ONLY ON THE PROCESS BY WHICH ACCIDENTS ARE OCCURRING -- (NOT BY 'HIGH ACCIDENT LOCATION.')
◊ PAST DATA SHOULD BE REVIEWED, BUT NOT RELIED ON ENTIRELY. SOME DEFICIENCIES MAY HAVE CHANGED OVER THE YEARS, BUT A HISTORY OF ACCIDENTS SHOULD BE VERY IMPORTANT IN THE AUDIT.
◊ I FEEL ACCIDENT DATA MUST BE CONSIDERED, IF USED IN A STATISTICALLY VALID MANNER. ONLY 3 YEARS OF DATA SHOWING 2 ACCIDENTS ON A ROAD MAY NOT BE OF VALUE. HOWEVER, 10 YEARS OF DATA SHOWING 5 ACCIDENTS AT ONE LOCATION COULD BE SIGNIFICANT.
◊ THIS WOULD BE A GOOD TOOL IN DETERMINING PROBLEMS THROUGH REOCCURRENCE
◊ ACCIDENT HISTORY, DIRECTLY RELATED TO ROAD PARAMETERS NEED TO BE INCLUDED. HOWEVER, ACCIDENTS DUE TO ALCOHOL, INATTENTIVE DRIVERS, ETC., SHOULD BE ELIMINATED FROM THE PROCESS."

Question #8

Should roadway classification be considered when prioritizing safety defects?

Discussion

If roadway classification is incorporated into the safety audit procedure this means that the same types of defects on two different roads may receive different rankings depending on the type of use the road receives.

A) Based on Traffic Volumes
B) Based on User types; local, residential, agriculture, mining, timber, recreation
C) Based on driver expectancy (discussed below and shown in Table 1, page 11)
D) Based on access and surface type (discussed and shown in Table 2, page 12)
E) Based on functional classification (page 12)
F) Combinations of Above (page 12)
G) Other, you specify:

A) Classification based on traffic volumes ensures that the public health factor (exposure) is considered. Developing a safety index based on exposure would be fairly easy. This type of classification would require local agencies to count traffic volumes. This may pose a problem for some agencies. In Wyoming, traffic counting devices are available for loan to local agencies from the Wyoming Technology Transfer Center.
B) Classification by user types would be easier for most agencies, but a clear correlation between user types and roadway safety is not known. This would make developing a safety index rather difficult.
C) Classification by driver expectancy may be useful in a safety audit procedure because it would tell the auditor at what level the driver is going to be driving the stretch of road. One of the most important roadway interaction characteristics of drivers is they tend to operate on a section of road based on expectations. Some expectations are developed over time and with experience (a priori), and some are developed over the section of road just traveled (ad hoc). On unpaved roads, drivers depend heavily on ad hoc expectancies due to the higher degree of variability found between these types of roads. An example of this type of classification was developed and tested in Kansas and is shown next.

Table 1. Roadway Classification Based on Driver Expectancy (not functional classification) [22]

	Road Type		
Characteristic	Type A	Type B	Type C - Primitive
Typical Width of Traveled Way and number of visible wheel paths	22' or greater, 3 or 4 visible wheel paths (if gravel)	16' - 24' 3 visible wheel paths	2 or no visible wheel paths
Prudent Operating Speed	40 mph or greater	25 - 45 mph	40 mph or less
Surface Material	paved or gravel	gravel, sand, or dirt	natural surface, may have some gravel or sand
Riding Quality	No adverse effect	may cause reduction in operating speed	typically poor; may be impassable due to poor weather
Drainage	All weather road, good surface drainage; water carried to ditches	All weather road, some surface ponding; water carried in ditches	Fair weather road, ditches are narrow or nonexistent; surface ponding is likely to affect driveability

D) Classification based on access and surface type would be relatively easy. This type of procedure could be done by most agencies without even going into the field. Some thought would have to go into developing safety indexes for this classification scheme.

Table 2, Classification based on Access and Surface Type

Dean Landman, Systems Plan Engineer, Kansas DOT, and Eugene R. Russell, Professor, Department of Civil Engineering, Kansas State University, have proposed a classification (or grouping) scheme for Kansas counties' local rural roads based on access type and road surface type. The scheme shown below has been altered slightly to reflect only unpaved roads.	
The primary access classifications would be:	• Residential Access (RA) • Farm Access (FA) • Resource/Industrial Access (R/IA) • Agricultural Land Access (AA) • Recreational Land Access (RCA)
The road surface classifications for unpaved roads would be: (further breakdowns could be made)	• Gravel (G) • Unimproved (U) • Primitive (PR)

E) Functional classification may or may not be already completed for unpaved roads. Usual classification for rural areas are; local, collectors, and arterials. Unpaved roads are usually local or collectors. This classification scheme may not offer enough detail for an audit procedure.

F) Combinations of the above schemes may be the best.

Respondents indicated choices by ranking their three top choices from the list shown below.

Do not include classification in the safety audit procedure
Based on Traffic Volumes
Based on User types; local, residential, agriculture, mining, timber, recreation
Based on driver expectancy as shown in Table 1, (above)
Based on access and surface type as shown in Table 2, (above)
Based on functional classification
Combination of:_______________________________________

Question #8 Ranking Results

1. Traffic Volumes
2. Driver Expectancy
3. Access and Surface Type
4. User Types
5. Functional Classification
6. Don't Use Classification

The top three choices were; Traffic Volumes, Driver Expectancy, and Access and Surface Type

Similar ranking results are obtained when analyzing subgroups with lower self-confidence. Therefore, self-confidence had no impact in determining the favorite choice.

Three combination schemes were also suggested:

- driver expectancy with access and surface type.
- traffic volumes with functional classification.
- traffic volumes with speed.

One respondent chose not to use roadway classification.

Comments:

◊ "IT WOULD BE GREAT TO HAVE ACCEPTED CRITERIA AS SHOWN IN TABLES 1 & 2 SO WE COULD ALL BE TALKING ABOUT THE SAME THING.
◊ I WOULD FIND IT RELATIVELY EASY TO IMPLEMENT A PROGRAM USING THE FIRST TABLE (#1, driver expectancy), BUT COULD SEE PROBLEMS WITH CONSISTENCY FROM ONE COUNTY TO THE NEXT.

THERE WOULD HAVE TO BE A MUTUAL AGREEMENT WITH ALL COUNTIES IN THE STATE IN ORDER TO MAKE ANY OF THESE SYSTEMS WORK

◊ CLASSIFICATION TYPE SHOULD BE CONSIDERED AND PART OF THE 'FORMULA' IN RANKING SITES. IT SHOULD BE WEIGHTED TO BE A MINOR PART OF THE OVERALL RANKING. THE BEST METHOD WOULD HAVE VOLUMES AND CLASSIFICATION INCLUDED BUT WEIGHTED WITH VOLUME HIGHER THAN CLASSIFICATION.

◊ DRIVER EXPECTANCY PROCESS THROUGH COMMENTARY DRIVING, AND INF. DEFICIENCY CHECK LISTS WORK VERY WELL FOR SIGNING/INF. DEFICIENCIES/ CONSISTENCY. I BELIEVE A, B, C ROADS (KANSAS LVR) ARE TIED TO VOLUMES: A = HIGHER, B = NEXT, C = VERY LOW. COUNTIES/TOWNSHIPS (ONLY IN KANSAS?) DO SOMETHING TO MAKE 'C' ROADS INTO 'A' ROADS FOR REASONS UNKNOWN TO ME -- 'GUESSED' USAGE? WE <u>KNOW</u> (I BELIEVE) THAT WE NEED MUCH LESS SIGNING ON C ROADS -- WE CAN HAVE LOTS OF HEADWALLS, OR SHARP TURNS ON C ROADS WHILE WE SIMPLY COULDN'T HAVE THE SAME CONDITIONS ON 'A' ROADS. RELATIVELY, C's AND A's ARE THEN PROBABLY EQUALLY SAFE. MUST BE DUE TO HIGHER SPEEDS, VOLUMES, EXPECTANCY ON A's AND DUE TO LOWER SPEEDS, VOLUMES, EXPECTANCY ON C's.

