MOTORIST INFORMATION NEEDS AND CHANGEABLE SIGN MESSAGES FOR ADVERSE WINTER TRAVEL

Eugene M. Wilson, P.E., Ph.D.
Stephen G. Pouliot

University of Wyoming

May 1992

Technical Report Documentation Page

1. Report No. MPC 92-11	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Motorist Information Needs and Changeable Sign Messages for Adverse Winter Travel		5. Report Date May 1992 6. Performing Organization Code
7. Author(s) Eugene M. Wilson, P.E., Ph.D. and Stephen G. Pouliot		8. Performing Organization Report No.
9. Performing Organization Name and Address Department of Civil Engineering University of Wyoming Laramie, WY		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Mountain-Plains Consortium North Dakota State University Fargo, ND		13. Type of Report and Period Covered Project Technical Report 14. Sponsoring Agency Code

15. Supplementary Notes

Supported by a grant from the U.S. Department of Transportation, University Transportation Centers Program

16. Abstract

The purpose of this study was to evaluate motorist information needs during adverse winter travel conditions, and the application of this information to changeable message signs. Local commuters and interstate truck traffic along Interstate 80 in southeast Wyoming were the principle source of information. Laboratory studies, field surveys and supplemental surveys were used for the collection of data.

Specific objectives of this research were to identify and separate user groups within the study population; to identify information need consistencies within user groups for particular adverse winter travel conditions; to determine the priority of winter travel information needs; and to develop changeable sign messages to be displayed for different adverse weather travel conditions.

17. Key Words weather, road condition, travel condition, winter, changeable signs, messages	18. Distribution Statement		
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages 100	22. Price

This cooperative study was funded by the U.S. DOT's University Transportation Centers Program through the Mountain Plains Consortium, the Wyoming Transportation Department (WTD) and the University of Wyoming. Special recognition is given to the WTD efforts of Mike Gostovich, A. J. Schepp, Joe Yovich and members of the Traffic Operations Branch and the Laramie District who assisted in the data collection.

TABLE OF CONTENTS

LIST OF TABLES

Page

Page

Page

LIST OF FIGURES

Page

EXECUTIVE SUMMARY[1]

The purpose of this study was to evaluate the information needs of motorists during adverse winter travel conditions. Commuters travelling on Interstate 80 between Laramie and Cheyenne, Wyoming and interstate truck drivers were the primary sources of field data. During poor winter travel conditions, motorists were asked to evaluate wind, visibility and pavement conditions and assign a severity rating between '1' (ideal conditions) and '6' (road closed). The survey participants also indicated their desired road and travel information for changeable message signs (CMSs).

The results indicated that motorists have generally consistent adverse winter travel information needs. Pavement condition was the primary information desired. Visibility was the secondary needed information, however, when pavement condition was poor, visibility information became more important. The local commuters most often sought road and travel information from the winter travel advisory phone. The primary source for interstate truckers was the CB radio. The CMS was indicated as an important source by almost 70% of the local commuters and 40% of the interstate truckers surveyed.

---

[1]Eugene M. Wilson, P.E., Ph.D., Dept. of Civil Engineering, University of Wyoming, Laramie, Wyoming 82070

CHAPTER 1

MOTORIST INFORMATION NEEDS AND CHANGEABLE SIGN MESSAGES FOR ADVERSE WINTER TRAVEL

by

Eugene M. Wilson and Stephen G. Pouliot

On December 11, 1990, twelve motorists were killed and fifty others seriously injured during a 99-vehicle pileup due to heavy fog on rural Interstate 75. As a result, the Transportation Safety Board (TSB) heard testimony claiming that highway agencies did not do enough to warn the public about the hazards of driving in adverse weather conditions, and singled out changeable message signs (CMSs) as a countermeasure for further study (Roads and Bridges). A recent survey of state traffic engineers revealed that few guidelines have been established regarding the proper use of CMSs for motorist information during adverse weather conditions (French).

The purpose of this study was to evaluate motorist information needs during adverse winter travel conditions, and the application of this information to changeable message signs. Local commuters and interstate truck traffic along Interstate 80 in southeast Wyoming were the principle source of information. Laboratory studies, field surveys and supplemental surveys were used for the collection of data.

The specific objectives of this research were as follows: (1) to identify and separate user groups within the study population; (2) to identify information need consistencies within user groups for particular adverse winter travel conditions; (3) to determine the priority of winter travel information needs; and (4) to develop changeable sign messages to be displayed for different adverse weather travel conditions.

Chapter 2 gives a chronological history of changeable message signs from the early 1950s to the latest technologies being evaluated for the future. The chapter is also a review of the guidelines which have been established for changeable message signs in an advisory role.

Chapter 3 describes the study site and the methodology used to develop the various means of data collection. The field surveys, supplemental surveys and the laboratory study are all described in detail. Techniques used to analyze the data are also described. Chapter 4 presents the results of the study. The various relationships between the information needs of the motorist and adverse winter travel conditions are identified. Chapter 5 lists the conclusions of the study and gives recommendations for further studies.

CHAPTER 2

BACKGROUND AND LITERATURE REVIEW

HISTORY OF CHANGEABLE MESSAGE SIGNS

Variable message signs, or changeable message signs (CMS), are referred to briefly in the Manual on Uniform Traffic Control Devices (MUTCD) as "designed to have one or more messages that may be displayed or deleted as required. Such a sign may be changed manually, by remote control, or by automatic controls that can 'sense' the conditions that require special sign messages." Over the years CMSs have been used in applications ranging from simple regulatory changeable speed signs to the more advanced advisory route diversion signs in congested freeway corridors.

The first changeable message signs (CMSs) appeared in the mid-1950s as fixed message signs (Dudek). The signs consisted of several panels which could be inserted or removed manually to display appropriate messages. These early CMSs were designed and built for specific purposes and were highly non-flexible, lacking any 'real-time' display capabilities.

Predecessors to the scroll and drum type CMSs appeared in the late 1950s. In 1957, changeable message signs were used to control the flow of traffic through the third tube of the Lincoln tunnel between New York and New Jersey (Bender). On the New York side, the control of traffic was accomplished using mounted scroll signs which displayed three separate three-line messages. A message set was changed by rotating panels inside the sign enclosure. In New Jersey, a rotating drum sign was used to tell motorists that the direction of traffic was operating eastbound toward New York, and rotated to display a DO NOT ENTER message if the traffic through the tunnel was flowing into New Jersey. About the same time, a drum type CMS was installed on I-70 near St. Louis, Missouri to control two reversible lanes of traffic (Dorsey). Only one of the two messages could be displayed at a time. The appropriate message was displayed by rotating the triangular shaped drum to the desired message face. These rotating panel and drum display types provided 'real-time' message capability, but traffic engineers were realizing the need for even more flexibility.

In the mid-1960's commercial sign companies began to investigate the possibility of highway application for their designs (Dorsey). By the end of the decade, further advances in CMS technology produced several mechanical multi-message signs which were available to the transportation field. These "off-the-shelf" signs included a two-message mechanical flap sign, an eight-message scroll sign, and a multi-message mechanical drum sign. Also under development were two electrical/mechanical type signs. The first, called an electrostatic vane matrix, used electrostatic charges to change an array of aluminum wafers. The second, called an electromagnetic disk matrix, used an electrical current to induce magnetic charges to flip an array of magnetic disks. Mechanical flap, vane and disk matrix signs provided the increased message flexibility which was desired, but only messages which were 'fixed' into the sign could be displayed (Dudek).

Also during the late sixties, several CMSs became available which utilized light sources. Early attempts to display 'real-time' advisory information on accidents and adverse weather conditions came in 1962 using neon signs (Dorsey). A total of 64 multi-message radio controlled signs appeared on and near the New Jersey turnpike. The signs were electrically connected neon tubes formed to create five messages. The messages could be activated by illuminating the appropriate tubes to display the desired information. Lamp matrix CMSs were also introduced into the market about the same time. These lamp matrix CMSs consisted of either a continuous array or figuregram array, and had the capability to form alphanumeric characters including numbers from 1 to 99.

The early 1970s promised lower cost computer equipment and many CMS manufacturers began to incorporate computers and microcomputers into their designs[4]. This advancement provided CMS technology with unlimited message capability. The lamp matrix CMS soon became the most popular with highway agencies and was chosen for almost all freeway surveillance, control, and motorist information systems. The newer, less expensive computers gave the vane flap, and disk matrix signs the capability of receiving messages directly from a keyboard, as well as increased message storage and a higher degree of message verification (Dorsey).

With the onset of the energy crisis in the 1970s, a decline in the popularity of the lamp matrix CMS was unavoidable. A more energy efficient, circular reflective disk (CRD) matrix CMS came into dominance in highway application (Dudek). Although its initial cost was greater than the bulb matrix, the CRD matrix was perceived to have lower maintenance cost as well as lower energy consumption. Trailer mounted, rectangular reflective disk (RRD) matrix CMSs found popularity in highway work zones. Larger RRD matrix signs are currently being evaluated for traffic management applications in freeway corridors.

Because of their higher target value and legibility, light-emitting CMS technologies such as fiber optics, light-emitting diodes (LED), and liquid crystal display (LCD) have been proposed for highway use since the early 1970s (Dudek). Fiber optic, reflective disk, cathode ray tube and laser scan technologies have also been submitted as newer light emitting technologies, but indications are that they are not feasible for highway use at the present time.

Fiber optic CMSs are used widely in Western Europe on high-speed highways but their use in the United States has been hampered in the past for three reasons (Dudek):

(1) Early fiber optic signs were considered too dim for daytime use.

(2) Only fixed grid fiber optic signs with limited message content have been available.

(3) New shutter fiber optic signs with unlimited message capabilities were manufactured with maximum character heights of 12.6 inches (The Manual on Real-Time Motorist Information Displays (Dudek and Huchingson) recommends 18 inch character heights for urban freeways).

Improvements in fiber optic CMS technology has resulted in improved legibility characteristics and sign designs with larger character heights (16.5 inch) and unlimited message capability. These developments have renewed an interest in fiber optic technology in the United States.

The recent development of super-bright light-emitting diodes (LEDs), which provide good luminance for outdoor use compared to standard LEDs, has led to a greater interest in LED technology for changeable message signs (Dudek). A major advantage of the LED is that it is completely solid state and has no moving parts. This means lower maintenance costs compared to other light-reflective CMSs. Another advantage is that the average LED life expectancy is about 100,000 hours of operation or 12 years of CMS operation (Dudek).

Liquid crystal display (LCD) technology has been used in a variety of applications including computer monitors, calculators, watches and clocks. There have been no highway applications as of yet. The allure of the LCD is that there are no mechanical parts to the display so the operation and maintenance costs should be low. Existing applications have indicated that the legibility of the LCD is not sufficient enough for highway use.

Holography has been considered since the early 1970s for use in highway changeable message signing. Although specific highway designs have not yet been developed, several advantages and applications were identified by the Federal Highway Administration (FHWA) in a December 1986 report. Some of the advantages and applications listed by the FHWA are shown in Table 2.1. The FHWA reported that "this new technology has the capability of providing a new generation of safety and informational highway signing to complement and enhance those presently in use."

Light-emitting CMS technologies appear to provide better target value and legibility characteristics than their light-reflective counterparts (Dudek). However, under certain environmental conditions they are not without their problems. There is still much to be gained through investigation of the design and legibility characteristics of light-emitting CMS technologies.

ADVISORY CMS APPLICATIONS AND GUIDELINES

As the need for improvements in safety, operation and the use of existing highway facilities extends beyond the urban setting, so does the need for real-time information on high speed highways and rural interstates. Over the past 30 years, the applications of real-time CMS displays have been investigated within five general areas as reported by the National Cooperative Highway Research Program (NCHRP-61), see Table 2.2.

Table 2.1. Advantages and Applications of Holographic Highway Sign Designs (FHWA).

Advantages:

- For highway signs, three dimensionality will have little value. Major benefits will ensue from the rainbow of colors available.
- Directionality is the most important feature. Messages and/or colors can change as a function of viewing position.
- Retro-reflective signs could carry different messages when illuminated from different directions.
- Holographic signs which contain multiple messages may provide an economical and efficient means of displaying highway signs.

Applications:

- A three inch square hologram activated with car headlights could show "green" when approaching safely, "yellow" for caution, and "red" to warn if a driver is about to go off the highway.
- Holograms could be used for head-ups display (projection from the dashboard of a vehicle onto the inside of the windshield) in new vehicles.

SOURCE: Assessment of Changeable Message Sign Technology. Federal Highway Administration. Report No. FHWA-RD-87-025. December 1986.

Table 2.2. Applications of Changeable Message and Other Types of Real-time Displays (NCHRP-61).

I. Traffic Management and Diversion

- Freeway Traffic Advisory and Incident Management
- Freeway to Freeway Diversion
- Special Events
- Adverse Road and Weather Conditions
- Speed Control

II. Warning of Adverse Weather Conditions

- Adverse Weather and Environmental Conditions (fog, smog, snow, rain, dust, wind, etc.)
- Adverse Road Conditions (ice, snow, slippery pavement, high water, etc.)
- High Truck Loads

III. Control at Crossings

- Bridge Control
- Tunnel Control
- Mountain Pass Control
- Weigh Station Control
- Toll Station Control

IV. Control During Construction and Maintenance

- Warnings
- Speed Control
- Path Control

V. Special Use Lane and Roadway Control

- Reversible Lanes
- Exclusive Lanes
- Contraflow Lanes
- Restricted Roadways

SOURCE: <u>Changeable Message Signs</u>. National Cooperative Highway Research Program. Synthesis of Highway Practice 61. July 1979.

There are four types of operational problems to which CMSs would be applicable: (NCHRP-61) recurring problems, non-recurring problems, environmental problems and special operational problems. Environmental problems such as snow, ice, wind and fog, typically require real-time advisory information. Changeable message signs in an advisory capacity must meet at least four basic functional requirements to cultivate effective communication: credibility, comprehensibility, legibility and conspicuity (Dudek). The following discussion focuses on the guidelines associated with credibility and comprehensibility.

Credibility

The nature of advisory CMS's elicits different motorist perceptions than would static regulatory, warning or guide signs. In the case of advisory CMS, the driver needs to perceive the information as reliable, accurate (up-to-date) and timely.

Credibility can be established if information which is displayed is consistent with the best interest of the driver. Wattleworth, et.al. report that changeable speed-limit signs appeared to be effective up to a point where motorists detected the cause of a speed reduction. At this point, the motorist returned to "a more natural speed" and ignored subsequent speed-limit signs. Because most drivers prefer to receive their information at home, they are unwilling to reroute or cancel a trip once on the highway (Wash. State Trans. Center). If a motorist reroutes or cancels a trip based on information from a CMS, then the perceived time savings or reduced aggravation must be significant. It is unlikely that a motorist who has diverted will do so again if the convenience is perceived as minimal.

Motorists expect information about adverse travel conditions to be accurate, and therefore it is important to meet these expectations. Any information which can be disproved by the motorist will lose its credibility (Dudek). Continuation expectancy states that events of the immediate past will continue (Ogden). An example of a situation which violates continuation expectancy might be the message ICY ROAD displayed on a bright summer day. The driver loses faith in the CMS because it is unlikely that conditions will change to create an icy road. Maintaining consistency in the "key" words and type of information displayed along a chain of CMSs also gains credibility by enhancing continuation expectancy. The Washington State Transportation Center (WSTC) recommends keeping real-time information relevant, therefore accurate, by avoiding "filler" messages such as BUCKLE UP and HAVE A NICE DAY.

Advisory information which is consistently inaccurate may lead the motorist into expecting that the given information at any time "has always been wrong, and therefore will continue to be wrong." This type of expectancy, called "event" expectancy (Ogden), may well turn against the traffic engineer if not established immediately.

The memory of the motorist has two stages: short-term memory and long term memory (Ogden). The majority of information that enters the driver's memory is stored in short-term memory and fades after about thirty seconds. This implies that advisory information given to the motorist requires an immediate response or that the information should be posted in proximity to the location which is the subject of the display. This concept has met with success with respect to changeable speed-limit signs in heavy fog areas in California. In another study conducted by the Texas Transportation Institute, speed control signs were effective in stabilizing traffic speeds even when the speed reducing incident was not readily apparent (Stephens). The credibility of this advisory display required that it give accurate advance notice of adverse conditions as well as being up-to-date.

