December 30, 2003

Final

Final Evaluation Report for the Greater Yellowstone Regional Traveler and Weather Information System (GYRTWIS)

Contract Number: DTFH61-96-C-00098

Task 9826

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1. Report No.	**2. Government Accession No.**	**3. Recipient's Catalog No.**

4. Title and Subtitle Final Evaluation Report for the Greater Yellowstone Regional Traveler and Weather Information System (GYRTWIS)	**5. Report Date** December 30, 2003 **6. Performing Organization Code**
7. Authors R. Sanchez (SAIC), R. Haas (SAIC), C. Mitchell (SAIC)	**8. Performing Organization Report No.**
9. Performing Organization Name and Address Science Applications International Corporation (SAIC) 1710 SAIC Drive M/S T1-12-3 McLean, VA 22102	**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** DTFH61-96-C-00098; Task 9826
12. Sponsoring Agency Name and Address United States Department of Transportation ITS Joint Program Office, HOIT-1 400 7th Street SW Washington, DC 20590	**13. Type of Report and Period Covered** **14. Sponsoring Agency Code** HOIT-1

15. Supplementary Notes

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16. Abstract

This final report describes the national evaluation of the Greater Yellowstone Regional Traveler and Weather Information System (GYRTWIS). This evaluation complements the ongoing GYRTWIS evaluation being conducted by WTI/MSU by investigating three areas: System impacts of 511; Pavement Thermal Model accuracy; and Case studies of the business model, institutional lessons learned, and 511 implementation challenges, guidelines, and standards.

The System Impacts Study investigated the impact of the deployment in terms of system usage and customer satisfaction. The number of calls to 511 indicated that travelers utilized the 511-telephone system more than they did the previous *ROAD and 800 information services. A majority of Montana travelers were quite satisfied with the accuracy, availability, usefulness, and ease of understanding of the GYRTWIS 511-telephone service when compared to the previous *ROAD and 800 telephone services. A copy of the 2002 and 2003 Montana Travel Information Surveys is provided in the Appendix of this report.

The Pavement Thermal Model (PTM) Accuracy Study investigated the accuracy of the predicted versus actual pavement temperatures. Although the PTM process showed promise for forecasting road surface temperatures, limitations in the accuracy of small-scale, long-term weather forecasts currently limit the accuracy of the road surface temperature forecasts. The overall accuracy of the model is not high enough at this time to make anti-icing decisions based primarily on the road surface temperatures forecast by the model.

The Case Studies investigated the GYRTWIS business model, institutional lessons learned, and 511 implementation challenges. A variety of key findings and lessons learned are presented.

Key Words 511; Intelligent Transportation Systems; Rural ITS; 511 Traveler Information System; Pavement Thermal Model; System Impacts; Montana; GYRTWIS; Business Model; Lessons Learned; 511 Challenges.	**18. Distribution Statement** No restrictions. This document is available to the public from: The National Technical Information Service, Springfield, VA 22161. This document is available to the public at: http://www.its.dot.gov/itsweb/welcome.htm

19. Security Classif. (of this report)	**20. Security Classif. (of this page)**	**21.No of Pages**	**22. Price**
Unclassified	Unclassified	71	N/A

Form DOT F 1700.7 (8-72)   Reproduction of completed page authorized.

GLOSSARY OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ARPS	Advanced Regional Prediction System
ATIS	Advanced Traveler Information System
DMS	Dynamic Message Sign
EDL	Electronic Document Library
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
GYRITS	Greater Yellowstone Rural Intelligent Transportation System
GYRTWIS	Greater Yellowstone Regional Traveler and Weather Information System
HAR	Highway Advisory Radio
HMVM	Hundred Million Vehicle Miles
ITS	Intelligent Transportation Systems
ITS America	Intelligent Transportation Society of America
IVR	Interactive Voice Response
JPO	Joint Program Office
MDSS	Maintenance Decision Support System
MDT	Montana Department of Transportation
MOE	Measure of Effectiveness
MOU	Memorandum of Understanding
MSU	Montana State University
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PAWG	Program Assessment Working Group
PCS	Pavement Condition Survey
P-P	Public-Private
PTM	Pavement Thermal Model
RWIS	Road Weather Information System
SAIC	Science Applications International Corporation
SOW	Statement of Work
TAP	Transportation Awareness Program
U.S. DOT	United States Department of Transportation
VMT	Vehicle Miles Traveled
WTI	Western Transportation Institute

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Executive Summary

Background

Montana is a large, rural state with a landmass of over 147,000 square miles and nearly 70,000 miles of public highways and roads. Although the State of Montana is larger than the combined areas of New York, Maryland, Delaware, Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, New Jersey, and Connecticut, it consists of only 2 percent of the combined population of those states.[1]

The mountainous corridors in Montana can be difficult to travel, especially during adverse weather conditions. Approximately 77.7 percent of Montana's vehicle miles traveled (VMT) take place outside of urban areas[2]. During the fall, winter, and early spring seasons, weather conditions can impact traveler safety and security, and pose major challenges to road maintenance operations. In 1998, Montana averaged 2.5 fatal crashes per hundred million vehicle miles (HMVM) versus the national average of 1.6 fatal crashes per HMVM[3]. To improve road conditions in 1999, Montana Department of Transportation (MDT) crews plowed 3,067,406 miles of highway, applied 1,856,376 gallons of liquid anti-icing/deicing materials, and deposited nearly 302,595 cubic yards of sand[4].