◊ I FEEL BEFORE A CLASSIFICATION OR A SAFETY AUDIT CAN BE DONE THE THREE THINGS I HAVE MARKED (user types, expectancy, access and surface type) PLUS A TRAFFIC COUNT WOULD ALL HAVE TO BE TAKEN INTO CONSIDERATION."

Question #9

Should the following roadway and user features be included in the safety audit procedure for unpaved roads?

Discussion

The completed procedure can not be all-encompassing. The elements covered by the safety audit should be ones that tell us the most about safety with the least amount of work (measuring, counting, surveying, etc.).

Respondents were asked to prioritize 30 unpaved roadway and user features. The results are shown below.

Question #9 Ranking Results

Rank	Safety Related Element
1	Road Surface Width, Signage
2	Consistency, Sight Distance, Surface Condition
3	Horizontal Curves, Prudent Operating Speed, Large trucks
4	Bridges, Railroad Crossings, Vertical Curves
5	Foreslope
6	Clear Zone, Pedestrians, Bicycles
7	Culverts
8	Cattle guards, Dust Condition, Grades, Guardrails, Superelevation, Recreational Vehicles
9	Environmental Conditions, Livestock, Wildlife, Local v. Tourist
10	Access Type, Links Higher Road Types
11	Lighting
12	Backslope

Comments:

◊ "INTERSECTION SIGHT DISTANCE IS VERY IMPORTANT & NOT TOO DIFFICULT TO MEASURE. STOPPING SIGHT DISTANCE IS HARD TO MEASURE. VERTICAL CURVES PROBABLY IMPORTANT ONLY AS RELATED TO SIGHT DISTANCE.

◊ Local v. tourist; TREAT AS THOUGH EVERYONE IS A STRANGER.

◊ THOSE ITEMS THAT DEAL WITH KEEPING THE VEHICLE ON THE ROAD ARE MOST IMPORTANT."

APPENDIX C

Second Delphi Survey Questionnaire
and
Summary Results

SECOND ROUND SURVEY RESPONSE FORM

Proposed Safety Improvement Program for Low Volume Unpaved Roads

Using results from the first round questionnaire, the following outline of a safety improvement program was drafted. Please read through the proposed procedure and make any comments you have. (Note any positive or negative aspects you see in the procedure and make recommendations on how to improve it.) All parts of this program represent suggested minimum analysis required to make safety improvement decisions for unpaved roads. An underlying presumption of this procedure is that readily identifiable safety improvements exist on local unpaved roads. Therefore, expensive engineering studies are not required to identify safety improvements and they have been minimized in this procedure. Local agencies ultimately have the responsibility of identifying special situations which require more rigorous engineering studies.

The proposed safety improvement program consists of four steps:

1. System-wide prioritization of unpaved roads
2. Identification of safety improvements on individual roads
3. Prioritization of safety improvements
4. Scheduling and Implementing safety improvements

Your input to this survey will help develop a systematic procedure for handling steps 1 and 2. Phase II of this project will address steps 3 and 4 at a later date.

Throughout this survey, "safety coordinator" refers to the employee at a local unpaved road agency responsible for managing a safety improvement program.

Step 1: System-wide Prioritization of Unpaved Roads

It is generally accepted that local road agencies do not have adequate resources to simultaneously address safety improvements on all of their unpaved roads. Therefore, the first step of the proposed procedure is to prioritize unpaved roads on a system-wide basis.

The goal of the prioritization process is to identify roads where the largest safety benefit is gained with limited funding. Some degree of professional judgment will be used during this process to eliminate the need for costly and time-consuming formal road inventory procedures.

List of Proposed Elements to Consider

Results of the first round survey conducted in December 1995 indicate that the following elements are important safety considerations for unpaved roads.

Traffic Volumes: Traffic volume is important because it relates directly to user exposure rates. It is logical that roads with high traffic volumes have more user exposure than roads with low volumes.

User Types: User types and their relative familiarity with the road is important due to differing driver characteristics and informational needs. Familiar drivers sometimes "overdrive" a road because they know the geometric layout. Also, the roadway features do not require their full concentration and so they are susceptible to "automatic pilot" operation. On the other hand, unfamiliar drivers loose their concentration due to the visual distractions of new surroundings. Inconsistencies in the roadway pose a larger challenge for unfamiliar drivers because they do not anticipate a road's geometric features ahead like familiar drivers do. Therefore, signing, positive guidance, and roadway consistency are important safety factors for these drivers.

Operating Speed: Accidents on higher speed roads generally result in more serious occupant injuries. Many high speed accidents result in roll-overs when combined with narrow unpaved roads and unforgiving roadside geometry. Therefore, a provision to weight higher speed roads is suggested.

High Percent Heavy Vehicles: The presence of heavy and large vehicles influence passenger car safety on narrow unpaved roads. Therefore, it is suggested that roads with a high percentage of heavy vehicles be weighted heavier.

Accident "Black Spots:" Accident data may be used to identify specific locations which have a high number of accidents. Such locations are commonly referred to as "black spots." Hopefully, countermeasures have already eliminated most black spots on modern unpaved roads. However, the procedure should be able to account for the presence of black spots, if they exist, as they may take priority regardless of the road's classification.

Provision for Unforeseen Elements: It is suggested that a variable weighting scale be included to account for unforeseen circumstances which may arise. This factor would be used to include such safety concerns as roadway inconsistency. It has been well documented that inconsistencies on a rural road increase the workload for unfamiliar drivers.

Proposed Road Prioritization Procedure

It is proposed that rating factors be developed for the elements listed above. The rating factors would then be used to prioritize unpaved roads for safety improvements.

One possible format is to establish a small number of subjective levels for each element. For example, traffic volume on any particular road could be subjectively classified as either low, medium, or high. An experienced road manager would be able to do this evaluation in the office using personal knowledge. By establishing these types of subjective ratings, the collection of formal traffic and user data would be minimized.

Overview of Step 1 as Proposed

A local agency's network of unpaved roads would first be separated into sections. Road sections would begin and end at natural break points, such as major intersections. It is proposed that each unpaved road section would then be assigned a ***primary rating factor*** determined by two critical elements. This primary factor would then be adjusted up or down by using ***modifying factors,*** which would account for other elements that may or may not be present on the road sections. The adjusted factors would then be used to prioritize the unpaved roads for safety improvements.

Example Procedure

It is suggested that two of the most important (or most telling) elements should be used together to form a "first cut" matrix. Ideally these elements should be applicable for all unpaved roads. In the following example it is suggested that the two elements, "traffic volume" and "user types," be used to establish a primary rating (or first cut elimination). The remaining elements will then be used as modifiers to the primary rating. In the finished procedure the modifiers would be used to adjust the primary ratings up or down to obtain a final priority rating for each road.

For example, a road section that has a primary rating of "B" may be adjusted up one class to an "A" rating based on low operating speed. On the other hand, the same "B" road may be adjusted down one class to a "C" rating based on high operating speed. If this scheme is used as presented, Class "E" roads would receive safety improvements first, class "D" second, and so on.

Developing the "Primary Rating" Matrix

Tables 1 and 2 contain example rating matrices based on user types and traffic volumes. Table 1 contains **five different rating levels**, "A" through "E." The logic pattern here is that high traffic volumes have priority, and that roads carrying predominately Local + Recreation + Tourist users have priority. By filling in the cells in a progressive manner the matrix is formed.