A list compiled by the Transportation Research Board (TRB) sums up the "credibility pitfalls to be avoided" (Table 2.3). This list was compiled from a review of the literature and through interviews with operations personnel and researchers.

Comprehensibility

Most of the information which the driver receives is visual, of which the majority is ignored because it is not perceived as relevant to the driving task (Ogden). It is important that the presentation of information which comes in the form of highway signing is clear and

Table 2.3. Credibility Problems of Changeable Message Signs (NCHRP-61).

1. Displaying inaccurate or unreliable information.
2. Displaying information too late for drivers to make appropriate responses (untimely information).
3. Displaying messages that drivers don't understand.
4. Displaying messages that are too long for drivers to read under prevailing highway speeds.
5. Not informing drivers of major incidents (adverse conditions) a large majority of the time.
6. Telling drivers something they already know.
7. Displaying information not related to environmental, roadway, or traffic conditions, or not related to routing.
8. Displaying garbled messages.

SOURCE: Changeable Message Signs. National Cooperative Highway Research Program. Synthesis of Highway Practice 61. July 1979.

concise. Confusing or unconventional messages and formats may result in a breakdown of the driving tasks.

The driving task requires information which will allow the driver to predict alternative actions, decide on the most appropriate action, execute the action, and observe the effects of the chosen action through reception and new information (Ogden). Advisory information signs are intended to provide the motorist with enough information to make a decision (Dudek). The message content of an advisory sign presents four elements,or distinct units of information:

(1) A problem statement (accident, maintenance, construction, etc.)

(2) An effect statement (delay, heavy congestion, etc.)

(3) An attention statement (addressing a certain group or audience)

(4) An action statement (what to do)

An example of a message containing these four elements is shown in Figure 2.1.

Each unit of information answers a question which the motorist might ask and typically consists of two words, although three or four is acceptable (Dudek). Minimally, the driver needs to have two questions answered: "What do I need to do?" and "Why do I need to do it?" The elements which answer these two questions are the action and problem statements.

Dudek suggests that no more than three units of information should be displayed at any one time, but that four units is acceptable if one of the units is minor and does not need to be recalled to take the appropriate action. Moreover, one unit of information may be displayed on two lines, but a single line should not contain more than two units of information.

ACCIDENT AT MILFORD STREET	<---- **Problem Statement**
HEAVY CONGESTION	<---- **Effect Statement**
UTOPIA TRAFFIC	<---- **Attention Statement**
USE WILLIAMS STREET	<---- **Action Statement**

Figure 2.1. The Four Elements of an Advisory Changeable Sign Message.

SOURCE: Dudek, Conrad L. Guidelines on the Use of Changeable Message Signs. Federal Highway Administration. Report No. FHWA-TS-90-043. July 1991.

The changeable message signs in the study area use a discrete display format (i.e. the message is displayed all at once). The presentation of messages in a discrete format can be accomplished in four manners: vertical, compact, chunk extended and message extended (Dudek). These four presentation methods are illustrated in Figure 2.2. For discrete displays on high speed highways, the formats recommended are the compact and the chunk extended. In the case of a three-line, compact display format, Dudek recommends that at least six seconds of exposure time be allowed for the motorist to read and comprehend the message. This format is being used for the CMSs in the study area.

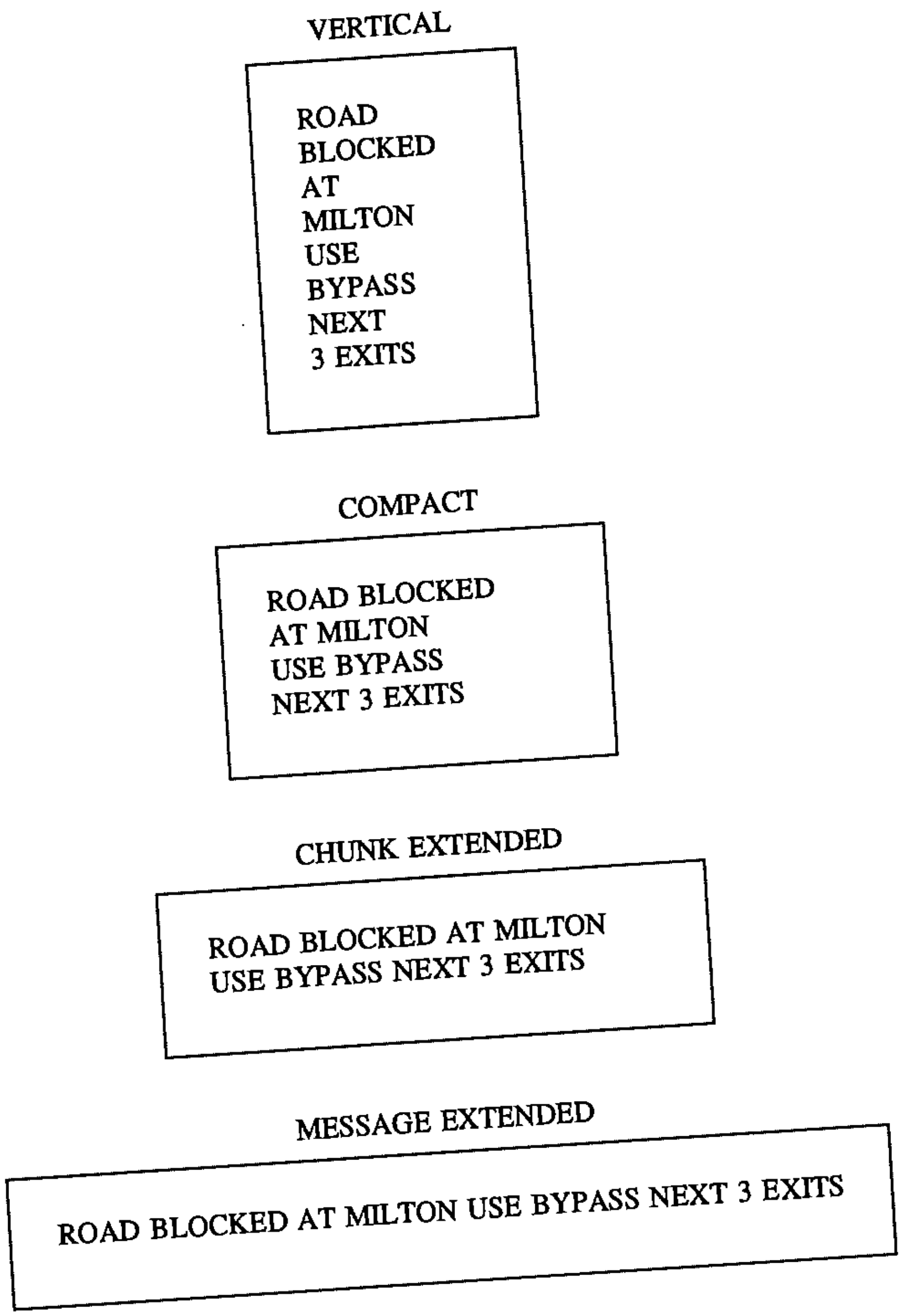

Figure 2.2. The Four Types of Discrete Display Formats.

SOURCE: Dudek, Conrad L. Guidelines on the Use of Changeable Message Signs. Federal Highway Administration. Report No. FHWA-TS-90-043. July 1991.

SUMMARY

The improvements made in changeable message signs over the past 30 years has increased their appeal for a wide variety of applications. The application of CMS to adverse winter travel advisories has not yet been thoroughly investigated.

A major problem to overcome in CMS road and travel advisories is the need for CMS credibility with respect to changing weather conditions. In the case of the CMSs under evaluation in this study, the information presented to the motorist must accurately describe road conditions in a span of about six to ten seconds of sign viewing time. This requires that the information is presented in such a way that the most important information is given first (on the top line) with secondary and tertiary information following. With such a brief amount of time allowed for the motorist to read and understand the information presented, the message must be short, explicit and yet maintain a level of comprehensibility for all motorists using the interstate.

CHAPTER 3

METHODOLOGY

FIELD STUDY OVERVIEW

During poor travel conditions the motorist is faced with many decisions regarding route choice, vehicle choice and speed of travel. Information which is credible and comprehensible must be provided. The primary objective of this study was to determine the information needs of the motorist in adverse winter travel conditions. The second objective of the study was to examine the priority by which adverse road and travel information is presented to the road user. Candidate messages for use on advisory changeable message signs during adverse winter travel conditions were also considered. The study was conducted from the beginning of the winter season in late October 1990 to late winter in December 1991.

The population surveyed consisted of local commuters in the Laramie and Cheyenne, Wyoming area and travellers passing through the study area on Interstate 80. The commuters were asked to keep a travel diary of their trips during adverse weather conditions between the two cities. Interstate truck drivers and travellers were surveyed through CB interviews and on-site interviews at coffee shops, restaurants and gas stations. The postcard survey was another method used to contact travellers within the study area. The postcards were distributed to various gas stations and restaurants which were near the interstate. Postcards were also left on the wind-shields of Cheyenne-bound vehicles during collegiate basketball games in Laramie when road conditions were poor.

The subjects were asked to evaluate the road and travel conditions within the study area during poor winter conditions, and give indications as to what road and travel information would help them make decisions about driving on the interstate. To evaluate the data, two methods were used: cross tabulation and a regression modelling technique.

The primary independent variables were chosen to describe the road and travel conditions which can exist on I-80. The variables chosen were broken down into four categories: time, wind, visibility and pavement. Levels of each of the four variables were assigned as follows:

TIME	WIND	VISIBILITY	PAVEMENT	
day	calm, breezy	clear	dry	snowpacked
night	strong, gusty	limited	wet	slick/spots
		very limited	slushy	icy

All combinations of these levels create a condition matrix of 72 (2x2x3x6) different cells. Figure 3.1 contains the 36-cell condition matrix for daytime operation. Each cell represents a combination of time, wind, visibility, and pavement conditions which a motorist may encounter on the highway. The lay-out and numbering of the cell blocks in the matrix was chosen so that it reflects a more severe condition as the numbers get larger, without respect to time (ie... cell block 29: very limited visibility, calm winds and slick in spots, is a more severe condition than cell block 10: clear visibility, strong and gusty winds and a snow-packed pavement surface). It was initially assumed that the pavement condition was the most influential factor on the severity rating, followed by visibility, wind, and time.

WIND	PAVEMENT	VISIBILITY		
		clear	limited	very limited
calm	dry	1	13	25
	wet	2	14	26
	slushy	3	15	27
	snow packed	4	16	28
	slick in spots	5	17	29
	icy	6	18	30
strong & gusty	dry	7	19	31
	wet	8	20	32
	slushy	9	21	33
	snow packed	10	22	34
	slick in spots	11	23	35
	icy	12	24	36

Figure 3.1. Condition Matrix for Daytime Operation.

The levels of the TIME (day or night) variable for the field study were established using the 1991 World Almanac. Daylight was defined as one half-hour before sunrise and one half-hour after sunset. During this span of time it was felt that the lighting conditions were favorable. The almanac gave precise times of sunrise and sunset at 40 degrees latitude. These times were averaged over a 15-day period for each month. The appropriate half-hour was then added or subtracted to give the time of daylight used to define the variable TIME. Daylight Savings was taken into account for the months of October and April.

The dependent variable chosen for the regression model reflects the severity of the road and travel conditions. For this dependent variable, a linear rating scale was established to rate the severity of adverse road and travel conditions. The linear rating scale was defined from '1' to '6', where '1' was an ideal driving condition and '6' was a condition in which the motorist believed the road should be closed. The road users were asked to rate the severity of the road and travel conditions on the rating scale and then identify the level of each independent variable which best described the road and travel conditions which they encountered (Figure 3.2). The dependent variable SEVERITY RATING was then modeled as a function of the independent variables TIME, WIND, VISIBILITY and PAVEMENT and their interactions.

In many cases, the motorists encountered more than one pavement condition during their trip. As a result, the motorist described the pavement condition by selecting several levels of the variable PAVEMENT. Because the nature of the analysis allows for only one level to be selected for each variable, the multiple PAVEMENT levels were consolidated using sound reasoning and judgement. For example, if the PAVEMENT levels 1 (dry), 5 (slick in spots) and 6 (icy) were all selected, the pavement condition would be assigned the level 5, slick in spots. Dry and icy pavement conditions imply that the road was slick in spots, and since this level had already been selected, the PAVEMENT variable was assigned the value 5. The most frequent combinations of the PAVEMENT variable and assigned values are presented in Table 3.1.

LINEAR RATING SCALE FOR ADVERSE WINTER TRAVEL CONDITIONS

1	2	3	4	5	6
Ideal Travel					Road Closed

SELECTIONS FOR ADVERSE WINTER TRAVEL CONDITIONS

Wind Condition
1. Calm to breezy
2. Strong and gusty

Visibility Condition
1. Clear
2. Limited
3. Very Limited

Pavement Condition
1. Dry
2. Wet
3. Slushy
4. Snowpacked
5. Slick in Spots
6. Icy

Figure 3.2. Linear Rating Scale and Adverse Winter Travel Conditions

Table 3.1. Combinations of Pavement Conditions and Assigned Values.

DR=(dry) WT=(wet) SL=(slushy)

SP=(snowpacked) SS=(slick in spots) IY=(icy)

COMBO #	PAVEMENT CONDITIONS	EQUIVALENT
1	DR WT	WT
2	DR SP	SS
3	DR IY	SS
4	DR SS	SS
5	DR SL	SL
6	WT SL	SL
7	WT SP	SS
8	WT SS	SS
9	WT IY	SS
10	SL SP	SP
11	SL IY	IY
12	SL SS	SS
13	SP SS	SS
14	SP IY	IY
15	SS IY	SS
16	SP SS IY	SS
17	WT SL SS	SS

Table 3.1 continued.

COMBO #	PAVEMENT CONDITIONS	EQUIVALENT
18	WT SL SP SS	SS
19	DR SP SS	SS
20	WT SP IY	SS
21	WT SL SS IY	SS
22	DR WT IY	SS
23	WT SL SP SS IY	SS
24	WT SL SP	SP
25	SL SP SS IY	SS
26	WT SP SS IY	SS
27	SL SS IY	SS
28	DR SS IY	SS
29	WT SP SS	SS
30	WT SL IY	IY
31	SL SP IY	SP
32	WT SS IY	SS
33	DR SP IY	SP
34	SL SP SS	SS
35	WT SL SP IY	SP
36	DR WT SL	SL

Other data were gathered to describe the population characteristics and vehicle type. User characteristic variables were chosen as age, sex, experience, and the motorists' winter driving confidence. The vehicle type was to describe the vehicle used by the motorist in adverse road conditions.

The experience the motorist had driving in adverse weather conditions was obtained in three separate questions, each with its own levels of response. The first question determined the number of miles the motorist drove yearly. The second question identified the driver's experience driving outside the city during the winter season, and finally, experience was defined as a percentage of these trips driven in adverse road conditions. In addition, the motorists' experience driving in Wyoming was categorized by the origin of their vehicle license plates (local Wyoming county 2 or 5, non-local Wyoming, and out-of-state).

Identifying the confidence a person had in their driving skill and ability was obtained by asking the motorist two questions. First, the motorist was asked to select the statement which best described their winter driving confidence during adverse weather conditions. Second, the motorist was asked to select the statement which best described how they would use information given to them about poor road and travel conditions.

Two classes of vehicle type were identified as commercial freight and passenger vehicles and each was separated into further sub-groups:

COMMERCIAL FREIGHT	PASSENGER VEHICLES	
Single Trailer	Car	Van
Double Trailer	Truck	Delivery Van/Truck
Other	Pickup	Recreational Vehicle

An additional question was added to the study to identify the sources (TV, radio, CMS, etc...) being used to determine road and travel conditions. Thirteen choices were given including 'none' and 'other'.