Table 1, Primary Rating Classification by Traffic Volume and User Type

User Types (users consist mainly of...)	Traffic Volume		
	Low	Medium	High
Local	A	B	C
Local + Recreation	B	C	D
Local + Recreation + Tourist	C	D	E

In Table 2 the same procedure is used, but some cells are grouped together resulting in **three different rating levels**, "A," "B," and "C." A similar low to high hierarchy is assumed for user types and traffic volume.

Table 2, Alternate Primary Rating Classification Scheme

User Types (users consist mainly of...)	Traffic Volume		
	Low	Medium	High
Local	A	A	B
Local + Recreation	A	B	C
Local + Recreation + Tourist	B	C	C

(Your Input is Needed): *If you feel that one of the schemes presented in Tables 1 and 2 will provide the best "first cut" in the prioritization process please circle your choice below. Table 1 would provide 5 primary rating classifications and Table 2 would provide 3 primary rating classifications. If you feel that the Primary Rating should utilize a combination of elements other than those shown in Tables 1 and 2, please enter your recommendation in Table 3 below. Please feel free to use any elements you wish -- you are not restricted to the elements previously listed.*

It you feel that Traffic Volume and User Type are appropriate, but don't agree with the categories of User Type as presented, please suggest any other breakdown of user types that you feel would be easier for local safety coordinators to identify. For example, other possible breakdowns would be: Local Access + In-State + Recreation & Tourist or Local + In-State + Out-of-State. In any case, the user groups should be readily identifiable by the local agency's safety coordinator and should reflect differences in each group's familiarity with the road. Again, please enter any suggestions in Table 3 below.

➔ Circle Your Choice of Primary Rating Scheme: Table 1, Table 2, or Table 3

Primary Rating Results: Five of the respondents chose Table 2 with no changes. Three respondents chose Table 1 with no changes. Three respondents entered their own tables shown below:

Table 3, Respondents' Recommended Primary Rating Classification Scheme

Alignment (terrain)	Traffic Volume		
	Low	Medium	High
Level	A	B	C
Rolling	B	C	D
Mountainous	B	C	D

*THE COLUMNS DON'T GO "ABC" OR "BCD" BECAUSE I THINK VOLUME SHOULD CARRY MORE WEIGHT THAN TERRAIN OR ALIGNMENT. [ALIGNMENT GENERALLY COVERS CURVATURE, SIGHT DISTANCE, CLEAR ZONES, MAYBE MORE] TABLE 1 WOULD BE MY NEXT CHOICE.

Table 3, Respondents' Recommended Primary Rating Classification Scheme

User Types (users consist mainly of...)	Traffic Volume		
	Low	Medium	High
Local	A	A	A
Local + Recreation	B	B	B
Local + Recreation + Tourist	C	C	C

Table 3, Respondents' Recommended Primary Rating Classification Scheme

User Types (users consist mainly of...)	Traffic Volume		
	Low	Medium	High
Local	A	A	B
Local + Recreation	A	B	C
Local + Recreation + Commercial	B	C	D

NOTE: Survey Respondents' comments are typed in **ALL CAPS.**

Comments:

- "I THINK ANOTHER ELEMENT TO CONSIDER WOULD BE RANCHING EQUIPMENT AND POTENTIAL FOR LIVESTOCK TO BE ON THE ROAD. ALSO, WHAT ABOUT OILFIELD AND MINING TRAFFIC - WHERE DO THEY FIT IN THESE TYPES? THE TYPES SHOWN ARE GOOD - BUT MAYBE ONE OR TWO MORE TYPES WOULD BE NEEDED FOR SOME ROADS.

- THE DEFINITION OF LOCAL BEING A COMBINATION OF IN-COUNTY AND IN-STATE TRAFFIC, I.E., HUNTING - SUBDIVISION TRAFFIC?
- I WOULD MAKE 'E' THE WORST CONDITION - LIKE LOS. INTUITIVELY, 'A' IS GOOD."

Developing the Modifying Elements and their Adjustment Factors

It is proposed that modifying elements be used to adjust the initial primary ratings. The previous list of elements is presented below again with suggested Levels of Ranking and associated Adjustment Factors.

(Your Input is Needed): *Please indicate if you agree or disagree with the suggested Levels of Ranking and Adjustment factors presented below. Please use the provided space to suggest any other elements you think should be included in the procedure. Traffic volumes and user types have also been included because their use as primary rating elements has been suggested and demonstrated above, but not yet agreed on by the committee.*

Table 4, Modifying Elements and their Adjustment Factors

Element	Levels of Ranking	Adjustment Factor	Agree ☑	Disagree *(enter your Adjustment Factor)*
Operating Speed	High	Move down one class		
	Medium	Neutral		
	Low	Move up one class		
Heavy Vehicles	High	Move down one class		
	Average	Neutral		
	Low	Move up one class		
Black Spots	Present	Move down __ class(es) (please fill in, or should these take ultimate priority?)		
Unforeseen Elements	High	Move down two class		
	Medium	Move down one class		
	Low	Move up one class		
Traffic Volume	High	Move down one class		
	Medium	Neutral		
	Low	Move up one class		
User Type	Local + Recreation + Tourist	Move down one class		
	Local + Recreation	Neutral		
	Local	Move up one class		

Modifying Element Results:

The focus group generally agreed on the adjustment factors as present in Table 4. There were some variations suggested such as moving up in half steps, or leaving more levels of ranking neutral. Overall, the factors as they were presented represent the group's average response best.

Four additional elements were suggested:

- terrain (mountainous, rolling, level)
- ranching equipment and livestock
- school bus route
- commercial traffic

Summary of Road Selection Process

The proposed system-wide road prioritization process presented above consists of two main parts:

1. Assignment of a ***Primary Rating Factor*** determined by two critical elements, and
2. Modification of the Primary Rating Factor by ***Adjustment Factors*** to account for other elements which may or may not be present on the roads.

This procedure would then result in a final Rating Factor for each road section. The final Rating Factors would establish groups of unpaved road sections at different priority levels. For example, an agency may end up with 12 "A" roads, 24 "B" roads, 12 "C" roads, etc. In this scheme, "A" roads would have the lowest priority with an increase in priority level for each successive character. The next question would be, "How should improvements be implemented on the roads?"

(Your input is needed):

Implementation Policy

After the roads are prioritized, and needed improvements are identified (the subject of step 2, which follows), what should the standard policy procedure be among all local agencies for making the improvements? (Please check one of the below)

_____ *A.)* *One of the priority roads should be selected and all improvements made on that road before moving on to another priority road.*

_____ *B.)* *One type of improvement should be selected and performed on all of the priority roads before moving on to the next type of improvement for the other same priority roads.*

_____ *C.)* *There should be no standard policy on this matter and the decision should be made on a case by case basis by the local safety coordinator.*

_____ *D.)* *Other:*

Implementation Policy Response:

- eight out of 10 respondents chose "C," (no standard policy needed)
- one respondent chose "B."
- one respondent wrote in, "High priority roads 1st, prioritize on safety, local factors and costs."

Order of improvements Policy

The main purpose of prioritizing an agency's roads is to eliminate the necessity of analyzing <u>all</u> of the agency's roads at the same time. However, this implies that no safety improvements will be made on the lower priority roads until all of the improvements are completed on the higher priority roads.

Do you feel it is acceptable that no safety improvements be made on the lower priority roads until all improvements have been made on the higher priority roads?
Yes No

Order of improvements Policy Response:

Nine out of ten respondents answered "NO."
One respondent answered "YES."