For each observation made in the field, the motorist was asked to give the date, time, direction of travel and if the road and travel conditions reduced their travel speed. Following this were questions regarding the nature of the trip such as, was the trip necessary and would the trip have been canceled or delayed given the information they wanted. Finally, a question was asked about the appropriateness of the CMS message displayed by the Wyoming Transportation Department during the adverse road and travel conditions (if one was given).

THE STUDY AREA

The study area was limited to a 41 mile section of I-80 between Laramie, Wyoming (elevation 7,165 feet) and Cheyenne, Wyoming (elevation 6,062 feet). Figure 3.3 illustrates the study area. The two CMSs under evaluation are located on the outskirts of both cities. The Laramie CMS is located immediately east of Laramie over eastbound I-80 and the Cheyenne CMS is located two miles west of Cheyenne over westbound I-80. Both CMSs are drum-type signs with three lines of copy. The first two lines of copy each consist of one six-sided drum with the capacity to hold a 24 character message per line. The last line of copy consists of two six-sided drums end-to-end, with the capacity to hold an 18 character and a 6 character message respectively (see Figure 3.4). Each of the four drums can be rotated separately from the others to display the appropriate message.

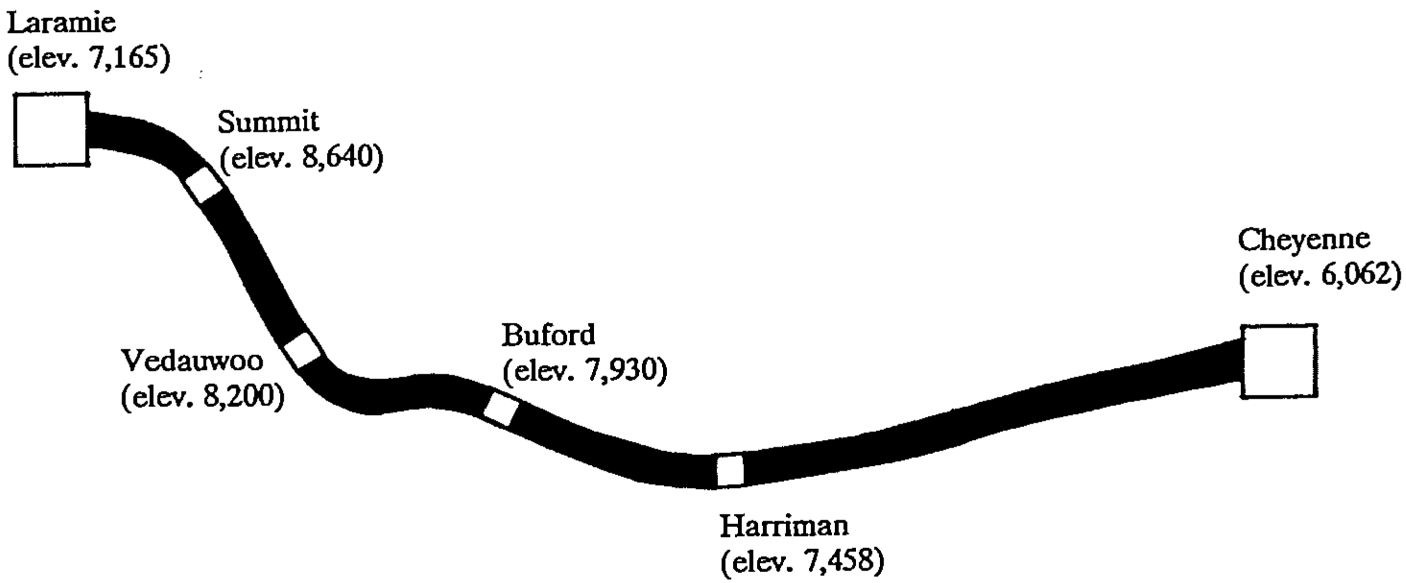

Figure 3.3. Map of the Study Area.

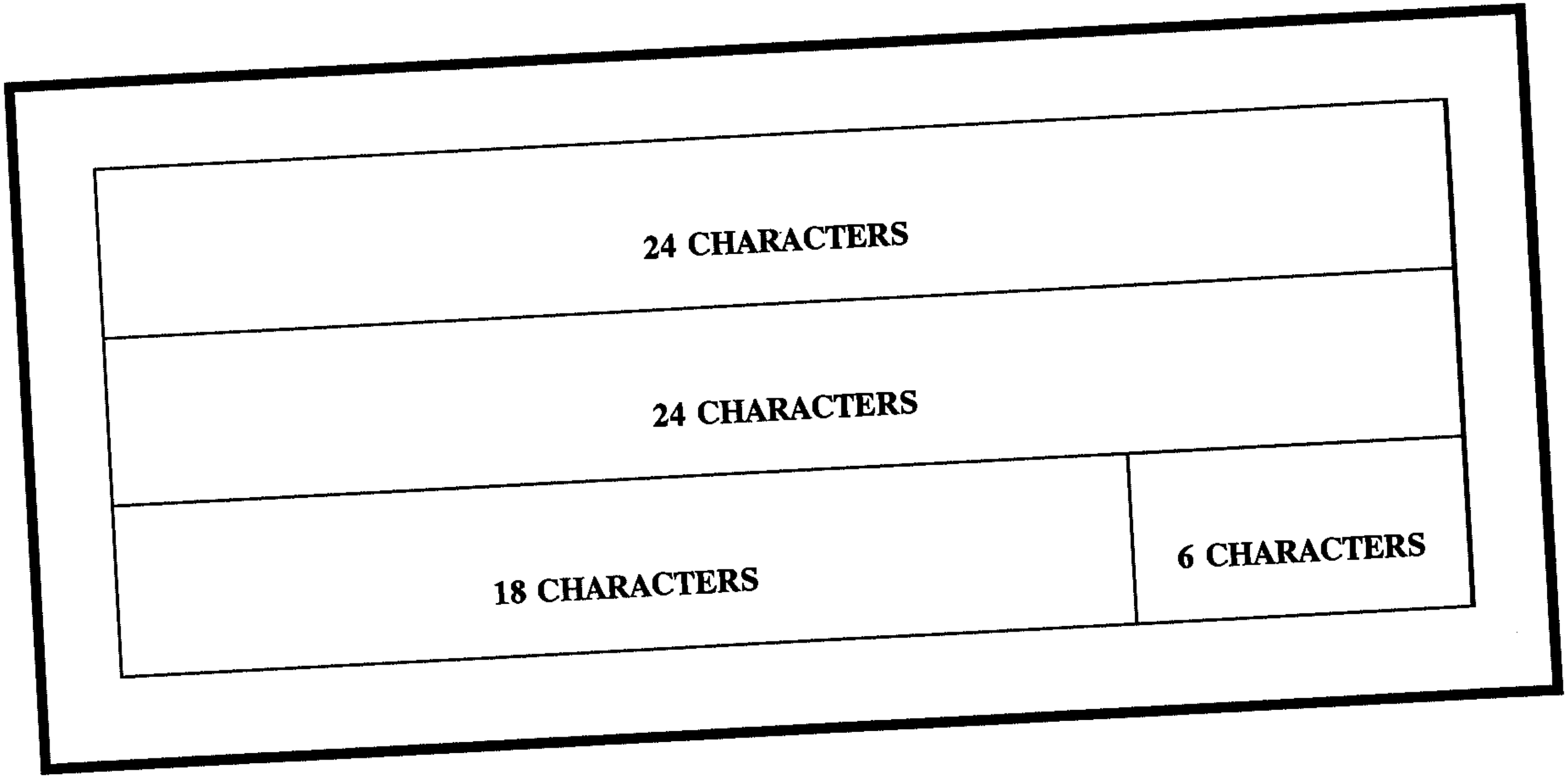

Figure 3.4. Drum and Display Configuration of the Study Area CMSs.

The study area is prone to high winds, poor pavement conditions, and low visibility problems due to inclement winter weather patterns. The highest elevation within the study area exists at a point seven miles east of Laramie, known as the Lincoln Monument or the Summit (elevation 8,640 feet). The lowest elevation occurs at the eastern most point of the study area in Cheyenne, a difference of 2,578 feet. The terrain is mostly flat with open plains near Cheyenne, becoming more hilly and rolling approaching the Summit where the terrain turns mountainous.

The extreme differences in elevation and terrain often cause hazardous driving conditions to occur in isolated areas of the interstate. Where it might be fair weather and clear in both Laramie and Cheyenne, fog and heavy snowfall may be present near the Summit, causing poor visibility and icy pavement conditions. For this reason, there has been some difficulty advising motorists of adverse road and travel conditions through the existing CMSs in the study area.

FIELD SURVEYS

Field data were collected by three methods: travel diaries, interview forms, and postcards. Samples of each data collection method are presented in Appendix A. The travel diary users were made up entirely of commuters between Laramie and Cheyenne, Wyoming. Most commuters were identified through the University of Wyoming Campus Directory as persons who listed both permanent and school addresses in Cheyenne. More were recruited at a commuters carpool meeting in Cheyenne, through flyers posted in various campus, city, and state buildings in both cities, through newspaper and radio ads, and by word of mouth. All persons were contacted by telephone to determine their willingness to participate in the study. Those who were interested were sent a numbered travel diary with instructions on its use. A record was kept of each volunteer's name, diary number, address, and home phone. A total of 235 diaries were sent out during the spring of 1991 and an additional 270 diaries were sent out during the fall of 1991. Figure 3.5 contains a primary page of the travel diary.

The interview forms were designed to be used at pre-determined sites on days when adverse road and travel conditions existed. Sites were chosen based on proximity to interstate on/off ramps and type of population using the site. Typical sites were truck stops, large filling stations, and restaurants. Interviewers (Wyoming Transportation Department employees) were to ask the questions on the form to persons just travelling on the interstate between Cheyenne and Laramie. The interviews did not contain questions about winter driving confidence.

After several failed attempts to predict adverse weather conditions several days in advance, interviews on-site were carried out at the discretion of the interview team supervisors at the Wyoming Transportation Departments (WTD) in Cheyenne and Laramie. With advice from the WTD, CB radio interviews were implemented because the on-site interviews were not cost effective. Due to the limited range on the CB, only a few minutes of time were allowed for each interview, consequently the amount of data collected for each interview was reduced. The majority of the interviews were made over the CB radio (337) and the remainder on-site (56).

Postcard surveys were developed to be left in small boxes on restaurant and gas station counter tops around Cheyenne and Laramie as the primary means to obtain non-resident passenger car data. The boxes of postcards contained a brief explanation of the survey and instructions on how to complete the survey. The postcards were intended to be

TRIP #1

Date: ______________

Trip departure time: ______________ AM PM

Trip arrival time: ______________ AM PM

Direction of travel: ______
1. Eastbound
2. Westbound

On a scale of 1 – 6, how would you rate the road and travel conditions of your trip between Cheyenne and Laramie? ______

1 best   2   3   4   5 worst   6 road closed

How would you rate the visibility condition? ______
1. Clear
2. Limited
3. Very limited

Was there snow blowing across the roadway (ground blizzard)? ______
Y – yes   N – no

How would you rate the wind condition? ______
1. Calm to breezy
2. Gusty to strong

How would you rate the pavement condition? ______
1. Dry
2. Wet
3. Slushy
4. Snow–packed
5. Slick in spots
6. Icy

Did these conditions cause you to reduce your travel speed? ______
Y – yes   N – no
If yes – by how much did you reduce your speed? ______mph
(round to nearest 5 mph – ie... 10, 15, 20, etc...)

What information would you like to have seen on the changeable message sign before you began the trip between Cheyenne and Laramie?
____
____
____
____

If you were given the above information on the changeable message sign, would you have cancelled or delayed your trip? ______
Y – yes   N – no

Was the trip you just made an essential trip? ______
Y – yes   N – no

Was the message sign (CMS) on? ______
Y – yes   N – no
If yes – was the message appropriate? ______
Y – yes   N – no

Comments:

Figure 3.5. Sample Diary Page.

quick and easy to fill out and did not contain questions about experience or confidence. The idea was to have the motorist take a postcard either before or after a trip between Cheyenne and Laramie, fill the card out, and mail it back post-paid. The postcard survey was also left on the windshields of Cheyenne-bound vehicles during collegiate basketball games in Laramie. A total of 1400 postcards were distributed during the course of the study (800 counter-top, 600 windshield). The countertop surveys were limited to only 57 returned postcards and the windshield survey returned 107 postcards.

SUPPLEMENTAL SURVEYS

Three follow-up surveys were sent to diary users during the course of the study. The first survey was designed to identify the messages which were of the most benefit to the motorist. The second survey evaluated the use of a six-point road rating system with respect to the different conditions existing within the study area. The third survey evaluated combinations of three-line messages for different adverse winter travel conditions. A simple frequency analysis was used to analyze each of the surveys. The surveys were developed specifically to apply the results to the CMSs in the study area.

Survey One

The purpose of the first survey was to investigate the suitability of CMS messages for adverse road and travel advisories (see Figure 3.6). Fourteen CMS messages were developed based on motorist responses from the field data in the winter of 1990-91. The survey was sent to 235 diary users. The diary users were asked if they had ever made a trip relying only on the CMS for road and travel information. The diary users were also asked to answer

Road users reported that they use several options to obtain road and travel information including radio reports and the road and travel telephone number during times of bad weather. Did you ever make a trip during bad weather relying **only** on information provided by the changeable message sign? __YES __NO

Understanding that specific location and severity of winter road and travel conditions cannot be displayed, which of the following messages would benefit you if the changeable message sign were your **only** source of information? Please check yes, no, or maybe.

WIND GUSTS TO XX MPH	__YES __NO __MAYBE
HEAVY FOG AHEAD	__YES __NO __MAYBE
AREAS OF SNOWPACK	__YES __NO __MAYBE
ICY ROAD AHEAD	__YES __NO __MAYBE
CAUTION: SLICK SPOTS	__YES __NO __MAYBE
CAUTION: STRONG WINDS	__YES __NO __MAYBE
CAUTION: POOR VISIBILITY	__YES __NO __MAYBE
SLIPPERY ROAD AHEAD	__YES __NO __MAYBE
REDUCED VISIBILITY AHEAD	__YES __NO __MAYBE
AREAS OF BLOWING SNOW	__YES __NO __MAYBE
CAUTION: WATCH FOR ICE	__YES __NO __MAYBE
STRONG WINDS POSSIBLE	__YES __NO __MAYBE
DRIFTING SNOW AHEAD	__YES __NO __MAYBE

Would you like to see a rating of the overall road and travel condition, where rating 1 = Excellent, 5 = Very Poor, and 6 = Road Closed? __YES __NO __MAYBE

Figure 3.6. Sample of Survey One Sent to Diary Users.

"YES", "NO", or "MAYBE" as to whether or not any of the 14 given messages would be of benefit to them if the CMS was their only source of information, and if they would like to see a road rating system for adverse winter travel conditions.

Survey Two

The purpose of the second survey was to evaluate the use of a road rating system for the CMS, and identify rating consistencies for a series of different adverse road and travel conditions (see Figure 3.7). The survey was based on the response to the first survey and concerns the changing weather patterns at any given moment along Interstate 80. The survey was sent to 240 diary users. The diary users were asked to label a rating scale from 1-6 with terms describing the severity of adverse winter travel conditions. Considering their own scale, users were also asked to rate six adverse winter travel conditions which described differences in both the severity and exposure time of the adverse conditions along the interstate.

Survey Three

The purpose of the third survey was to identify three-line CMS message combinations to be used during adverse winter travel conditions (see Figure 3.8). This final survey tied together the first and second surveys, incorporating the chosen messages from survey one and the road rating system evaluated in survey two. The survey was sent to 240 diary users. Six descriptions of adverse road and travel conditions were given along with two message choices for each of the three lines on the CMS display. For each description, the diary users were asked to select the most appropriate message for each line of the CMS display.

If a 1-6 Road Rating System were used on the CMS, what terms would you use to describe the increasing severity of winter road conditions?

Dry Roads---> Road Closed

1	2	3	4	5	6
______	______	______	______	______	______

The following statements describe several daytime road and travel conditions which may occur on I-80 between Cheyenne and Laramie. Please read each statement carefully, then rate the severity of the road and travel conditions described. Use the 1-6 rating scale considered above. If your rating would be different at night, then put the night rating in the brackets.