Respondents Comments:

- "DEPENDS ON SEVERITY OF PROBLEM.
- THERE MAY BE A TIME WHEN VERY SMALL REPAIRS COULD BE DONE ON LOW PRIORITY ROADS WHILE WAITING ON MATERIALS OR WEATHER OR SEVERAL OTHER REASONS ON A HIGHER PRIORITY ROAD.
- I AM IN FAVOR OF A 'CLASS' SYSTEM, BUT I THINK IS UNREASONABLE TO PUT ASIDE SMALLER, LESS EXPENSIVE REPAIRS WHILE FOCUSING ON A LARGER PROBLEM.
- CASE BY CASE BASIS SHOULD BE CONSIDERED.
- SOMEWHERE WE NEED TO LOOK AT COSTS AND EASE OF IMPROVEMENTS. IF MANY LOWER PRIORITY ROAD IMPROVEMENTS CAN BE IMPROVED FOR SUBSTANTIALLY LESS MONEY THAN ONE OR TWO HIGHER PRIORITY ROAD IMPROVEMENTS, THEN MAYBE A LOWER PRIORITY ROAD SHOULD BE IMPROVED.
- A BLACK HOLE MIGHT DEVELOP ON A LOWER PRIORITY ROAD THAT WILL NEED TO BE ADDRESSED BEFORE A HIGHER PRIORITY ROAD.
- I FEEL BENEFIT/COST HAS TO BE CONSIDERED. IF WE CAN SAVE 2 LIVES FOR AN EXPENDITURE OF $100 ON A LOWER PRIORITY ROAD, OR 1 LIFE FOR $1000 ON A HIGHER PRIORITY ROAD... FOR THIS REASON, I THINK SOME FLEXIBILITY SHOULD REMAIN FOR THE SAFETY COORDINATOR.
- I WOULD REVIEW THE MODIFIER - THEY MIGHT LEAD ME TO WORK ON A LOWER PRIORITY ROAD (OVER A HIGHER PRIORITY ROAD), BUT THEY INDICATE PROBLEMS TO BE CORRECTED.
- BLACK SPOTS AND UNFORESEEN ELEMENTS NEED TO BE EVALUATED ON ALL ROADS, REGARDLESS OF RATING."

If you do not agree with the general philosophy of this part of the safety improvement program, please include your concerns and recommendations.

Step 2: Perform the Safety Improvement Identification Procedure on the Unpaved Roads Selected

After the priority roads are established using step 1, it is proposed that a Safety Improvement Identification Procedure (SIIP) then be used. Safety audits as used in Europe and Australia are performed by panels of safety experts using long and exhaustive procedures. For unpaved road agencies this approach is too costly. The approach suggested here utilizes a downscaled procedure, economically appropriate for the limited budgets of local unpaved road agencies.

It is proposed that the Safety Improvement Identification Procedure be carried out with the help of unpaved road users whom are directly concerned with safety on "their" particular roads. The feasibility of this approach is currently being tested in Albany County, Wyoming using the following groups of road users:

- property owners (residential, agricultural, summer homes and cabins)
- route drivers (school bus, mail carriers, United Parcel Service)
- sheriff's deputies
- road and bridge personnel

(Your Input is Needed): *Do you agree with the concept of involving road users to help identify safety improvements on unpaved roads? Yes No*

Include Road Users Response:

Nine of the 10 respondents answered "YES."
One answered "NO."

Respondents Comments:

- "ONLY FOR INPUT. FINAL DECISIONS NEED TO BE LEFT TO PROFESSIONALS.
- WE HAVE TOO MUCH OF THAT RIGHT NOW. IN MANY CASES IT BECOMES VERY POLITICAL. LEAVE IT TO THE PERSONNEL PERFORMING THE WORK.
- COMMUNICATION IS NEEDED FOR INFORMATION TO ELIMINATE CONFRONTATION.
- LOOKS GOOD
- INCLUDE EMERGENCY MEDICAL PERSONNEL
- TOWN MEETING OR PUBLIC IN-PUT MEETING COULD BE UTILIZED
- GOOD IDEA"

In the procedure proposed here, local agencies would use survey forms to facilitate the collection of data from the user groups. A sample of the survey form currently being used in the Albany County test study is enclosed with this outline. Local tax assessor's records would provide names and addresses of land owners who use particular roads to access their property. Road agency personnel may also identify people who live along the roads they are responsible for. The involvement of route drivers, such as rural mail carriers, school bus drivers, UPS drivers, etc., would be gained by contacting appropriate local organizations. During the recent test study in Albany County, a list of 30 names and addresses for property owners along three roads in Albany County was created with little effort. It was estimated that this list constituted 90 percent of the property owners who use the roads on a regular basis.

There would be several distinct advantages of involving local road users in the audit procedure. First, regular users are familiar with areas of the road that present problems for them. They drive the roads often, and under various conditions. People who live near the road may be aware of unreported accidents. Second, by involving the road users, and opening a line of communication, road agencies would demonstrate that they are genuinely concerned with safety conditions on local roads. By including local road users in the safety audit process, the agency would gain not only information, but would also foster "partnership" ties to the community.

By involving local law enforcement officers, the agency would gain first-hand knowledge of accidents and possible countermeasures to prevent them. Law officers not only investigate accidents, but also patrol unpaved roads. Hopefully, by maintaining communications between the local law enforcement agencies and the local road agencies, notice of safety deficiencies would be expedited. Again, survey or report forms should be developed to encourage and enhance a uniform reporting process.

Road agency personnel also should be trained and encouraged to recognize potential safety improvements on unpaved roads. For example, recurring areas of washboarding should be noted, as these areas are a safety concern and a maintenance problem. It may be possible to employ countermeasures such as chemical stabilization that will improve safety and reduce maintenance at the same time. It is not acceptable for agency personnel to ignore potential safety problems just because they know there is inadequate funding available to make all needed improvements.

Summary of Proposed Safety Improvement Identification Procedure

Unpaved road user groups are identified and contacted. They are asked to identify potential safety improvements on "their" roads by completing survey forms. After the user groups have identified safety improvements, the road agency's safety coordinator would create an improvement list for each road. By utilizing road user input, this procedure would be carried out without conducting costly and time consuming engineering studies.

(Your input is needed):

In Step 1 of the proposed procedure roads are prioritized for improvements. In Step 2, a list of possible safety improvements is created for each road section. Should there be a standard policy concerning the time schedule for Step 2?

_____ *A)* *Identifying Improvements should be done only on the current priority roads (such as "A" roads first, then "B" roads after all "A" roads have been addressed).*

_____ *B)* *Identifying Improvements should be done on a predetermined time scale (such as 1/2 , 1/3 , 1/4 , or 1/5 of the agency's roads per year. Circle one if you choose this method).*

_____ *C)* *It is not necessary to have a standard policy on this matter, and Identifying Improvements should be done as soon as funding allows (some agencies may be able to complete all roads at once, others a few at a time).*

_____ *D)* *Other:*

Identify Improvements Policy Response:

- Four out of 10 respondents answered "C," no standard policy needed.
- Two respondents answered "B," a predetermined time scale should be used, with a third of all roads being surveyed each year.
- Two respondents answered "A," Identifying Improvements should be done only on the current priority roads.
- Two respondents answered "Other":
    1. Identification of all improvements must be completed so that the worst areas are included.
    2. I would like a list of possible projects for all roads. I could do a mini cost-benefit to choose which I feel is most important to do first.

Respondents Comments:

- "I FEEL IT IS UP TO THE R&B SUPERVISORS TO IDENTIFY THE SAFETY PROBLEMS AS THEY TRAVEL ALL ROADS, AT THE LEAST, ON A WEEKLY BASIS. BY ADDING ADDITIONAL INPUT, (WHICH WE ARE ALREADY GETTING, BUT NOT IN A WRITTEN FORM) WOULD FORCE US TO DO PROJECTS THAT WE MAY NOT HAVE FUNDING OR MATERIALS ON HAND TO PERFORM."

Do you have any additional comments on the proposed Safety Improvement Identification Procedure?

Step 3: Prioritize Safety Improvements

After Step 2 is completed, and the lists of possible safety improvements are created, the road safety coordinator would then prioritize the improvements. A standardized procedure for prioritizing improvements should be developed. The overall goal of the prioritizing procedure would be to attain the largest possible safety improvement per dollar spent. Phase II of this research would develop the prioritization process.

Step 4: Program the Identified Improvements

After Steps 1, 2, and 3 are completed, a work schedule could be drafted. As funding allowed, improvements would then be made in prioritized order.

Your Comments on the Overall Safety Improvement Procedure for Low Volume Unpaved Roads:

- "NEED TO DEVELOP PRIORITY LIST FOR ALL ROADS. NEED TO KEEP EMOTIONAL AND POLITICAL FACTORS OUT OF PROCESS. BEST TO DEVELOP A NUMERICAL LIST OF PRIORITIES THAT PUBLIC AND POLITICIANS ARE WILLING TO ACCEPT.
- I FEEL WE NEED TO BE FLEXIBLE IN PERFORMING LESS EXPENSIVE REPAIRS ON LOWER (priority) ROADS, WITHOUT BEING HELD TO TASK ON (a higher priority) ROAD UNTIL FUNDING, WEATHER, ETC. ALLOW.
- I THINK THIS IS HEADING IN THE RIGHT DIRECTION. THERE WILL NEED TO BE FLEXIBILITY IN THE SYSTEM, BECAUSE EACH COUNTY MAY HAVE DIFFERENT GOALS AND PRIORITIES, NOT TO MENTION DIFFERENT CONDITIONS AND USERS. SO FAR THIS LOOKS GOOD AND I'M ANXIOUS TO TRY IT OUT ON SOME ROADS. I THINK WE WILL NEED TO START ON A SMALL SCALE AND WORK UP. I THINK AFTER THE FIRST EVALUATION A TIME SCHEDULE SHOULD BE SET UP TO RE-EVALUATE THE ROADS - MAYBE EVERY 3 YEARS OR MAYBE 5. ONE CONCERN I HAVE - IF A USER IDENTIFIES A PROBLEM THAT ISN'T CORRECTED - IS THE LIABILITY INCREASED TO THE COUNTY?
- I FEEL THE SAFETY IMPROVEMENT PROCEDURE IS GOING VERY WELL, HOWEVER, IN OUR COUNTY WE HAVE TO LOOK AT ROAD SAFETY ON A SEASONAL BASIS ALSO. THERE ARE SOME PARTS OF THE COUNTY WE HAVE NO TRAFFIC EXCEPT FOR WINTER AND THEN OUR SAFETY CONCERNS CHANGE.
- I BELIEVE THAT THIS PROCEDURE WILL BE OF TREMENDOUS BENEFIT ONCE IT IS FINE TUNED AND ACCEPTED BY SEVERAL AGENCIES.
- I THINK YOU ARE ON TO SOMETHING GOOD!
- LOOKS REASONABLE."

APPENDIX D

Unpaved Road User Safety Survey

Albany County Unpaved Road
User Survey

Fox Creek Road

1. Approximately how many miles per week do you travel on Fox Creek road? _____

2. Approximately how long have you used Fox Creek road on a regular basis?
_____ years _____ months

3. Do you use Fox Creek road to access property that you own? Yes No

4. Is your main use of Fox Creek road for;

   Agriculture Commuting to Work Seasonal Home Route Driver

   Other: __________

For the following four questions, please rate your satisfaction on a scale of 1 to 5, with 1 being the best and 5 being the worst.

5. How do you rate the smoothness and rideability of Fox Creek road? (consider washboarding, rutting, approaches to cattleguards, etc.)
   1 2 3 4 5

6. How do you rate the surface condition of Fox Creek road? (is there adequate gravel? does it become slippery or extremely muddy when wet?)
   1 2 3 4 5

7. How do you rate the overall safety of Fox Creek road.
   1 2 3 4 5

8. Does Fox Creek road adequately meet your needs.
   1 2 3 4 5

9. List two specific <u>safety</u> improvements for Fox Creek road in the order you believe they should receive attention.
   i.

   ii.

10. a. Do you feel that Fox Creek road has adequate warning signs? Yes No

b. If No, please indicate specific locations you believe need warning signs.

Unpaved County Roads in General

11. Approximately how many miles per week do you travel on unpaved county roads?

______

12. Knowing that county budgets are limited and that all improvements can not be made at once, please rank the following items. Rank each item using the numbers 1 through 5. "1" indicates you believe the item should have highest priority on an improvement list and "5" indicates the item should have lowest priority.

_____ Improve Cattleguards
_____ Improve Curves
_____ Remove Washboarding
_____ Widen Roads
_____ Flatten Steep Shoulders
_____ Improve Bridges and Culverts
_____ Add Guardrail
_____ Add Warning Signs
_____ Improve Railroad Crossings
_____ Add Delineation on Curves
_____ Add Gravel
_____ Remove Roadside Objects
_____ Add Snow Fence
_____ Other: _______________

13. If certain safety improvements are made to one location, should they then be made at all similar locations? Yes No

Comment:

14. a. Do you think additional taxes should be collected to help improve safety on unpaved roads in Wyoming? Yes No

b. If Yes, what type of taxes should be collected?
Property Fuel Sales User Other:_________

15. Do you feel that having more warning signs would reduce accidents on unpaved roads?

Yes No

16. Please prioritize the following roads according to how safe you feel while driving on them. Use "1" for safest and "3" for most dangerous.

_____ Interstate Highways
_____ Paved, two-lane Highways
_____ Unpaved County Roads

17. Do you feel that accidents on unpaved roads are due largely to deficiencies in the roadway or to driver behavior (which has the most influence on accidents).

Roadway Deficiencies Driver

18. Do you have any additional comments you would like to make concerning safety on unpaved county roads in general?

19. Please list your name below if you would be willing to answer follow up questions to this survey.

APPENDIX E

Pilot Testing Results of User Safety Survey for Albany County Roads

FOX CREEK ROAD

Question	Fox Creek Road - Residents 12 Respondents	Results	
1	Miles Driven per Week	36.8	average
2	Used on Regular Basis (Yrs.)	16.9	average
3	Own Property Access? **Yes**	12	total
	No	0	total
4	Used For:		
	Agriculture	1	total
	Commuting to Work	6	total
	Seasonal Home	0	total
	Route Driver	0	total
	Home	6	total
	Other	0	total
5	Smoothness and rideability (1=good, 5=bad)	3.2	average
6	Surface condition (1=good, 5=bad)	3.2	average
7	Overall Safety (1=good, 5=bad)	2.9	average
8	Adequate for Needs (1=good, 5=bad)	2.5	average
10.a.	Adequate warning signs **Yes**	5	total
	No	6	total

Question 9, List specific <u>safety</u> deficiencies on Fox Creek road.

Property Owners

- Washboarding roughness
- More gravel for mud
- Washboarding
- A couple of narrow cattleguards
- Gravel the whole road from highway 11 to highway 230
- Put in widened cattleguards and snow fences where needed and maintain road suitable for all vehicles to travel on.
- Widen the road, especially at cattleguards
- Gravel the road
- None needed on the portion with gravel
- Graded on a more regular basis
- Warning Signs

FOX CREEK ROAD (continued)

- Widen some cattleguards
- Widen Cattleguards
- Do a better job of grading Washboards, (inexperienced drivers lose control on curves)
- Several spots need additional gravel to reduce slick conditions during heavy rain & in spring.
- A sign at each end stating the need to go slowly - some people drive far too fast on the road.
- More gravel on hills and curves - take out blind before curves
- Clear brush before curves
- Surface
- Blind Corners

County Maintenance Personnel

- Road Mill
- Signs
- Remove some of the Big rocks on the side
- Snow fence
- Straighten curves
- Two Cattleguards
- Build more snow fence
- Straighten some sharp curves
- Re-gravel
- Widen
- Snow Fence
- Curve Work

Question 10.b. Indicate specific locations you believe need warning signs on Fox Creek road.