Day [Night]

1. Heavy fog and wet pavement between the Lincoln Monument and Harriman, otherwise, the conditions are dry and clear. ____[ ]

2. Strong wind and reduced visibility from Cheyenne to Laramie, with areas of snowpack and drifting snow. ____[ ]

3. Snowpacked to icy pavement conditions between Buford and Laramie, otherwise pavement conditions are wet to snowpacked. ____[ ]

4. Areas of blowing snow (ground blizzards) between the Lincoln Monument and Harriman. Strong wind and dry roads for the entire trip. ____[ ]

5. Icy pavement conditions from Vedauwoo to the Lincoln Monument, otherwise conditions are dry. ____[ ]

6. Slushy pavement conditions from Laramie to Buford with snowfall continuing into Cheyenne. ____[ ]

Figure 3.7. Sample of Survey Two Sent to Diary Users.

Listed below are six road and travel conditions which may occur on I-80. Accompanying each condition are three CMS message lines which are being considered for future use. For each line, if there is a choice, circle the message you find most appropriate.

Example: Heavy rainfall and strong winds over all of I-80.
LINE 1: blank or SLIPPERY IN SPOTS
LINE 2: REDUCED VISIBILITY
LINE 3: blank or CONDITIONS: POOR

---

1. Thick fog extending from Cheyenne to the summit. Wet road in some places.
LINE 1: blank
LINE 2: HEAVY FOG AHEAD
LINE 3: CONDITIONS: POOR or CONDITIONS: VERY POOR

2. Between Laramie and Buford there is heavy snowfall and the road is snow-packed and icy.
LINE 1: SLIPPERY IN SPOTS or ICY ROAD AHEAD
LINE 2: REDUCED VISIBILITY
LINE 3: CONDITIONS: POOR or CONDITIONS: VERY POOR

3. Dry road and strong winds. Ground blizzards near Vedauwoo and the summit.
LINE 1: blank or DRIFTING SNOW
LINE 2: BLOWING SNOW
LINE 3: blank or CONDITIONS: POOR

4. Snow-packed to slushy road conditions with snowfall and fog between the summit and Buford. Conditions elsewhere are slick in spots and clear.
LINE 1: SLIPPERY IN SPOTS or ICY ROAD AHEAD
LINE 2: REDUCED VISIBILITY or HEAVY FOG AHEAD
LINE 3: CONDITIONS: POOR or CONDITIONS: VERY POOR

5. Slushy road conditions from Laramie to Vedauwoo, becoming dry towards Cheyenne.
LINE 1: blank or SLIPPERY IN SPOTS
LINE 2: blank or FASTEN SEATBELTS
LINE 3: blank or CONDITIONS: POOR

6. Heavy snowfall, blowing and drifting snow across all of I-80 between Laramie and Cheyenne. Road conditions are snow-packed and slick.
LINE 1: DRIFTING SNOW or ICY ROAD AHEAD
LINE 2: REDUCED VISIBILITY or BLOWING SNOW AHEAD
LINE 3: CONDITIONS: VERY POOR or CONDITIONS: SEVERE

Figure 3.8. Sample of Survey Three Sent to Diary Users.

THE LABORATORY STUDY

The purpose of the laboratory study was to evaluate motorists' perceptions of adverse winter travel conditions which were not actually experienced. The results of the laboratory analysis were to be compared to the results of the field analysis. Six different slide shows were used to evaluate motorist responses to combinations of road conditions. Each slide show gave the subject a look at 12 statements describing a combination of time, wind, visibility and pavement conditions, where each statement represented one of the 72 cells in the condition matrix. An example of a statement on a slide which was used to describe the road and travel conditions would be:

You are driving at night and there
is no wind. The road is slick in spots and
the visibility is limited due to snowfall.

The 72 cells in the condition matrix were divided among the six slide shows using an incomplete block design. The design used allowed each level of each variable to be viewed an equal number of times during the 12 slides in a slide show. For instance, the two levels of wind conditions (calm, strong and gusty) were combined with the other variables (time, visibility, pavement) six times each. The three levels of visibility conditions (clear, limited, very limited) were combined with the other variables four times each. The same design was applicable to the remaining two independent variables. The main effect combinations were selected using a manual trial and error approach so that each of the four main effects were equally represented within each category.

The subjects for the laboratory study came from groups representing fraternities, sororities, engineering classes, special interest groups, Kiwanis, and Lions clubs. Each group viewed only one slide show. A total of 276 subjects were evaluated for 3,288 observations. The smallest group consisted of 17 individuals, while the largest group contained 28 individuals. The minimum number of observations in a cell was 36, while the maximum number in a cell was 54.

A lab booklet was provided to the subjects to collect user characteristic data and the severity ratings of the 12 road and travel conditions to be evaluated. Figure 3.9 contains a sample response page from the lab booklet. Each subject was briefed on the purpose of the study and the procedure which was to be followed. They were asked to assume they were driving on the interstate and imagine what it would be like to encounter the conditions described by the statement on the slide.

The subjects then gave a severity rating between '1' and '6' to each statement and indicated what information should be displayed on the CMS. The subjects also indicated whether or not they would cancel or delay their trip given the desired information.

STUDY PROCEDURES

One objective of the study was to determine the information needs of the motorist during adverse winter travel conditions. In each of the field surveys and lab study the subjects were asked to list the information they would like to have on the changeable message sign during a particular adverse winter travel condition. The analysis of the information needs required each response to be coded in the following manner. Each bit of information identified by the motorist was categorized as wind, visibility, or pavement

▼
669

CONDITION RATING:

1 2 3 4 5 6

"ideal conditions" "close the road"

Information needed / Sign should read (Please be specific):

____

____

____

If you were given this information, would you delay or cancel the trip?

Trip is essential: Yes ___ No ___

Trip is non-essential: Yes ___ No ___

▼
319

CONDITION RATING:

1 2 3 4 5 6

"ideal conditions" "close the road"

Information needed / Sign should read (Please be specific):

____

____

____

If you were given this information, would you delay or cancel the trip?

Trip is essential: Yes ___ No ___

Trip is non-essential: Yes ___ No ___

Figure 3.9. Sample Response Page from the Laboratory Booklet

information. In each of these categories, a number from 1 to 100 was assigned to the bit of information. Like bits of information were assigned the same number within the appropriate category. Information which was not appropriate to any category was assigned to the category with the most available numbers left. By coding the information bits in this manner, any information wanted by a motorist could be cross-tabulated with a particular date or combination of adverse travel conditions. Cross tabulation analysis was performed by the Statistical Analysis System (SAS) computer program.

In order to establish consistency in the road conditions of the field survey, the information needs of the motorist were tabulated on particular dates when the weather was poor. Twenty-five dates were selected which contained at least 20 observations of road conditions by the motorist. A cross table was made of each information need category with the 25 dates. After reviewing the number of responses on each date, it was felt at least ten information bits had to exist on the date being investigated in order to evaluate the data. An example of this procedure using the visibility information data is shown in Table 3.2. The bits of information were grouped by "key" words being used by the motorists. The frequencies of the key words were then compiled for a particular date and summed across all dates to identify the most commonly requested pieces of information. As an example in Table 3.2, the date 3/5 contained six requests for visibility information having the key words SNOWFALL, three requests for HEAVY SNOWFALL and one request each for BLOWING /DRIFTING SNOW, REDUCED VISIBILITY, FOG and LIMITED VISIBILITY. Summing the key-word frequencies over the selected dates, the top four most requested key words were SNOWFALL, BLOWING/DRIFTING SNOW, FOG and REDUCED VISIBILITY. These key words were then considered as possible candidates for use in describing adverse travel

Table 3.2. Sample Visibility Information Needs Analysis Procedure.

KEY WORDS	DATE 91 2/25	91 3/5	91 4/12	91 4/18	91 11/15	91 11/16	91 11/19	91 11/20	91 12/2	TOTAL
snowfall	1	6	2	2	1	1				13
blowing/drifting snow	2	1	2	1			3	3		12
fog					9	2				11
reduced visibility	1	1						2	4	8
fog, limited visibility		1		3	2		1			7
ground blizzard							3	2	1	6
heavy snowfall		3	2	1						6
limited visibility		1			2	2	1			6
poor visibility	1		1		2				2	6
limited visibility, snowfall			3				2			5

conditions to motorists. The same procedure was used for the wind and pavement information.

Another objective of the study was to examine the priority by which adverse road and travel information was to be presented to the road user. Regression procedures were used to develop the severity rating as a function of the main effects variables and their interactions. The parameters in the chosen model were then standardized and ranked in order of magnitude to give a relative importance to the variables.

The best regression model was initially chosen using the SAS STEPWISE regression procedure. The procedure begins with no variables in the model and selects variables with F statistics significant at a specified level ($\alpha = .15$). After a variable is added, F statistics for all variables in the model are recalculated and again compared to the specified level. A variable which does not meet the .15 alpha level is removed from the model. The procedure stops when there are no more significant variables which can be added to the model. Although this procedure is adequate for finding models with all variables being significant to the model, it does not necessarily find the model with the largest coefficient of correlation (R^2). The SAS RSQUARE procedure was used to help identify the model which would best predict the dependent variable - SEVERITY RATING. The R SQUARE procedure selects model subsets based on the optimal R^2 value in that subset. While neither procedure selects the "true" model, they can be used to identify the best model for the data. The best model was chosen as the one which offers the best R^2 value and contains only variables which are significant to the model.

After the best model was chosen, the SAS regression procedure was used to calculate the parameter estimates and evaluate the significance of each. The parameter estimates were then standardized by dividing the estimate by the ratio of the sample standard deviation of the dependent variable to the sample standard deviation of the regressor (regression option /STB). By standardizing the parameter estimates in this manner, the estimates can be evaluated by their relative importance to the model. Ranking the standardized parameter estimates in order of decreasing magnitude gives the priority by which information is to be presented to the road user.

A check on the normality of the data was also performed for the regression model. A plot of the residuals of the fitted values versus their normal scores in a standard population was analyzed for non-normality in each case. The correlation coefficient for the plot was checked against Table 3.3 (Neter et al). For example, the residuals plot of the data in the local driver group in Figure 3.10 has a correlation coefficient of $R^2 = .990$ (perfect correlation = 1.00). From Table 3.3 the critical value is .987 (level of significance = .05, n > 100) which is less than .990 indicating that the assumption of normality is not rejected.

A check for constant variance of the data was also performed. Plots of the residuals versus their fitted values and main effects (TIME, WIND, VISIBILITY and PAVEMENT) were analyzed for each analysis. The plots were analyzed for non-random patterns in the variance of the residuals. An example plot of the residuals versus the fitted values of the local data in Figure 3.11 shows a random pattern of points, indicating constant variance of error terms. The plot reveals a distinct "striped" pattern in the data. The "striped" pattern of the plot in Figure 3.11 is due to the function of the severity rating's discrete linear scale and consequently the vertical distance between each "stripe" on the plot is exactly one unit. To better illustrate this point, consider the following equation;

$$Y - Y_{fit} = e$$

where: $\underline{Y}$ = a discrete linear value
$\underline{Y_{fit}}$ = a continuous linear value
$\underline{e}$ = the residual value.

Table 3.3. Critical Values for Coefficient of Correlation between Ordered Residuals and Expected Values under Normality when Distribution of Error Terms is Normal.

n	Level of Significance		
	.10	.05	.01
5	.903	.880	.826
10	.934	.918	.879
15	.951	.939	.910
20	.960	.951	.926
25	.966	.959	.939
30	.971	.964	.947
40	.977	.972	.959
50	.981	.977	.966
75	.987	.984	.976
100	.989	.987	.982

If $\underline{Y}$ is equal to some discrete value $\underline{k}$ (1, 2,..., k) and $\underline{Y_{fit}}$ is equal to a continuous value $\underline{f}$ (1-f), then $\underline{e}$ can only be equal to values one unit apart at each value of $\underline{Y_{fit}}$. Hence the "stripes" on the residual variance plot. The "striping" pattern of the data is of no concern and the plot indicates that there is constant variance among the residuals.

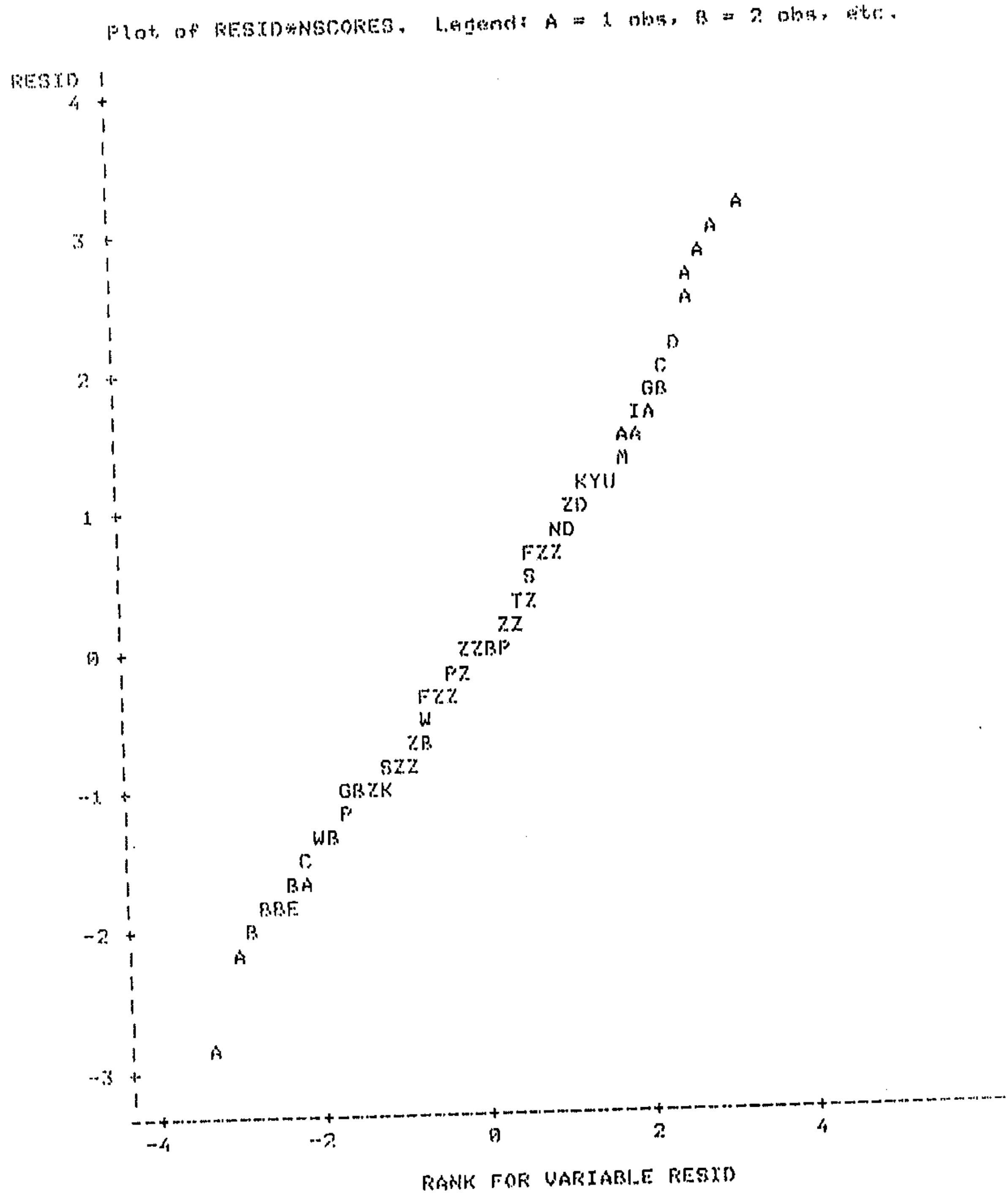

Figure 3.10. Residual Plot for the Local Driver Data.

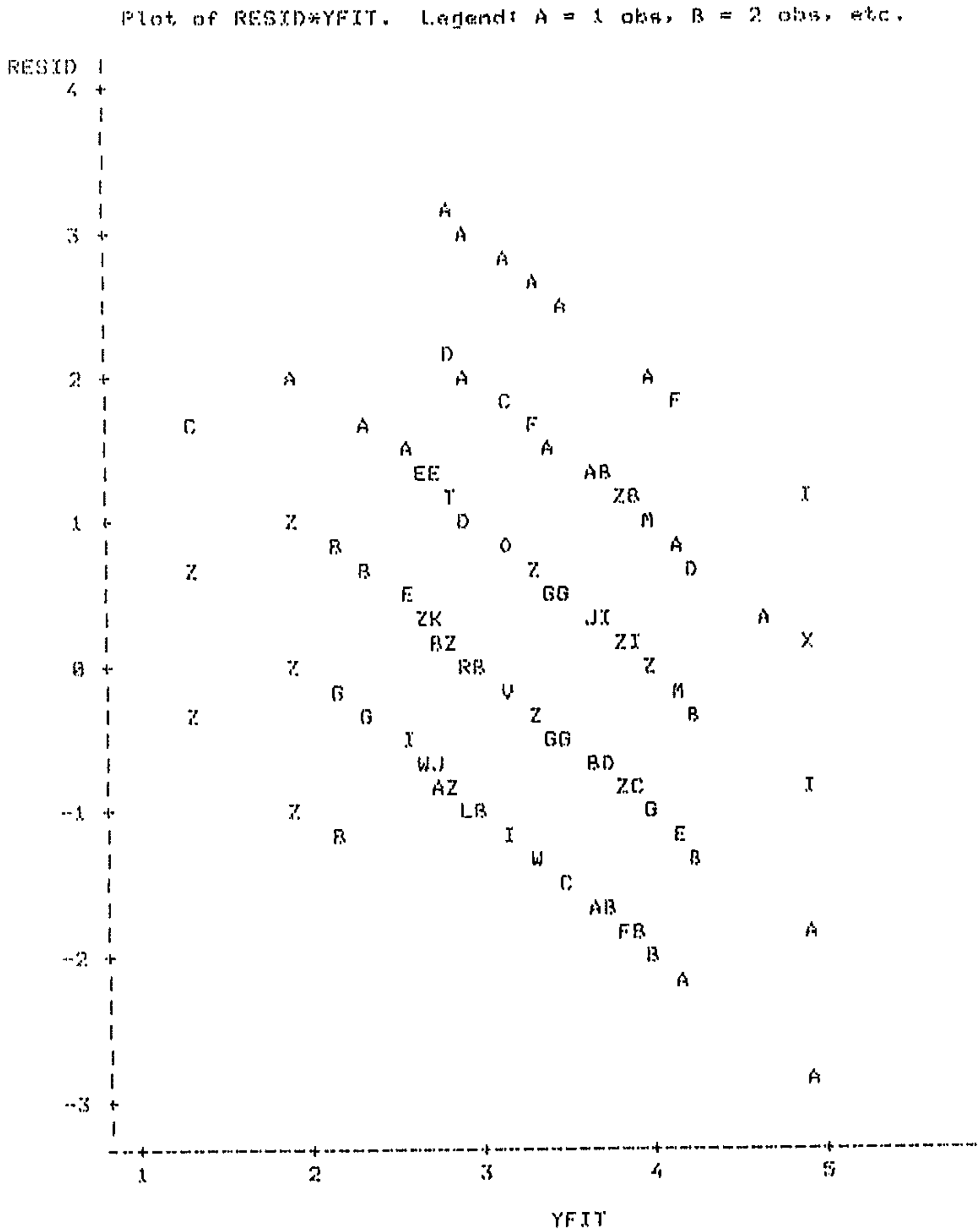

Figure 3.11. Variance Plot for the Local Driver Data.

CHAPTER 4

RESULTS AND FINDINGS

OVERVIEW OF THE FIELD ANALYSIS

The methodology presented in chapter three provided a framework of analysis designed to meet the objectives of this research. The focus of this chapter is to identify the information needs and priorities of the motorists using the techniques developed in the previous chapter.

In the analysis, the entire field population was separated into consistent groups. Based on vehicle type and origin of the vehicle license plates, five motorist groups were identified. The groups were defined as follows:

(1) Trucks: all commercial freight vehicles

(2) Locals: passenger vehicles with local Wyoming license plates county 2 or 5 and non-commercial diary users

(3) Resident: passenger vehicles with Wyoming license plates not county 2 or 5

(4) Non-resident: passenger vehicles with out-of-state license plates

(5) Unknown: vehicle identification not determined

Contained in Table 4.1 is a crosstable of survey type by group classification. Each cell in the table identifies the sample size of each classification. For example, considering the local group and the travel diaries cell, local drivers returned 128 travel diaries containing 1,134 observations of adverse winter travel conditions, or an average of about nine observations per travel diary user. The number of observations by the local drivers using diaries accounted for 65.25 percent of all observations in the data set. Local drivers recorded 96.02 percent of all diary observations, while the travel diaries accounted for 91.30 percent of all local driver observations. Over 70 percent of all observations came from the local driver group. Due to limited data, user information analysis consisted only of the local commuter group.

LOCAL AND TRUCK GROUP CHARACTERISTICS

User characteristics of the local drivers are presented in Tables 4.2 to 4.9. The ages of the local drivers were closely divided among the 26-40 group (38.3 percent) and 41-60 group (43.8 percent) (see Table 4.2). This was due to the fact the drivers were mostly non-traditional (over 25 years old) college students commuting from Cheyenne, and Laramie residents commuting to work in Cheyenne. The sex distribution was slightly in favor of the male gender (58.7 percent) (see Table 4.3).

Nearly half the of local drivers (45.6 percent) reported they travel 10,000 - 20,000 miles yearly and almost 60 percent travel 3-5 days a week outside the city during the winter (see Tables 4.5 and 4.6). Again, this is due to the large majority of commuters in the local driver population. The measures of confidence for the local drivers revealed that 56.3 percent felt they had good experience and would most often travel during adverse winter driving conditions (see Table 4.8). Finally, 62.7 percent of the locals reported that after obtaining road and travel information, they would travel regardless of the conditions, or after searching for another route (see Table 4.9). This is significant in that, information about adverse winter travel conditions will not deter the local population unless the road is closed.

Table 4.1. Crosstable of Survey Type by Group.

LEGEND: Observations (Individuals Surveyed) Percent of All Observations Row Percent Column Percent	Trucks	Locals	Residents	Non-residents	Unknown	Total
Diaries	29 (1) 1.67 2.46 7.97	1134 (128) 65.25 96.02 91.30	0 (0) 0 0 0	0 (0) 0 0 0	18 (2) 1.04 1.52 18.37	1181 (131) 67.95
Interviews	334 (334) 19.22 84.99 91.76	11 (11) 0.63 2.80 0.89	5 (5) 0.29 1.27 38.46	20 (20) 1.15 5.09 95.24	23 (23) 1.32 5.85 23.47	393 (393) 22.61
Postcards	1 (1) 0.06 0.61 0.27	97 (97) 5.58 59.15 7.81	8 (8) 0.46 4.88 61.54	1 (1) 0.06 0.61 4.76	57 (57) 3.28 34.76 58.16	164 (164) 9.44
Total	364 (336) 20.94	1242 (236) 71.46	13 (13) 0.75	21 (21) 1.21	98 (82) 5.64	1738 (688) 100.00

Table 4.2. Age Distribution of the Local Group.

AGE	Frequency	Percent
15 - 25	22	9.4
26 - 40	90	38.3
41 - 60	103	43.8
Over 60	20	8.5

Table 4.3. Sex Distribution of the Local Group.

SEX	Frequency	Percent
Female	97	41.3
Male	138	58.7

Table 4.4. Vehicle Distribution of the Local Group.

VEHICLE	Frequency	Percent
Car	164	69.5
Pickup Trucks	55	23.3
Van	15	6.4
Delivery Van/Truck	2	0.8

Table 4.5. Distribution of Annual Miles Driven by the Local Group.

MILES DRIVEN ANNUALLY	Frequency	Percent
Less than 5,000	4	3.5
5,000 - 10,000	24	21.1
10,000 - 20,000	52	45.6
More than 20,000	33	28.9

Table 4.6. Distribution of Days per Week Driven on Rural Highways during the Winter by the Local Group.

DAYS PER WEEK	Frequency	Percent
Less than 1	5	3.8
1 - 2	31	23.3
3 - 5	78	58.6
More than 5	18	13.5

Table 4.7. Distribution of the Percentage of Days per Week Driven on Rural Highways during the Winter on Adverse Conditions by the Local Group.

ADVERSE CONDITIONS	Frequency	Percent
Less than 5%	13	10.3
5 - 10%	40	31.7
10 - 25%	56	44.4
More than 25%	17	13.5

Table 4.8. Distribution of the Winter Driving Confidence of the Local Group.

WINTER DRIVING CONFIDENCE	Frequency	Percent
Limited experience, never travel	1	0.8
Some experience, seldom travel	24	18.8
Good experience, most often travel	72	56.3
Always travel	31	24.2

Table 4.9. Distribution of the Usefulness of Information to the Local Group.

USEFULNESS OF INFORMATION	Frequency	Percent
Travel if road is open	58	46.0
Delay trip for improved conditions	47	37.3
Look for alternate route, will make trip	21	16.7

In Table 4.10, it is shown that 80 percent of the local drivers use the road and travel phone number to receive information about adverse conditions. This is consistent with the fact that most drivers will try to obtain information about the road and travel conditions before they leave their home or work. Over two-thirds of the local group indicated using the CMS as an information source and slightly more than 60 percent indicated using the radio.

Table 4.10. Information Source Distribution for the Local Group.

SOURCE OF INFORMATION	Percent of All
Road and travel phone	80
CMS	69
Radio	61
Television	50
NOAH / Nat'l Weather Service	28
Other drivers	24
Newspaper	12
CB radio	6
Service station	4
Dispatcher	3
Other	2
Port of entry	1
No sources used	1

The user characteristics for the truck driver group are presented in Tables 4.11 to 4.17. The distribution of ages was relatively equal between the 26-40 year old group (51.7 percent) and the 41-60 year old group (45.8 percent) (see Table 4.11). The sex characteristic was predominantly male (90.9 percent) due to the male dominated truck driving profession (see Table 4.12). The majority of trucks in the survey were single trailer trucks (87.2 percent) with out-of-state license plates (91.3 percent) (see Tables 4.13 and 4.14).

Seventy-two truck drivers were surveyed about information sources they use for road and travel information. As shown in Table 4.18 the majority of the truck drivers' road and travel information came from the CB radio (72 percent) and regular radio broadcasts (63 percent). Changeable message signs were indicated as a source of information by 40 percent of the truck drivers surveyed.

Table 4.11. Age Distribution of the Truck Group.

AGE	Frequency	Percent
15 - 25	4	2.0
26 - 40	105	51.7
41 - 60	93	45.8
Over 60	1	0.5

Table 4.12. Sex Distribution of the Truck Group.

SEX	Frequency	Percent
Female	29	9.1
Male	291	90.9

Table 4.13. Vehicle Distribution of the Truck Group.

VEHICLE	Frequency	Percent
Single Trailer	293	87.2
Double Trailer	30	8.9
Other	13	3.9

Table 4.14. Distribution of License Plates for the Truck Group.

LICENSE PLATE	Frequency	Percent
Local Wyoming	4	1.7
Resident Wyoming	16	7.0
Out-of-state	210	91.3

Table 4.15. Distribution of Annual Miles Driven by the Truck Group.

MILES DRIVEN ANNU-ALLY	Frequency	Percent
Less than 25,000	0	0.0
25,000 - 50,000	4	9.8
50,000 - 100,000	8	18.6
More than 100,000	22	53.7

Table 4.16. Distribution of Days per Week Driven on Rural Highways during the Winter by the Truck Group.

DAYS PER WEEK	Frequency	Percent
Less than 1	0	0.0
1 - 2	2	4.7
3 - 5	8	18.6
More than 5	33	76.7

Table 4.17. Distribution of the Percentage of Days per Week Driven on Rural Highways during the Winter on Adverse Conditions by the Truck Group.

ADVERSE CONDITIONS	Frequency	Percent
Less than 5%	1	2.3
5 - 10%	4	9.3
10 - 25%	16	37.2
More than 25%	22	51.2

Table 4.18. Information Source Distribution for the Truck Group.

SOURCE OF INFORMATION	Percent of All
CB radio	72
Radio	63
CMS	40
Other drivers	37
Port of entry	37
Road and travel phone	23
Newspaper	21
Television	21
Dispatcher	16
Truck stop	16
NOAH / Nat'l Weather Service	14
Other	2
No sources used	0

Comparing the two groups based on their sources of road and travel information, it is apparent that the truck drivers do not rely on the changeable message sign as heavily as do the local drivers. This would suggest that the CMSs in the study area should be geared toward presenting information to the motorist in a passenger vehicle.

INFORMATION NEEDS ANALYSIS

During adverse weather conditions, the motorist will seek road and travel information. Sources providing road and travel information must satisfy the needs of the motorist. The adverse travel information needs of the road user were to be determined using the analysis procedures developed in Chapter Three. The following three sections identify the "key" types of information consistently requested by the local population. This information was to be considered for use in adverse road and travel reports and displays.

Five of the selected twenty-five dates contained ten or more observations where wind information was recorded by the motorist. From the crosstable of wind information in Table 4.19, the four most requested pieces of information were taken as STRONG WINDS, HIGH WINDS, WIND AHEAD and WIND GUSTS TO XX MPH.

Nine of the selected twenty-five dates contained ten or more observations where the motorist recorded visibility information. Consistency in the requests for visibility information on each date are found in Table 4.20. For example, on 3/5/91 the majority of respondents indicated a need to know of SNOWFALL or HEAVY SNOWFALL, and on 11/15/91 the response was to have information concerning FOG. Over all the dates considered, the four most requested bits of information were SNOWFALL, BLOWING/ DRIFTING SNOW, FOG and REDUCED VISIBILITY.

Table 4.19. Information Needs Analysis for the Wind Condition.

KEY WORDS	DATE 90 12/17	91 2/25	91 3/5	91 3/6	91 10/28	TOTAL
strong winds		6	1	4	4	15
high winds	2	2	4		3	12
wind ahead/warning	4	1	4	1	2	12
wind gusts to xx mph	1	1	2	2		6
strong and gusty		1	1	2		4
blowing/drifting snow			2			2
gusty wind				1	1	2
no light trailers		1		1		2
wind speed	2					2
calm	1					1
very high wind		1				1

Twelve of the twenty-five dates chosen contained ten observations where pavement information was recorded by the motorist. In the crosstable of pavement information (Table 4.21), the bits of information requested are consistent within the majority of dates. The dates 2/18/91, 3/5/91, 3/6/91, 3/7/91 and 11/18/91 are instances where the information ICY ROAD or SLICK ROAD were requested consistently. The four most requested pieces of information were ICY ROAD, SLICK ROAD, SLICK (in) SPOTS and SNOWPACKED & ICY ROAD.

Table 4.20. Information Needs Analysis for the Visibility Condition.

KEY WORDS	DATE 91 2/25	91 3/5	91 4/12	91 4/18	91 11/15	91 11/16	91 11/19	91 11/20	91 12/2	TOTAL
snowfall	1	6	2	2	1	1				13
blowing/drifting snow	2	1	2	1			3	3		12
fog					9	2				11
reduced visibility	1	1						2	4	8
fog, limited visibility		1		3	2		1			7
ground blizzard							3	2	1	6
heavy snowfall		3	2	1						6
limited visibility		1			2	2	1			6
poor visibility	1		1		2				2	6
limited visibility, snowfall			3				2			5
limited visibility, dense fog						4				4
reduce speed	1	1					1	1		4
very limited visibility	1		1						2	4
limited visib., snow, blowing snow	2							1		3
visibility xx miles	1		2						3	
blizzard	2									2

Table 4.20, Continued

KEY WORDS	DATE 91 2/25	91 3/5	91 4/12	91 4/18	91 11/15	91 11/16	91 11/19	91 11/20	91 12/2	TOTAL
dense/heavy fog					2					2
very poor visibility									2	2
bad visibility	1									1
extreme conditions					1					1
extremely limited visibility									1	1
fog, blowing snow							1			1
heavy snowfall, low visibility								1		1
limited visibility, heavy snowfall		1								1
patchy fog, limited visibility					1					1
poor visibility, heavy snowfall		1								1
snowfall, fog		1								1
very dense fog, very poor visibility						1				1
very foggy xx miles				1						1
very foggy, very limited visibility					1					1
very limited visibility, snowfall				1						1

Table 4.21. Information Needs Analysis for the Pavement Condition.