- Curves slippery when wet and no travel except residents unless the road is properly maintained
- On curves - They are sometimes unexpected
- Need warning signs on curves
- Approx. 223 & 226 - 230
- The sharp curve immediately east of the "Lake Owen Y" and Fence Creek Hill
- Slow signs at both ends

MONUMENT ROAD

Monument Road - Residents		
Question	14 Respondents	Results
1	Miles Driven per Week	55.3 average
2	Used on Regular Basis (Yrs.)	15.4 average
3	Own Property Access? **Yes**	14 total
	No	0 total
4	Used For:	
	Agriculture	5 total
	Commuting to Work	6 total
	Seasonal Home	0 total
	Route Driver	0 total
	Home	2 total
	Other	1 total
5	Smoothness and rideability (1=good, 5=bad)	4.1 average
6	Surface condition (1=good, 5=bad)	3.0 average
7	Overall Safety (1=good, 5=bad)	3.3 average
8	Adequate for Needs (1=good, 5=bad)	3.2 average
10.a.	Adequate warning signs **Yes**	4 total
	No	11 total

Question 9, List specific safety deficiencies on Monument road.

Property Owners

- Chip Seal the first two miles
- More snow fences
- Chip Seal the road
- More frequent road maintenance
- Proper foundation and maintenance
- A better surface and shoulder work
- Signs
- Road Surface
- Two miles north of the railroad tracks there is a cattle guard at the end of a curve. The curve is declining when approaching down the hill on the north.

MONUMENT ROAD (continued)

- Quite a few people have missed the curve and hit the fence just south of the track at the top of a hill there is a blind curve. Also a rock which keeps people on the left side going south a mile south of the tracks there is a blind spot and the road could be a little wider there.
- Bad curve coming out sect. 7 south of tower should have curve sign and maybe slow sign. Had two or three wrecks in last few years.
- Remove washboards from Ames monument to highway.
- Take out curve in Sect. 7 before cattle guard.
- Build better base for road. Raising it would prevent drifting and cover large rocks sticking up.
- Improve corner at cattle guard from sect. 18 to sect. 19. Corner shouldn't be so sharp. Would prevent accidents from missing corner.
- Bad curve south of tower between sections 7 and 18.
- Snow drift control/removal.
- More adequate grading
- Raise the elevation of the road to help in the amount of snow drifting
- When raising the elevation of the road bed use a material that doesn't washboard as bad.
- Grade road to remove washboarding first then apply more gravel if needed, don't just fill in the washboarding, it comes right out.
- Completely cover exposed rocks
- Eliminate Washboard
- Reduce Speed
- Do something to improve the washboarding - it's hard to keep the car on the road. At present, grading lasts only a few days.
- Speed limits would be good if they were followed.

County Maintenance Workers

- Put a speed limit sign up and enforce it. (people drive too fast and that tears up the road)
- Mix some kind of binder in with the granite so the road won't washboard
- Some warning signs on the sharp curves
- Straighten or widen a few curves
- Take out one cattleguard
- Raise road in a couple places
- Control Washboarding
- Snow control
- Widen
- Haul in some material to bind gravel that is already in place
- Put up a speed limit if there was a way to enforce it

Question 10.b. Indicate specific locations you believe need warning signs on Monument road.

- When you first get on it and at Ames Monument
- Curve before 1st cattle guard
- Speed limit signs
- Warning for cattle guard
- Cattleguards
- Intersections
- Road surface Problems
- Intersections and problem areas
- Cattleguard 2 miles north of railroad
- Curve south of tracks
- Signs are hard to keep up. They are either knocked down or shot by vandals. We did have some signs at one time.
- Curve south of railroad
- Curve on hill south of Williams' house (*dangerous as traveling north*)
- Curve in sect. 7
- South side of Dale crossing - sharp corner
- At curve south of tower, between sections 7 and 18
- There should be a yield sign at the junction of Monument and Hermosa roads, (*234 and 222*)

FETTERMAN ROAD

Fetterman Road - Residents			
Question	3 Respondents	Results	
1	Miles Driven per Week	93.3	average
2	Used on Regular Basis (Yrs.)	17.5	average
3	Own Property Access? **Yes**	2	total
	No	1	total
4	Used For:		
	Agriculture	2	total
	Commuting to Work	1	total
	Seasonal Home	0	total
	Route Driver	1	total
	Home	0	total
	Other	0	total
5	Smoothness and rideability (1=good, 5=bad)	4.3	average
6	Surface condition (1=good, 5=bad)	5.0	average
7	Overall Safety (1=good, 5=bad)	3.3	average
8	Adequate for Needs (1=good, 5=bad)	4.3	average
10.a.	Adequate warning signs **Yes**	0	total
	No	3	total

Question 9, List specific safety deficiencies on Fetterman road.

Property Owners
- Black Top
- Curve signs
- Road Surface
- Signage
- Should have more gravel on them
- Should be graded more often

County Maintenance Personnel
- Rebuild sharp curve southwest of Rock Creek
- Widen Road in places
- Gravel about 5 miles of road
- Gravel Clay Spots

FETTERMAN ROAD (continued)

- Straighten Sharp Curves
- Widen Fill Areas
- Straighten Some Sharp Curves
- Gravel some problem spots
- More Snow Fence
- Straighten curve 1/2 mile west of Rock Creek
- Gravel Several Short Places
- Washboarding
- Signing
- Pave

Question 10.b. Indicate specific locations you believe need warning signs on Fetterman road.

- First Curve after leaving U.S. 30
- All junctions and sharp curves
- On the curves / rough cattleguards.

ALL UNPAVED ROADS

	All Residents		
Question	30 respondents	**Results**	
11	Miles per Week on Unpaved Roads	110.20	average
14.a.	Collect more Taxes **Yes**	12	total
	No	16	total
b.	Which Taxes		
	Property	2	total
	Fuel	6	total
	Sales	6	total
	User	2	total
	Other:	0	total
15	More Warning Signs **Yes**	11	total
	No	16	total
16	How Safe (1=good, 3=bad)		
	Interstate Highways	1.75	average
	Paved, two lane Highways	2.25	average
	Unpaved County Roads	1.93	average
17	Influence Accidents Most		
	Roadway Deficiencies	4.5	total
	Driver	25.5	total

ALL UNPAVED ROADS (continued)

Sheriff's Deputies			
Question	8 Respondents	Results	
1	Miles per Week on Unpaved Roads	115.3	average
2	Smoothness and rideability (1=good, 5=bad)	2.7	average
3	Surface condition (1=good, 5=bad)	3	average
4	Overall Safety (1=good, 5=bad)	3	average
6	Adequate Warning Signs **Yes**	6	total
	No	2	total
7	More Warning Signs **Yes**	2	total
	No	6	total
8	Improvements made to one location, then made to all? **Yes**	6	total
	No	2	total
9	Collect more Taxes **Yes**	1	total
	No	6	total
	Which Taxes		
	Property	0	total
	Fuel	2	total
	Sales	1	total
	User	1	total
	Other:	0	total
10	How Safe (1 = good, 3 = bad)		
	Interstate Highways	1.1	average
	Paved, two lane Highways	2.5	average
	Unpaved County Roads	1.9	average
11	Influence Accidents Most		
	Roadway Deficiencies	1	total
	Driver	7	total

ALL UNPAVED ROADS (continued)