KEY WORDS	DATE 90 12/17	91 2/18	91 2/25	91 3/5	91 3/6	91 3/7	91 4/12	91 4/18	91 11/15	91 11/18	91 11/19	91 11/25	TOTAL
icy road	3	7	2	12	11	4	2	2	3	2	2	2	52
slick road	2	1	1	3	1	4	2	1		2	4		21
slick spots	4		3	1	1	1		1		2	4	2	19
snowpacked & icy				2		2			3	1	6		14
slippery road			1	2	1		1		3	2		1	11
snowpack	1			5	1				2	1			10
extremely/very/severely icy		1		2	2	1	1				1		8
icy spots		1	1					1			3	2	8
road condition	1										1	4	6
slick to snowpacked		1		1	2								4
slick spots to snowpacked					1					1	1		3
wet & icy			1				1	1					3
wet to slick spots								3					3
black ice									1	1			2
wet road								2					2
very slick									1	1			2

Table 4.21, Continued

KEY WORDS	DATE 90 12/17	91 2/18	91 2/25	91 3/5	91 3/6	91 3/7	91 4/12	91 4/18	91 11/15	91 11/18	91 11/19	91 11/25	TOTAL
advise no travel									1				1
chain law				1									1
dry road												1	1
extremely hazardous						1							1
freezing slush								1					1
icy to slick in spots											1		1
no sand			1										1
slippery spots	1												1
slushy									1				1
snowpacked to slushy									1				1
very slippery								1					1
wet & slushy											1		1
wet to snowpacked spots							1						1
wet to very slushy							1						1

INFORMATION PRIORITY ANALYSIS

Information priority analysis was performed for the local driver population and is presented in the following section. The priority by which information should be given to the motorists is established for this group. Table 4.22 contains a list of the four main variables and their computer labels, used in the regression modelling analysis.

Table 4.22. Analysis Variables and Computer Designations.

ANALYSIS VARIABLE	COMPUTER LABEL
INDEPENDENT VARIABLES	
Time	T
Wind	W
Visibility	V
Pavement	P
DEPENDENT VARIABLE	
Severity Rating	RATING

Interactions between independent variables were listed by joining the two variables. For example, the interaction between VISIBILITY and PAVEMENT is shown as VP.

Local Information Priority

A total of 1,167 of the 1,242 local group observations were used for the regression modelling procedure. The six levels of the pavement condition were combined into three levels to create a better fit of the model to the data. The new levels were defined as dry/wet, slick in spots/slushy and snowpacked/icy. For the analysis, the levels of the main effects were assigned the following values:

TIME:	0 - day	1 - night	
WIND: 0 - calm	1 - strong		
VISIBILITY:	0 - clear	1 - limited	2 - very limited
PAVEMENT:	0 - dry/wet	1 - slick/slushy	2 - snowpacked/icy

The best regression model was dependent on the variables P, V, V^2, W and V*P. This model produced an R-square value of 0.565, indicating that 56.5 percent of the variability of the severity rating can be explained by the variables in the model. All variables and interactions in the model were found to be significant to the model at an α=.05 level. The regression model which gave the best fit to the data was found to be as follows:

$$\mathit{RATING} = 1.67 + 0.94P + 0.60V + 0.22V^2 + 0.19W - 0.32(V*P);\ R^2 = 0.565$$

Where: Variables defined in Table 4.22

The variable TIME was found not to have a significant effect on the model and was removed from the model. The variables PAVEMENT and WIND were found to have a positive effect on the severity rating. The variable VISIBILITY was found to have an optimal effect as a quadratic term, indicating that severity rating is most affected when the visibility is "very limited." The effect of the interaction between VISIBILITY and PAVEMENT is to scale down the severity rating should both conditions exist. Stated simply, the combined effect of both visibility and pavement conditions is not strictly additive, but must include an adjustment factor to remain in the 1-5 range of the severity rating. The severity rating matrix contained in Figure 4.1 summarizes the severity ratings derived from the model for the condition matrix containing the main effects of wind, visibility and pavement.

Of interest were several interaction plots. A plot of the interaction between the variables W and P (Figure 4.2) offered the following explanation: The severity rating was controlled by poor pavement conditions. Once the pavement conditions became poor, the driver was more concerned about ice and snow on the roadway and the wind was of no consequence. The wind became interactive only if the pavement conditions were favorable. Similarly, a plot of the interaction between V and P (Figure 4.3) offered this explanation: The severity of the winter travel conditions was compounded by the combination of visibility and pavement conditions. The visibility conditions significantly affected the severity rating more when the pavement conditions were good and again when the pavement was icy. The lack of parallelism in the plot lines indicated the interaction between V and P.

The magnitudes of the standardized regression parameter estimates for the main effects were found to be:

VISIBILITY	0.36
WIND	0.07
PAVEMENT	0.58

Wind	Pavement	Visibility		
		Clear	Limited	Very Limited
Calm	dry/wet	2[a]	2	4
	slick in spots/ slushy	3	3	4
	snowpacked/icy	4	4	4
Strong	dry/wet	2	3	4
	slick in spots/ slushy	3	3	4
	snowpacked/icy	4	4	5

[a]2=FAIR, 3=POOR, 4=VERY POOR, 5=SEVERE

Figure 4.1. Severity Rating Matrix.

After ranking the standardized estimates in decreasing order of magnitude, the local drivers' information priority was found to be as follows:

(1) Pavement conditions

(2) Visibility conditions

The normality and variance analysis of the local group data showed no significant problems with the data.

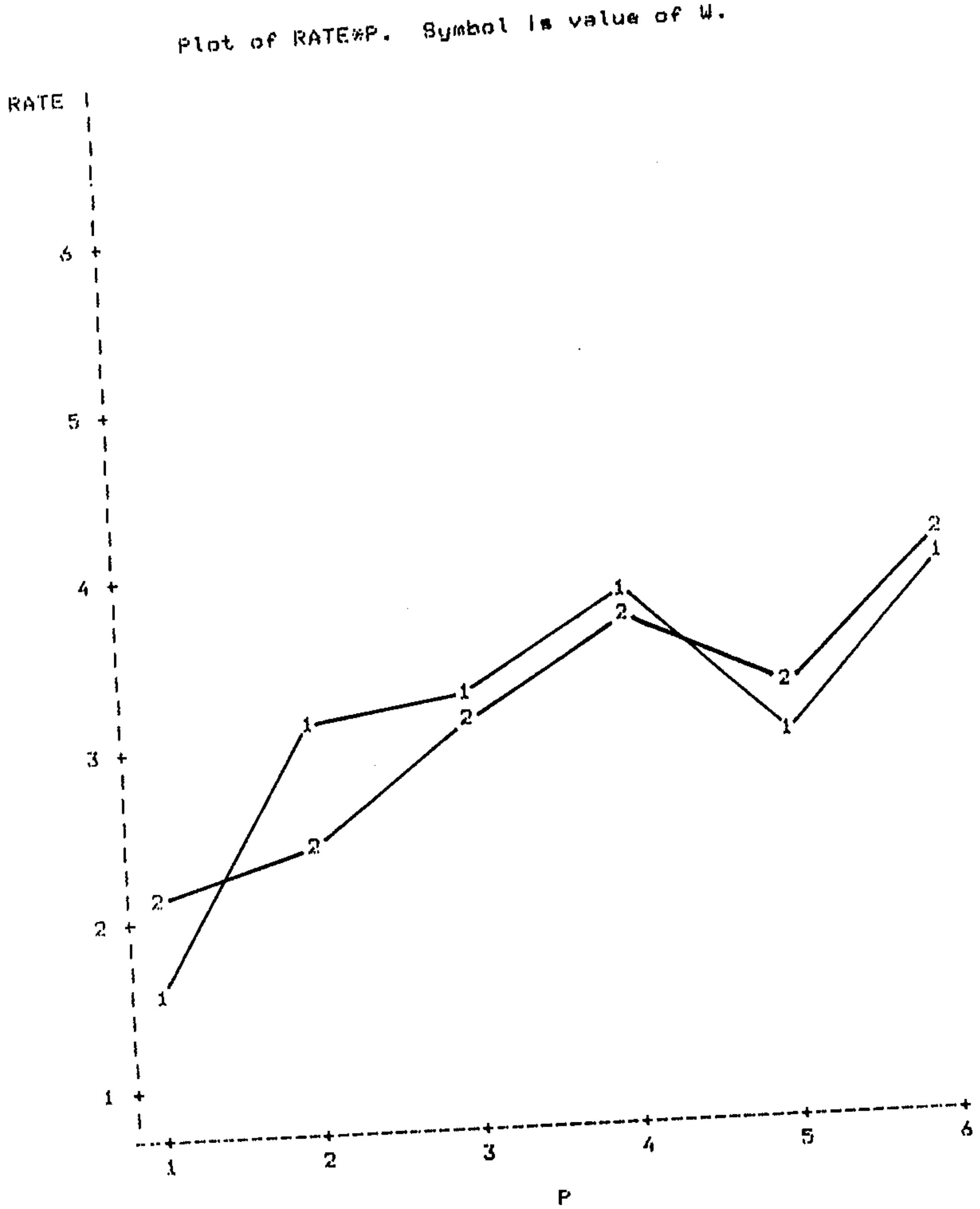

Figure 4.2. Interaction Plot between W and P.

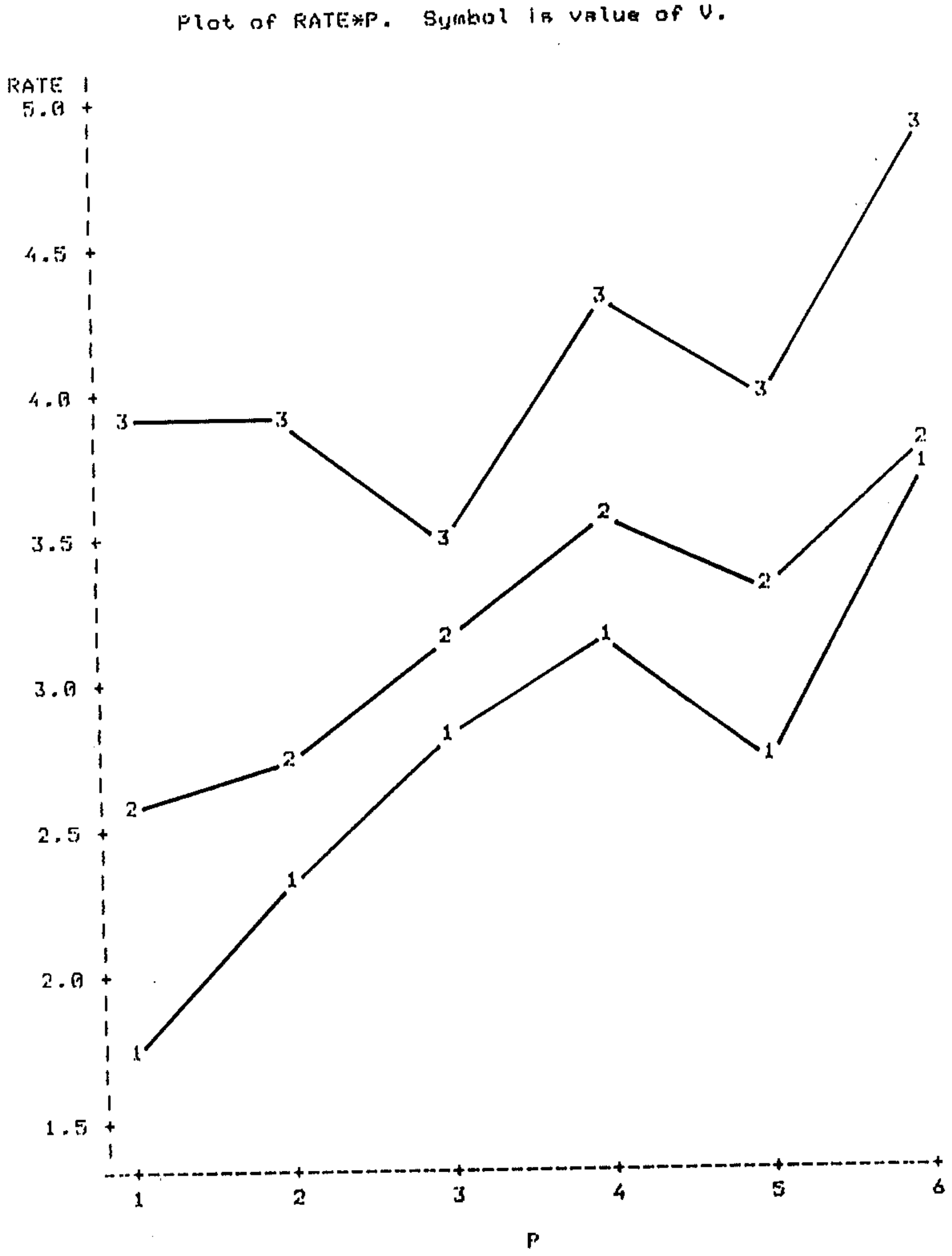

Figure 4.3. Interaction Plot between V and P.

From the results of the information priority analysis, it was clear that the local driver group perceived pavement and visibility conditions to be the most significant factor in the severity condition of a road. Changeable message signs on high-speed rural highways and interstates allow only seconds of sign viewing time for a message to be read. For this reason, the most important information should be displayed first. In the case of the CMSs under evaluation in this study, the pavement information should be displayed first and the visibility information second.

SUPPLEMENTAL SURVEY ANALYSIS

The supplemental surveys were developed to identify specific messages for the drum-type CMSs under evaluation and were based only on diary user responses. It is important to realize that the conditions which are described in surveys #2 and #3 are simply descriptions, not actual conditions which are experienced by the motorist.

Survey One

Survey one investigated the suitability of CMS messages for road and travel advisories. The survey was developed based on the conclusions developed from the information needs analysis of the local group and messages already in use by the Wyoming Transportation Department (WTD). Eighty-five (85) surveys were returned for analysis. Fifty-one percent of the respondents indicated that they had traveled in bad weather conditions, relying only on information provided by the CMS, 47 percent indicated that they had not. The diary users were asked to indicate whether or not the 14 messages given would be of benefit to them if the CMS was their only source of information. Table 4.23 contains a rank of the messages

Table 4.23. Ranks of the Messages in Survey One.

RANKING	MESSAGE	% POSITIVE*	% NO*
1	Icy Road Ahead	93	5
2	Heavy Fog Ahead	92	6
3	Wind Gusts to xx MPH	89	7
4	Drifting Snow Ahead	88	7
5	Reduced Visibility Ahead	85	12
6	Caution: Poor Visibility	85	9
7	Areas of Blowing Snow	84	8
8	Areas of Snowpack	81	13
9	Caution: Slick Spots	81	15
10	Slippery Road Ahead	75	18
11	Caution: Watch for Ice	75	19
12	Caution: Strong Winds	75	21
13	Strong Winds Possible	51	41
14	Winter Driving Conditions	48	41

*The difference from 100% is due to no response.

by percent of motorists indicating a YES response. The "key" messages which received YES responses were: ICY ROAD AHEAD, HEAVY FOG AHEAD, DRIFTING SNOW AHEAD, WIND GUSTS TO XX MPH and REDUCED VISIBILITY AHEAD.

In response to the suggestion of a road and travel rating system based on a scale from 1 to 6, 75 percent said they would like to have this system, 9 percent said they would not, and 14 percent said "maybe". From this result, survey two was developed to investigate the possibility of using a 1-6 road rating system for the CMSs.

Survey Two

The second survey was sent to 270 diary users. Sixty (60) surveys were returned with the following results contained in Tables 4.24 and 4.25. The levels of the rating scale were labeled by the diary user either with an adjective or by describing a road and travel condition. Table 4.24 contains a list of the most frequent adjectives and descriptions for the rating scale.

Shown in Table 4.25 are the statistics which describe the users' response from the survey. The MEAN described the average rating response to the road and travel condition and the 95% CONFIDENCE INTERVAL was the range which will cover the sample mean 95 percent of the time. The MINIMUM and MAXIMUM were the smallest and largest values recorded by the respondent and the LIKELY GROUPING was the median, indicating the value of the severity rating for which 50 percent of the observations were less than and 50 percent were greater than, for a given road and travel condition.

The analysis identifies several adverse winter travel conditions which were comparable based on MEAN road rating. Short periods of icy roads in question #5 from Vedauwoo to the

Table 4.24. Adjectives and Descriptions for the Rating Scale in Survey Two.

RATING	ADJECTIVES	CONDITIONS
1	good clear excellent	
2	fair good	wet/dry/slick spots windy blowing snow
3	poor caution difficulties	ground blizzards wet/slushy patches of ice slippery
4	difficult bad alert dangerous very poor	ice/blowing snow windy/severely limited visibility
5	hazardous extremely bad extreme caution	snowpacked icy/snowfall/windy
6	closed impassable	blizzard conditions

Table 4.25. Statistics of the Road Condition Survey in Survey Two.

N = 60

QUESTION #		MEAN	95% CON. INT.	MIN, MAX	LIKELY GROUPING
1	DAY	2.95	2.73 - 3.17	2, 5	3
	NIGHT	3.73	3.48 - 3.98	2, 6	4
2	DAY	4.25	4.06 - 4.44	3, 6	4
	NIGHT	4.87	4.69 - 5.04	3, 6	5
3	DAY	3.85	3.64 - 4.06	2, 5	4
	NIGHT	4.27	4.06 - 4.48	2, 6	4
4	DAY	3.37	3.08 - 3.66	2, 6	3
	NIGHT	3.97	3.70 - 4.23	2, 6	4
5	DAY	3.22	2.98 - 3.46	2, 5	3
	NIGHT	3.63	3.37 - 3.89	2, 6	4
6	DAY	3.15	2.90 - 3.41	1, 5	3
	NIGHT	3.58	3.32 - 3.84	1, 5	4

Lincoln Monument, were equal in severity to longer periods of poor visibility in question #1 from Harriman to Lincoln Monument. Questions #5 and #6 were equal as well, with longer lengths of a less severe pavement condition warranting the same road rating as a shorter length of a more severe pavement condition.

Based on the information needs and priority analysis of the local group, the two previous supplemental surveys and an existing set of WTD messages, a set of candidate CMS messages (Figure 4.4) was developed to be applied to the CMSs in the study area. The first line of information on the CMS was reserved for pavement information. The second line was reserved for visibility and wind information, thus eliminating a display containing both types of information simultaneously. The restrictions on the space available on the CMS contributed to the decision to use this configuration. The message REDUCED VISIBILITY was added to describe conditions not described by HEAVY FOG AHEAD and BLOWING SNOW. The road rating information on the third line was derived from the adjectives contained in Table 4.24 (Figure 4.1 contains a guideline for selecting the appropriate road rating for the third line of the display). Several exceptions to the above guidelines were made. The message ADVISE NO LIGHT TRAILERS was intended to be displayed with a strong wind warning and was therefore listed on the first line. Messages which were not specific to weather advisories were included in the displays. The message RETURN TO CHEYENNE or RETURN TO LARAMIE was intended to be displayed with the I-80 CLOSED message, and was placed on the third line of the display. The message CHAIN LAW IN EFFECT was also included on the third line, to be displayed when chains were required for travel on the interstate. The message FASTEN SEATBELTS was deliberately added to the message set to gain motorist response. The messages used in the third survey were selected from this set of messages.

Survey Three

The third survey was sent to 240 diary users to determine which three-line message would be most appropriate for a given adverse road and travel condition. The diary users were asked to select the most appropriate message for each line of the CMS display. The

DRUM NUMBER	POSITION	MESSAGE
1	0	Blank
	1	Icy Road Ahead
	2	Slippery in Spots
	3	Drifting Snow
	4	Advise No Light Trailers
	5	I-80 Closed
2	0	Blank
	1	Reduced Visibility
	2	Blowing Snow
	3	Heavy Fog Ahead
	4	Wind Gusts To
	5	Fasten Seatbelts
3	0	Blank
	1	25 MPH
	2	35 MPH
	3	40 MPH
	4	45 MPH
	5	55 MPH
4	0	Blank
	1	Conditions: Poor
	2	Conditions: Very Poor
	3	Conditions: Severe
	4	Chain Law in Effect
	5	Return to Laramie or Return to Cheyenne

Figure 4.4. Candidate CMS Messages.

Table 4.26. Three-Line Message Choices of Survey Three.

BOLD TYPE indicates the most requested three-line message set.

1. Thick fog extending from Cheyenne to the summit. Wet road in some places.

LINE 1:	**blank**	
LINE 2:	**HEAVY FOG AHEAD**	
LINE 3:	44% **CONDITIONS: POOR**	36% CONDITIONS: VERY POOR

2. Between Laramie and Buford there is heavy snowfall and the road is snow-packed and icy.

LINE 1:	87% **ICY ROAD AHEAD**	6% SLIPPERY IN SPOTS
LINE 2:	**REDUCED VISIBILITY**	
LINE 3:	65% **CONDITIONS: VERY POOR**	28% CONDITIONS: POOR

3. Dry road and strong winds. Ground blizzards near Vedauwoo and the summit.

LINE 1:	37% **blank**	31% DRIFTING SNOW
LINE 2:	**BLOWING SNOW**	
LINE 3:	46% **CONDITIONS: POOR**	33% blank

4. Snow-packed to slushy road conditions with snowfall and fog between the summit and Buford. Conditions elsewhere are slick in spots and clear.

LINE 1:	50% **SLIPPERY IN SPOTS**	40% ICY ROAD AHEAD
LINE 2:	53% **REDUCED VISIBILITY**	37% HEAVY FOG AHEAD
LINE 3:	56% **CONDITIONS: POOR**	32% CONDITIONS: VERY POOR

5. Slushy road conditions from Laramie to Vedauwoo, becoming dry towards Cheyenne.

LINE 1:	85% **SLIPPERY IN SPOTS**	7% blank
LINE 2:	50% **FASTEN SEATBELTS**	26% blank
LINE 3:	46% **blank**	31% CONDITIONS: POOR

6. Heavy snowfall, blowing and drifting snow across all of I-80 between Laramie and Cheyenne. Road conditions are snow-packed and slick.

LINE 1:	63% **ICY ROAD AHEAD**	28% DRIFTING SNOW
LINE 2:	63% **BLOWING SNOW AHEAD**	28% REDUCED VISIBILITY
LINE 3:	82% **CONDITIONS: SEVERE**	12% CONDITIONS: VERY POOR

results were compiled from 72 returned surveys. The results of the survey indicating the preferred message for the road and travel description are shown in Table 4.26.

The choice consistency of the message may be related to the description of the condition. As the severity of the condition worsens and/or as the description of the condition becomes more detailed, the choice consistency considerably. Questions #1, #3, and #5 did not provide detailed enough information about the condition to be evaluated and therefore the choice consistency is spread.

The results offer guidelines to selecting the appropriate message for a given condition. Respondents indicate that if a combination of snow and fog was present (question #4), then the message REDUCED VISIBILITY is more appropriate than HEAVY FOG AHEAD. In question #6, respondents were presented with a combination of heavy snowfall, blowing and drifting snow; the message BLOWING SNOW AHEAD was preferred 2:1 over REDUCED VISIBILITY. The CMS display offers no specific information about slushy road conditions. In question #5, slushy road conditions were presented and 85 percent of the locals surveyed requested SLIPPERY IN SPOTS as information to describe this condition. This may indicate that the user would rather have some information about poor road conditions, than none at all. However, subscribing to this would violate the "accuracy" principle of credibility. The FASTEN SEATBELTS message was requested by 50 percent of the respondents which may indicate that it adds a sense of urgency to the complete message, or perhaps the respondents thought the message was simply a "good idea."

LABORATORY ANALYSIS

The following section outlines the results of the laboratory analysis. The characteristics of the laboratory survey population are contained in Tables 4.27 to 4.35. The majority of the persons surveyed were male, college age students (see Tables 4.27 and 4.28). Because the population was mostly students, the number of trips taken outside the city in the winter season during the week was low as expected (less than 1 day/week). Table 4.31 contains the frequency count of days per week driven on rural highways during the winter for the laboratory population. A high percentage (55 percent) of the population indicated that they have much experience driving during adverse weather conditions (see Table 4.33). This was attributed to the fact that the majority of the University of Wyoming student body is from many areas of Wyoming and Colorado.

The radio was the number one source of information used to obtain road and travel conditions (Table 4.35), followed by the road and travel phone number and the television. This parallels the idea that the motorist will seek out road and travel information before leaving home or work.

Table 4.27. Age Distribution of the Laboratory Group.

AGE	Frequency	Percent
15 - 25	202	74.0
26 - 40	36	13.2
41 - 60	17	6.2
Over 60	18	6.6

Table 4.28. Sex Distribution of the Laboratory Group.

SEX	Frequency	Percent
Female	84	31.8
Male	180	68.2

Table 4.29. Vehicle Distribution of the Laboratory Group.

VEHICLE	Frequency	Percent
Car	179	75.2
Pickup Trucks	56	23.5
Van	2	0.8
Delivery Van/Truck	0	0.0

Table 4.30. Distribution of Annual Miles Driven by the Laboratory Group.

MILES DRIVEN ANNUALLY	Frequency	Percent
Less than 5,000	59	25.8
5,000 - 10,000	71	31.2
10,000 - 20,000	72	31.6
More than 20,000	20	8.8

Table 4.31. Distribution of Days per Week Driven on Rural Highways during the Winter by the Laboratory Group.

DAYS PER WEEK	Frequency	Percent
Less than 1	121	44.6
1 - 2	82	30.3
3 - 5	34	12.5
More than 5	34	12.5

Table 4.32. Distribution of the Percentage of Days per Week Driven on Rural Highways during the Winter on Adverse Conditions by the Laboratory Group.

ADVERSE CONDITIONS	Frequency	Percent
Less than 5%	64	23.8
5 - 10%	65	24.2
10 - 25%	97	36.1
More than 25%	43	16.0

Table 4.33. Distribution of the Winter Driving Confidence of the Laboratory Group.

WINTER DRIVING CONFIDENCE	Frequency	Percent
Limited, never travel	0	0.0
Some, seldom travel	82	29.9
Good, most often travel	151	55.1
Always travel	41	15.0

Table 4.34. Distribution of the Usefulness of Information to the Laboratory Group.

USEFULNESS OF INFORMATION	Frequency	Percent
Travel if road is open	82	29.9
Delay trip for improved conditions	96	35.0
Look for alternate route, will make trip	96	35.0

An analysis of the information needs of the laboratory population revealed that the respondents were simply copying what they read on the screen to their response sheets. This was believed to have happened due to the fact that the statement on the screen was a "convenient answer." Consequently the analysis was not considered to be an accurate determination of the information needs of the population.

A total of 3,240 observations were used for the laboratory regression modelling procedure, using the same variable conventions as for the field analysis. The best regression model was found to be:

$$\mathit{RATING} = 1.5 + 0.34\,T + 0.98\,V + 0.83\,W + 0.77\,P - 0.14\,VP; \quad R^2 = 0.568$$

Where: Variables are defined in Table 4.22

Table 4.35. Information Source Distribution for the Laboratory Group.

SOURCE OF INFORMATION	Percent of All
Radio	75
Road and travel phone	68
Television	58
Other drivers	36
CMS	34
Newspaper	26
NOAH / Nat'l Weather Service	13
Service station	11
Other	6
CB radio	4
Port of entry	3
No sources used	2
Dispatcher	1

All main effects were contained in the model and had a positive effect on the severity rating. The negative interaction parameter serves to scale down the severity rating if both conditions exist. Standardizing the regression parameters for the main effects resulted in the following priority ranking.

TIME	0.13
VISIBILITY	0.62
WIND	0.32
PAVEMENT	0.49

After ranking the standardized estimates in decreasing order of magnitude, the information priority for the laboratory group was found to be as follows:

(1) Visibility conditions

(2) Pavement conditions

(3) Wind conditions

(4) Time conditions

The normality and variance analysis of the laboratory group data showed no significant problems with the data.

The field study produced a different priority for the road and travel information. It was assumed that the differences between the field study and the lab study are attributable to the methodology used. The lab subjects did not have the opportunity to actually experience the adverse winter travel conditions as did the field subjects. The fact that the lab subjects were pretending to experience the adverse conditions, while at the same time consciously examining these conditions certainly had an influence on the outcome. The field groups, on the other hand, did not have the opportunity to consciously compare the influences of the main effects on the severity rating and the different levels contained within each.

The analysis of these data focused on identifying the consistencies in the information needs of the motorists and the delivery priority for road and travel information sources. Chapter five contains a summary of the research and the major findings and results of this analysis. Recommendations for further study are also presented.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

The need to improve the safety of adverse winter travel on rural highways and interstates prompted this research. Road and travel information on changeable message signs has been identified by the Transportation Safety Board as a countermeasure to the hazards of adverse travel conditions. The primary objective of this study was to identify the information needs of motorists during adverse winter travel conditions. The secondary objective was to identify the priority by which these information needs were to be delivered to the motorists.

The study area was selected as a 41 mile section of Interstate 80 between Laramie and Cheyenne, Wyoming. During the winter season, this stretch of highway is prone to high winds, poor pavement conditions and low visibility problems. Two drum-type changeable message signs exist within the study area which serve as adverse road and travel information sources.

Travel diaries, CB interviews and postcard surveys were utilized to gather motorist characteristics, sources of road and travel information used by the motorist, their winter road and travel information needs, and their perceptions of the severity of adverse winter travel conditions. The travel diaries were provided to commuters between Laramie and Cheyenne. Interviews of motorists were conducted at truck stops and restaurants located closer to the interstate. Postcards were distributed to gas stations and restaurants and placed on windshields of local vehicles at University of Wyoming basketball games. In each case, the motorists recorded adverse winter travel conditions, assigned a severity rating to the conditions and requested information they needed to warn them of the impending adverse winter travel conditions.

The consistencies in the information needs of the motorist were identified using cross tabulation and frequency counts of "key" words used by the motorist to describe adverse travel conditions. The information priority analysis used regression modelling to identify controlling variables of the winter travel condition's severity rating. From these relationships new surveys were developed specifically for application to the drum-type CMSs in the study area.

CONCLUSIONS

This section summarizes the major findings and conclusions based on the techniques of analysis described in Chapter Three and the results and findings of Chapter Four. The conclusions which follow from the discussion of the major findings focus on the consistencies of the information needs of the motorist and the delivery priority of these information needs.

The majority of the population surveyed were local drivers. The local drivers were primarily passenger vehicle commuters, accounting for 91.3 percent of the local driver observations. The truck drivers surveyed were mostly out-of-state, single-trailer traffic (87.2 percent and 91.3 percent respectively).

The local drivers used at-home information sources (phone, 80 percent; radio, 61 percent; and TV,50 percent) to receive road and travel information. The changeable message signs were identified as an information source by 69 percent of the local drivers. Despite receiving information about adverse travel conditions, 62.7 percent of the local drivers would travel if the road is open, regardless of the conditions, or after searching for another route. This indicates that the information sources are not being used by the local drivers to make a decision about whether or not to travel, but as a gauge of the severity of the conditions to expect when traveling and/or as a guideline for route selection decisions.

The truck drivers indicated they receive their road and travel information from the use of the CB radio. Through communication with other drivers utilizing the CB radio network, the truck drivers are able to gather information at various points along their route. This system and the regular broadcast radio account for the majority of information sources. Forty percent of the truck drivers indicated using the CMS as a source of road and travel information. It is conceivable that truck drivers receive first-hand knowledge of adverse travel conditions over the CB radio which is more accurate and up-to-date than the CMS. This is in contrast to the non-interactive information sources received at home by the local drivers.