	UPS Drivers		
Question	4 Respondents	Results	
1	Miles per Week on Unpaved Roads	162.25	average
2	Smoothness and rideability (1=good, 5=bad)	3	average
3	Surface condition (1=good, 5=bad)	2.75	average
4	Overall Safety (1=good, 5=bad)	3.5	average
6	Adequate Warning Signs **Yes**	1	total
	No	3	total
7	More Warning Signs **Yes**	4	total
	No	0	total
8	Improvements made to one location, then made to all? **Yes**	4	total
	No	0	total
9	Collect more Taxes **Yes**	1	total
	No	2	total
	Which Taxes		
	Property	0	total
	Fuel	2	total
	Sales	0	total
	User	0	total
	Other:	0	total
	How Safe (1 = good, 3 = bad)		
10	Interstate Highways	1.3	average
	Paved, two lane Highways	2	average
	Unpaved County Roads	3	average
	Influence Accidents Most		
11	Roadway Deficiencies	1	total
	Driver	2	total

ALL UNPAVED ROADS (continued)

Road and Bridge Employees			
Question	13 Respondents	Results	
1	How long have you performed maintenance on this road? (yrs.)	13.6	average
2	Smoothness and rideability (1 = good, 5 = bad)	2.8	average
3	Surface condition (1 = good, 5 = bad)	2.9	average
4	Overall Safety (1 = good, 5 = bad)	2.8	average
5	Adequate for users needs (1 = good, 5 = bad)	2.5	average
7	Influence Accidents Most		
	Roadway Deficiencies	0	total
	Driver	13	total

Combined Safety Improvement Priorities for all Groups Surveyed						
	Roadway	Tally				
Priority	Element	Total	Users	Deputies	UPS	R & B
1	Remove Washboarding	71	29	13	7	22
2	Add Gravel	95	40	21	6	28
3	Improve Curves	107	54	22	12	19
3	Add Snow Fence	107	42	31	10	24
4	Add Warning Signs	118	56	30	8	24
5	Improve Cattleguards	120	49	28	14	29
6	Widen Roads	121	59	26	9	27
7	Add Delineation on Curves	122	56	24	8	34
8	Flatten Steep Shoulders	133	64	30	12	27
9	Improve Bridges and Culverts	137	64	22	12	39
10	Remove Roadside Objects	158	75	31	14	38
11	Improve Railroad Crossings	166	82	29	12	43
12	Add Guardrail	172	81	34	13	44

ALL UNPAVED ROADS (continued)

Question 13, If certain safety improvements are made to one location, should they then be made at all similar locations?

YES = 22

NO = 17

Yes Comments

- If and when it is possible. Monument road is in very bad condition as far as Ames Monument.
- Dirt roads in this county are very dangerous

No Comments

- Judge each one on its own merit
- Safety should be priority
- Low cost studies should be made to determine priorities for improvements
- Due to amount of traffic from interstate to at least monument, if possible to radio tower south of monument.
- Each road has its own problems
- It should be dependent on the amount of traffic and the amount of concern for safety
- Ease of maintenance & snow removal varies from location to location; and other consideration
- Depends on how much the road is used
- It's not necessary everywhere and of course the use of the road must be considered. Many factors need to be analyzed before changes are made.
- Only on most traveled roads
- Each location should be analyzed independently
- Improvements should be made when and where needed, not just because improvements were made somewhere else Some areas in county differ, so to improve at one area then move to another area and improve that before a final finish is done on the whole road... Fix the worst first - Do additional high priority
- Not necessarily
- (only) If the usage of the road at that location justifies the cost

ALL UNPAVED ROADS (continued)

Question 18, Do you have any additional comments you would like to make concerning safety on unpaved county roads in general?

- Some safety tips specific to unpaved roads in drivers manual and on test might help
- Both drivers and road deficiencies cause serious problems
- Properly built and maintained, unpaved roads are much safer.
- Additional taxes should not be for paving but for maintaining
- Most people drive too fast
- Raise road bed
- Many people show no consideration for others
- Raise road base
- Warning signs are generally used for target practice
- The road is very washboardy in places, but people drive at excessive speed rates; 60 mph +
- Not safety, but signs should be put up indicating the private property
- Approaches to cattleguards are in terrible shape (Monument Rd.)
- A majority of the time it's not the road conditions that are the danger - It's the other driver.
- Roadway deficiencies have to be considered, however the driver's behavior, mental and physical condition are ultimately responsible.
- Washboarding is the roadway deficiency that most influences accidents
- Re-direct taxes from schools to areas such as roads
- Improve washboards
- Improve road in areas that drift
- Dramatically stiffer penalties for alcohol and drug abuse while driving. Same for Speeding
- I think the taxes that are already collected should be proportioned differently to allow more of them to be used on improving unpaved roads.
- People are careless when they get in the country
- Most people do not know how dangerous gravel roads can be even when dry. They usually drive on gravel to fast and loose control.
- Teach drivers to slow down on county roads.
- I do not feel that people should expect a year round smooth road for use from the county. If people do not assume a good road they will slow down some.
- I think people need to slow down on all dirt roads.
- I feel we need to be more efficient with the money budgeted for our road and bridge department.
- I feel that overall our county roads are good, The problem is with drivers who don't have "road sense."
- Snow fence would save money in the long run.
- Most accidents on dirt roads are caused by driver traveling too <u>fast</u>.

ALL UNPAVED ROADS (continued)

- (tax) On out of state vehicles, snowmobiles and hunting
- I don't feel there are that many accidents on county roads
- Out of state and city drivers are unsafe
- Town people speed on road
- For the amount of money that our road and bridge department gets, they do a great Job. We should take more money from the sheriffs department and tax out of state vehicles, snowmobiles, hunters, and fisherman to upgrade county roads.
- Road should be widened at the crest of hills
- Large rocks should be removed from borrow ditches.
- Raise roads in areas that are prone to catching snow.
- Replace all single cattleguards with doubles. I would rather see the road and bridge department get a larger % of the moneys available - Cut money from sheriff and jail
- I would like to see the road paved!
- I feel there is enough money, just not used properly
- I said in question 14.a., "no" to taxes, but if the tax money would be used to pave our county roads, I would be for that. I am from Wisconsin and we had no unpaved roads - Why?
- I have a star route mail contract from Marshall to Medicine Bow. Have had this for 48 years and also ranch. I expect I've driven this road more than any other person. Have never had an accident mostly because I know the road. But have come close on these blind hills a few times. The UPS driver was killed 3 years ago on bad curve 20 miles south of where I live and has been several roll-overs on this curve.

Safety Improvements Identified by Sheriff Deputies on all Albany County Roads

- Washboard roads need more attention. I have investigated numerous roll-overs due to loss of control on these roads.
- To widen a majority of the county roads seems to increase safety as well as make them easier to navigate. Most notable improvements have been areas such as Mandel Lane, and Big Hollow. To finish roads such as McGill, Forbes, and Dalles lane would help greatly. As would widening Fox Creek Road.
- Gravel, widen and remove washboards from Curtis street, Sand Creek, Brubaker Lane, and northern county roads.
- Brubaker Lane and Sandcreek Rd. - Intersection "Y" sign for East Bound traffic on Brubaker.

Safety Improvements Identified by UPS Drivers on all Albany County Roads

- Add Gravel on the Garrett road especially in duck creek stretch, delineation on curves, flatten steep shoulders
- Add gravel on county road 61 (Fetterman), 15 mile mark to Esterbrook turnoff
- Replace wooden bridges on Mandel Lane, Dalles Lane, Forbes Lane, Dinwiddy Road
- Add gravel on Dinwiddy road on the stretch between Highway 11 and the bridge on the Little Laramie
- Add gravel on Marshall Road, especially in Deadman's curve area
- Add Gravel on Brubaker Lane
- Utility poles on Duck creek area of Garrett Road
- Need warning signs at sharp curves and steep grades, and slippery when wet at no gravel stretches.
- All roads need warning signs
- All roads need warning signs

REFERENCES

1 Walzer, Norman, and David L. Chicoine, Rural Roads and Bridges, A Dilemma for Local Officials, U.S.D.A., Office of Transportation, Washington, D.C., 1989

2 Carstens, R.L., and J.V. Dickinson, Safer Construction and Maintenance Practices to Minimize Potential Liability by Counties from Accidents, Iowa Highway Research Board, HR-204, Iowa D.O.T., Ames, IO, 1979

3 Datta, Tapan K., Risk Management System, A Procedural Guide, Wayne State University, Detroit, MI, 1990

4 Wilson, Eugene M., Improving Safety on Low Volume Roads, Department of Civil & Architectural Engineering, University of Wyoming, Laramie, WY

5 Glennon, John C., Design and Traffic Control Guidelines for Low volume Rural Roads, NCHRP Report 214, Transportation Research Board, Washington D.C., 1979

6 USDOT Highway Safety Action Plan, Oregon Roads Newsletter, Oregon Technology Transfer Center, Salem, OR, Winter 1995-96

7 Yoder, Eldon J., Low Volume Roads, Transportation Research Board, Special Report 160, Washington, D.C., 1975

8 "The Basics of a Gravel Road Management System," Better Roads, November, 1995

9 South Dakota Department of Transportation, Office of Research, Publication SD95-16-G3, Rural Road Management Guide, Pierre, SD 1995

10 Eaton, R.A., S. Gerard, and D.W. Cate, Rating Unsurfaced Roads, A field manual for measuring maintenance problems, U.S. Army Corps of Engineers, Cold Regions Research & Engineering Laboratory, Special Report 87-15, August 1995

11 AASHTO survey on the status of sovereign immunity in the United States, 1983

12 Our Nation's Highways, Selected Facts and Figures, U.S.D.O.T., FHWA, Publication No. FHWA-PL-95-028, Washington, D.C., 1995

13 Harrington, W.G., Modern County Road Systems, Transportation Research Board, Special Report 160, Washington, D.C., 1975

14 Highway Safety Performance - 1992, U.S.D.O.T., Federal Highway Administration, Publication No. FHWA-SW-95-030, Washington, D.C., January 1995

15 Maynard, Theodore R., Maintenance and Rehabilitation of Local Streets and Roads, The Local Agencies' Dilemma, Chicago Department of Transportation,

16 Wilson, Eugene M. and R. Craig Caldwell, Variable Safety Improvements for Unpaved Roads, University of Wyoming, Laramie, WY, 1996

17 Oglesby, Clarkson H., Dilemmas in the Administration, Planning, Design, Construction, and Maintenance of Low volume Roads, Transportation Research Board, Special Report 160, Washington, D.C., 1975

18 Ivey, Don L. and Lindsay I. Griffin. Safety Improvements for Low Volume Rural Roads. Texas Transportation Institute, Texas A&M University, College Station, TX, 1992.

19 A Policy on Geometric Design of Highways and Streets. American Association of State Highway and Transportation Officials, Washington, D.C., 1994.

20 Polanis, Stanley F. Some Thoughts About Traffic Accidents, Traffic Safety and the Safety Management System. Institute of Transportation Engineers Journal, Vol. 65, No. 10, Washington, D.C., October, 1995.

21 Pline, James, and Eugene M. Wilson. Highway Capacity vs. Design Standards: The Low Volume Road Issue. Institute of Transportation Engineers, District 6 & 7 Joint Annual Meeting, Vancouver, B.C., July, 1986.

22 Handbook of Traffic Control Practices for Low Volume Rural Roads, Second Edition. Kansas Department of Transportation, Topeka, KS - Kansas County Engineers Association, 1991.

23 Driver Expectancy in Highway Design and Traffic Operations. U.S.D.O.T., FHWA, Report No. FHWA-TO-86-1, Washington, D.C., 1986.

24 FHWA Report No.TO-86-1, Driver Expectancy in Highway Design and Traffic Operations. USDOT-FHWA, Washington, D.C. May 1986.

25 Judycki, Dennis C. Highway Safety in the U.S.: Current Programs and Visions for the Future. Institute of Transportation Engineers Journal, Washington, D.C., July, 1991.

26 Highway Safety Improvement Program. Publication No. FHWA-TS-81-218. U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., 1981.

27 Safety Design and Operational Practices for Streets and Highways. U.S.D.O.T., FHWA, Technology Sharing Report 80-228, Washington, D.C., 1980.

28 Wallen, Martin A. "What Makes A Good Safety Management System?" ITE Journal, Volume 63, Number 1, January 1993, pp. 26-30.

29 Tort Liability, NACE action Guide Volume I-7. National Association of County Engineers, Washington, D.C., 1992.

30 Datta, Tapan K. "Roadway Defect Surveillance-A Personal Computer Based System." Institute of Transportation Engineers Journal. Washington, D.C., August, 1995.

31 ITE technical council committee 4s-7. "Road Safety Audit: A New Tool for Accident Prevention." ITE Journal, February 1995, Volume 65, Number 2, p. 15.

32 Croft, Peter. Guidelines and Standards for Traffic Safety Management. Australian Institute of Traffic Planning and Management 6th National Conference, Gold Coast, Queensland, June 1993.

33 Road Safety Audits. Austroads. Sydney, Australia, 1994.

34 Wortham, Sarah. "Make Safety Audits Work For You." Safety + Health. National Safety Council, Itasca, IL March, 1996.

35 Jordan, Philip W. "Road Safety Audit: The Australian Approach." Routes - Roads. Number 288, Paris, France September, 1995, pp. 77-85.

36 Ivanovic, Miomir. Methodology and Data Needs for Rural Accident Rate Analysis. M.S., Department of Civil Engineering, 1992.

37 Highway Safety Engineering Studies. Publication No. FHWA-TS-81-220. U.S.D.O.T., FHWA, Washington, D.C., 1981.

38 Highway Safety Evaluation. Publication No. FHWA-TS-81-219. U.S.D.O.T., FHWA, Washington, D.C., 1981.
39 Wilson, Eugene M., ed. Local Low Volume Roads and Streets. American Society of Civil Engineers, New York, NY 1992.
40 "How to Spot the Trouble Spots on Low Volume Roads." Interchange. Nebraska LTAP, Volume 07, Issue 03, April, 1993.
41 "Safety Improvements." NACE Action Guide. National Association of County Engineers, 1986.
42 Schwartz, David J., James A. Bonneson, and Patrick T. McCoy. Analysis of Policies for Safety Improvements on Low volume Rural Roadways. Dept. of Civil Engineering, University of Nebraska-Lincoln, with the Midwest Transportation Center, October, 1994.
43 McShane, William R. and Roger P. Roess. Traffic Engineering. Prentice Hall, Englewood Cliffs, NJ, 1990.
44 Walpole, Ronald E., and Raymond H. Meyers. Probability and Statistics for Engineers and Scientists, Fifth Edition. MacMillan, New York, NY 1993 pp. 335-339.
45 Linstone, Harold A. and Murray Turoff, eds. The Delphi Method: Techniques and Applications. Addison-Wesley Publishing Co. Inc., Reading, MA, 1975.
46 Hummer, Joseph E.. "Traffic Accident Studies." Manual of Transportation Engineering Studies. Institute of Transportation Engineers, Washington, D.C. 1994.
47 Wyoming's Comprehensive Report on Traffic Crashes, 1994. Wyoming Department of Transportation, Cheyenne, WY, 1995.
48 Highway Capacity Manual, Special Report 209. Transportation Research Board, National Research Council, Washington D.C., 1985.
49 Noyes, Patricia B. "Designing the Right Process for Involving the Public." Resource Papers for the 1996 ITE International Conference. Institute of Transportation Engineers, Washington, D.C., 1996, pp. 152-156.
50 Albany County Road Milepost System. Wyoming Department of Transportation Highway Safety Branch, in cooperation with the U.S.D.O.T., FHWA, 1994.