The laboratory participants were mostly college students. They indicated their primary sources of information to be from at-home sources (radio, 75 percent; phone, 68 percent; and TV, 58 percent), similar to the local drivers. However, they did not utilize the CMS quite as much, only 34 percent. It stands to reason that the students do not drive out of town during the winter as much as the local drivers (less than 1 day per week for students as compared to 3-5 days per week for local commuters) and therefore are not conditioned to reading the CMS on a regular basis.

The information needs analysis of the field data revealed consistencies in the type of information wanted for particular adverse travel conditions. Related "key" words were consistently requested on particular dates investigated during poor winter conditions. These key words may be applied to the information sources which access the local population.

Descriptions of the wind conditions were consistent throughout the dates investigated, with requests for wind warnings (STRONG/HIGH WIND) and wind speeds (WIND GUSTS TO XX MPH). Specific words used consistently for describing visibility conditions were SNOWFALL, FOG and BLOWING SNOW. The message REDUCED VISIBILITY was used as a catch-all phrase for mixed visibility conditions. For pavement conditions, consistent requests were made for words such as ICY, SLICK IN SPOTS and SNOWPACKED. The key words ICY and SNOWPACKED frequently occurred together to describe the same condition, however, the word ICY was used more often.

The information priority of the motorists' information needs for local drivers found that pavement conditions are the principal influence on the motorists' perception of the severity of adverse travel conditions. Visibility conditions were found to be the secondary influence.

The results of the supplemental surveys established a set of messages designed for the CMSs in the study area. These messages combined with the principles of advisory changeable message signs and careful consideration of the information needs of the local population and display priorities for this information, produced the final set of messages to be recommended for the Laramie and Cheyenne changeable message signs. The final set of messages is contained in Figure 5.1.

The specific conclusions drawn from the major findings are:

(1) The CMS is an important source of adverse winter travel information for rural interstate motorists.

(2) Pavement condition was the primary factor affecting the perception of the severity of adverse travel conditions for both local commuters and truck drivers. Visibility conditions were secondary and of greater importance as pavement conditions became more adverse.

(3) A three-point rating scale will meet motorist winter travel information needs when adverse conditions exist: Poor, Very Poor & Severe.

(4) Local motorist ratings of adverse conditions reflected the length of the condition. As the length of the adverse condition decreased, condition adjectives requested decreased from severe to very poor to poor.

(5) Local commuters primarily obtained adverse road and travel information from at-home sources.

(6) Interstate truck drivers primarily used the CB radio for adverse road and travel information and supplemented this by using broadcast radio and CMS information.

(7) Local commuters desired to travel regardless of road and travel conditions.

RECOMMENDATIONS

The emphasis of this section is to recommend alternative methods for delivering road and travel information to the motorist and to recommend studies for further research. The fact that the majority of information about adverse winter travel conditions is received primarily through the road and travel phone number, the radio and the television, expresses a need for investigation of these media. The results of this study are applicable to a certain degree. The messages developed for the CMSs in this study are limited to what the motorist can read in the brief time of exposure to the sign. The at-home sources have the potential to give highly detailed road and travel information which may deter the motorist from travelling in adverse winter conditions. If more accurate and reliable winter travel information could be provided to the motorist through these media, then perhaps fewer motorists would risk travelling and consequently lessen the chance of a weather related accident.

In an effort to increase the message flexibility of weather advisory changeable message signs, a bulb-matrix or circular reflective disk (CRD) CMS should be considered. The changing weather patterns in any area may warrant detailed information about road and travel conditions in certain locations. An issue here would be the credibility of the information provided. The ability to provide more information does not necessarily mean better information. Care must be taken to insure that the information posted is accurate and up-to-date. If the specific location of an adverse weather condition were to be identified on the CMS, the bulb-matrix or CRD has this kind of flexibility whereas the drum-type CMS does not. The limited flexibility of the drum-type

DRUM 1

POSITION: 0 blank
1 ICY ROAD AHEAD
2 SLIPPERY IN SPOTS
3 DRIFTING SNOW
4 ADVISE NO LIGHT TRAILERS
5 I-80 CLOSED

DRUM 2

POSITION: 0 blank
1 REDUCED VISIBILITY
2 BLOWING SNOW
3 HEAVY FOG AHEAD
4 WIND GUSTS TO
5 FASTEN SEATBELTS

DRUM 3

POSITION: 0 blank
1 25 MPH
2 35 MPH
3 40 MPH
4 45 MPH
5 55 MPH

DRUM 4

POSITION: 0 blank
1 CONDITIONS: POOR
2 CONDITIONS: VERY POOR
3 CONDITIONS: SEVERE
4 CHAIN LAW IN EFFECT
5 RETURN TO CHEYENNE
or RETURN TO LARAMIE

Figure 5.1. Final set of CMS messages.

CMS does not allow for a greater distinction between adverse travel conditions. A more flexible bulb-matrix or CRD has the capability to store more information bits describing adverse travel conditions to be displayed to the motorist. It is important to realize in the use of CMSs that the information posted is consistent for like conditions. Too many messages describing the same condition will not establish message expectancy for the motorist and credibility will be lost.

Of particular interest to the highway engineer would be the CB radio network utilized by the truck drivers. The CB was the primary source for information about adverse travel conditions for truck drivers. Investigation of a similar non-interactive system for passenger vehicles on a linear radio network would be of benefit. Also, it may be possible to use the CB radio network for gathering road and travel information at various locations along a section of highway, and relayed onto CMS controllers to post the appropriate information.

Although the motorists prefer to receive road and travel information from at-home sources and CB radios, the changeable message sign is still an effective means of communication to the driver. Further efforts should be made to evaluate the effect of weather advisory changeable message signs on the reduction of weather-related accidents, and the ability of a weather advisory CMS to invoke a positive response to adverse travel conditions for a driver not familiar with the surrounding area.

APPENDIX A

SURVEY FORMS

The following section contains examples of each of the three survey methods: travel diary, interview, postcard and laboratory survey. The travel diary contained twelve response pages, which do not include the introduction, the user characteristics pages and an example page.

TRIP #12

Date: ______________

Trip departure time: ______________ AM PM

Trip arrival time: ______________ AM PM

Direction of travel:
1. Eastbound
2. Westbound ______

On a scale of 1 - 6, how would you rate the road and travel conditions of your trip between Cheyenne and Laramie?

1 best   2   3   4   5 worst   6 road closed ______

How would you rate the visibility condition?
1. Clear
2. Limited
3. Very limited ______

Was there snow blowing across the roadway (ground blizzard)?
Y - yes   N - no ______

How would you rate the wind condition?
1. Calm to breezy
2. Gusty to strong ______

How would you rate the pavement condition?
1. Dry
2. Wet
3. Slushy
4. Snow-packed
5. Slick in spots
6. Icy ______

Did these conditions cause you to reduce your travel speed?
Y - yes   N - no ______

If yes - by how much did you reduce your speed?
(round to nearest 5 mph - ie... 10, 15, 20, etc...) ______mph

What information would you like to have seen on the changeable message sign before you began the trip between Cheyenne and Laramie?

____

____

____

____

If you were given the above information on the changeable message sign, would you have cancelled or delayed your trip?
Y - yes   N - no ______

Was the trip you just made an essential trip?
Y - yes   N - no ______

Was the message sign (CMS) on?
Y - yes   N - no ______

If yes - was the message appropriate?
Y - yes   N - no ______

Comments:

Figure A.1. Travel diary response page.

USER CHARACTERISTICS

Indicate your response in the column to the right for each question.

AGE:
1. 15 - 25
2. 26 - 40
3. 41 - 60
4. over 60 ____

SEX:
1. Female
2. Male ____

VEHICLE: Passenger Vehicle
4. Car
5. Truck
6. Pickup
7. Van
8. Delivery van/truck
9. RV ____

Estimate the number of miles you drive yearly:
Passenger Vehicle Driver
5. less than 5,000
6. 5,000 - 10,000
7. 10,000 - 20,000
8. more than 20,000 ____

Estimate the number of days a week you travel outside the city on rural highways during the winter:
1. less than 1
2. 1 - 2
3. 3 - 5
4. more than 5 ____

Estimate the percentage of the above weekly trips which are driven on adverse road conditions:
1. less than 5%
2. 5 - 10%
3. 10 - 25%
4. more than 25% ____

Which sources do you use for determining road and travel conditions? (check all that apply):

__Newspaper
__CB Radio
__Radio
__Other drivers
__Dispatcher
__NOAH radio / National Weather Service
__Service station / Truck stop
__Other
__Port of entry
__Television
__Road and travel phone number
__Message signs (CMS)
__None / No sources used

Indicate your winter driving confidence during adverse conditions on rural roads:
1. I have limited experience and never travel.
2. I have some experience and will seldom travel.
3. I have much experience and will most often travel.
4. I always travel due to the experience and confidence of my driving ability. ____

If accurate information describing poor road and travel conditions were given to you on a specific road, which best describes the way in which you will use this information?
1. Will travel as long as the road is open.
2. Will delay the trip until conditions improve.
3. Will look for an alternate route with better conditions, but will make the trip. ____

Figure A.1 continued. Travel diary user characteristics pages.

FIELD INTERVIEW FORM

Indicate your response in the column to the right for each question.

AGE:
1. 15 - 25
2. 26 - 40
3. 41 - 60
4. over 60
___

SEX:
1. Female
2. Male
___

VEHICLE:

Commercial Freight	Passenger Vehicle	
1. Single trailer	4. Car	7. Van
2. Double trailer	5. Truck	8. Delivery van/truck
3. Other	6. Pickup	9. RV

___

PLATES:
1. Local Wyoming plates (county 2 or 5 only)
2. Non-local Wyoming plates (not county 2 or 5)
3. Out-of-state
___

Estimate the number of miles you drive yearly:

Commercial Driver	Passenger Vehicle Driver
1. less than 25,000	5. less than 5,000
2. 25,000 - 50,000	6. 5,000 - 10,000
3. 50,000 - 100,000	7. 10,000 - 20,000
4. more than 100,000	8. more than 20,000

___

Estimate the number of days a week you travel outside the city on rural highways during the winter:
1. less than 1
2. 1 - 2
3. 3 - 5
4. more than 5
___

Estimate the percentage of the above weekly trips which are driven on adverse road conditions:
1. less than 5%
2. 5 - 10%
3. 10 - 25%
4. more than 25%
___

Which sources do you use for determining road and travel conditions?
(check all that apply):

___Newspaper
___CB Radio
___Radio
___Other drivers
___Dispatcher
___NOAH radio / National Weather Service
___Service station / Truck stop
___Other
___Port of entry
___Television
___Road and travel phone number
___Message signs (CMS)
___None / No sources used

Interviewer: ________________ Date: ____________

Time of interview: ____________ Trip departure time: ____________AM PM

Location: ________________ Trip arrival time: ____________AM PM

Direction of travel:
1. Eastbound
2. Westbound
___

On a scale of 1 - 6, how would you rate the road and travel conditions of your trip between Cheyenne and Laramie?

1	2	3	4	5	6
best					worst

___

How would you rate the visibility condition?
1. Clear
2. Limited
3. Very limited
___

Was there snow blowing across the roadway (ground blizzard)?
Y - yes N - no
___

How would you rate the wind condition?
1. Calm to breezy
2. Gusty to strong
___

How would you rate the pavement condition?
1. Dry
2. Wet
3. Slushy
4. Snow-packed
5. Slick in spots
6. Icy
___

Did these conditions cause you to reduce your travel speed?
Y - yes N - no
___
If yes - by how much did you reduce your speed?
(round to nearest 5 mph - ie... 10, 15, 20, etc...)
___

What information would you like to have seen on the changeable message sign before you began the trip between Cheyenne and Laramie?

____
____ ___
____ ___
____ ___

If you were given the above information on the changeable message sign, would you have cancelled or delayed your trip?
Y - yes N - no
___

Was the trip you just made an essential trip?
Y - yes N - no
___

Was the message sign (CMS) on?
Y - yes N - no
___
If yes - was the message appropriate?
Y - yes N - no
___

Comments:

Figure A.2. Interview survey form.

POSTCARD SURVEY FORM

Indicate your response in the column to the right for each question.

EXAMPLE: 1. NOT your answer 2. Your answer
If your answer is selection #2, then mark -------> 2

AGE: 1. 15 - 25 2. 26 - 40 3. 41 - 60 4. over 60 ____

SEX: 1. Female 2. Male ____

VEHICLE FOR THIS TRIP ONLY:
Commercial Freight: 1. Single trailer 2. Double trailer 3. Other
Passenger Vehicle: 4. Car 5. Truck 6. Pickup 7. Van 8. Delivery van/truck 9. RV ____

PLATES: 1. Local Wyoming plates (county 2 or 5 only) 2. Non-local Wyoming plates (not county 2 or 5) 3. Out-of-state ____

Date: ________

Departure time from Cheyenne (or Laramie): ________AM PM

Arrival time in Laramie (or Cheyenne): ________AM PM

Direction of travel:
1. Eastbound
2. Westbound ____

On a scale of 1 - 6, how would you rate the road and travel conditions of your trip between Cheyenne and Laramie only? (from Cheyenne to Laramie is one trip)

1 best 2 3 4 5 worst 6 road closed ____

How would you rate the visibility condition?
1. Clear
2. Limited
3. Very limited ____

Was there snow blowing across the roadway (ground blizzard)?
Y - yes N - no ____

How would you rate the wind condition?
1. Calm to breezy
2. Gusty to strong ____

How would you rate the pavement condition?
1. Dry 4. Snow-packed
2. Wet 5. Slick in spots
3. Slushy 6. Icy ____

What information would you like to have seen on the changeable message sign before you began the trip between Cheyenne and Laramie?

____

____

____

Was the message sign (CMS) on?
Y - yes N - no ____
If yes - was the message appropriate?
Y - yes N - no ____

Figure A.3. Postcard survey form.

SELECTED REFERENCES

1. Assessment of Changeable Message Sign Technology. Federal Highway Administration. Report No. FHWA-RD-87-025. December 1986.

2. Bender, Louis E. "Use of Changeable Message Signs by Port Authority." In The Changeable Message Concept of Traffic Control. Highway Research Board. Special Report 129, 1972. 17-19.

3. Changeable Message Signs. National Cooperative Highway Research Program. Synthesis of Highway Practice 61. July 1979.

4. Dudek, Conrad L. Guidelines on the Use of Changeable Message Signs. Federal Highway Administration. Report No. FHWA-TS-90-043. July 1991.

5. Dudek, Conrad L. and R. D. Huchingson. Manual on Real-Time Motorist Information Displays. Federal Highway Administration. Report No. FHWA-IP-86-16. August 1986.

6. Dorsey, Warren. Variable Message Signing for Traffic Surveillance and Control. Federal Highway Administration. Report No. FHWA-RD-77-98. January 1977.

7. "Fighting Fog in Tennessee." Roads and Bridges, July 1991, 32.

8. French, Kevin A. "Survey of State Traffic Engineers." Unpublished data. 1991.

9. Improving Motorist Information Systems: Towards a User-Based Motorist Information System in the Puget Sound Area. Washington State Transportation Center. Report No. WA-RD-18-72. April 1990.

10. Manual on Uniform Traffic Control Devices for Streets and Highways. Federal Highway Administration, 1988.

11. Neter, J., W. Wasserman and M. H. Kutner. Applied Linear Regression Models. 2nd ed. Richard D. Irwin, Inc., 1989.

12. Ogden, K. W. "Human Factors in Traffic Engineering." ITE Journal, August 1990, 41.

13. SAS User's Guide: Statistics, Version 5 Edition. SAS Institute Inc. Cary, NC: SAS Institute Inc., 1985.

14. Stephens, B. W. "Some Principles for Communicating with Drivers Through the Use of Variable-Message Displays." In The Changeable Message Concept of Traffic Control. Highway Research Board. Special Report 129, 1972. 2-6.

15. Tamburri, T. N. and D. J. Theobald. Reduced Visibility (Fog) Study. California Division of Highways. Study B-1-9. 1 March 1967.

16. Wattleworth, J. A., C. E. Wallace, M. Levin and J G. Sample. Evaluation of the Operational Effects of an On-Freeway Control System. Texas A&M University. Report 488-2. 1968.

17. World Almanac, 1991 ed. 279-290.