In an effort to make road and weather information more readily available to travelers and maintenance personnel, MDT implemented the Greater Yellowstone Regional Traveler and Weather Information System (GYRTWIS). This system provides road condition and weather forecasts through landline or cellular phones via a 511-telephone system and will ultimately be linked to neighboring states. GYRTWIS replaced the previous *ROAD service (a non-interactive, recorded message system) with 511 (a #SAFE-based system), which is interactive and uses better weather models. In 2004, researchers at Western Transportation Institute/Montana State University (WTI/MSU) will be investigating the efficacy of integrating a Pavement Thermal Model (PTM) being developed by WTI/MSU into the 511 system. The PTM computer model receives regional road weather information system (RWIS) and forecasted weather condition information and generates a location-specific prediction of pavement conditions.

This evaluation builds upon and complements the ongoing GYRTWIS evaluation being conducted by WTI/MSU. The WTI/MSU evaluation of GYRTWIS examines traveler perceptions of system accuracy; availability; usefulness and understandability; the accuracy and usefulness of the information for maintenance operations; and perceptions of project success.

This evaluation complements WTI/MSU's GYRTWIS evaluation by investigating the following three areas:

- System impacts of 511 on usage and customer satisfaction.

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[1] Montana Fast Facts, http://www.mdt.state.mt.us/map/fastfact.htm.
[2] Ibid.
[3] 1998 USDOT. See brochure for *Intelligent Transportation Systems in the Transportation Equity Act for the 21st Century*[3] at http://www.itsdocs.fhwa.dot.gov/jpodocs/brochure/4p601!.pdf
[4] Montana Fast Facts, http://www.mdt.state.mt.us/map/fastfact.htm.

- Pavement Thermal Model accuracy.
- Case studies of the business model, institutional challenges, and 511 implementation issues.

The three study areas and objectives are shown in Table ES-1. The System Impacts Study assessed the impact of the deployment on both travelers and maintenance personnel. This study investigated impacts in terms of system usage and customer satisfaction. System usage compared the baseline (“Before”) usage of MDT’s *ROAD and 800 road and weather information phone service to the “After” GYRTWIS 511 usage. In addition, Before and After perceptions of customer satisfaction were also compared. The Before perceptions focused on satisfaction with pre-511 travel information and perceived needs. The After perceptions investigated satisfaction with the 511 service and how well the pre-511 needs were addressed.

Table ES-1. Evaluation Study Areas and Objectives

Study Areas	Objectives
System Impacts Study:	
System Usage Test	Compare traveler usage of MDT’s new 511-telephone service to existing road and weather information phone service.
	Compare maintenance personnel usage of the new pavement and weather forecasts to existing information.
Customer Satisfaction Test	Compare traveler satisfaction with MDT’s new 511-telephone service to the existing road and weather information phone service.
	Compare maintenance personnel satisfaction with the new pavement and weather forecasts to the existing information available.
Pavement Thermal Model Study:	
PTM Test for Accuracy	Examine the accuracy of the Pavement Thermal Model to be used for MDT’s new 511-telephone service.
Case Studies:	
GYRTWIS Business Model	Examine the GYRTWIS business model; what it is; how MDT is paying for the services; and where it hopes to obtain funding for ongoing operations.
Institutional Lessons Learned	Identify the institutional benefits, challenges, and lessons learned from the GYRTWIS project.
511 Implementation Challenges, Guidelines, and Standards	Develop a case history of implementation challenges; the role of 511 guidelines/ITS Architecture standards; and the advantages, limitations, and suggested changes.

As previously mentioned, the efficacy of integrating information from the Pavement Thermal Model into the GYRTWIS 511 system is scheduled for investigation during 2004. The evaluation reported here examined the accuracy of the predicted versus actual pavement temperatures to determine the accuracy and reliability of the Pavement Thermal Model.

One objective of the Case Studies is to investigate the GYRTWIS business model for MDT's 511-telephone service (what it is, how they are paying for the services, and where they hope to obtain funding for ongoing operations). A second objective is to identify the institutional benefits, challenges, and lessons learned regarding the effort to deploy the 511-telephone service throughout the State of Montana. The third objective is to investigate the challenges of integrating the technologies and the role of 511 guidelines and the use of the National ITS Architecture and standards in system design and implementation.

In general, this document focuses on the comparison of the Before and After results based on the 2002 and 2003 winter driving seasons. For a description of the GYRTWIS evaluation methodology refer to the USDOT's Electronic Report # 13658 entitled *Final Greater Yellowstone Regional Traveler and Weather Information System Evaluation Plan*. For a copy of the Phase II (Baseline) results and conclusions refer to Report # 13758 entitled *Phase II (Baseline) Report for the Greater Yellowstone Regional Traveler and Weather Information System (GYRTWIS).* Both reports are available over the Internet and can be accessed from the Federal Highway Administration (FHWA) ITS Electronic Document Library http://www.its.dot.gov/itsweb/welcome.htm.

The key hypotheses for the evaluation are the following:

1. Travelers will use the new GYRTWIS service more than the existing road and weather information phone service.
2. Maintenance personnel will use the road and weather information provided through GYRTWIS more than existing systems.
3. Travelers will be more satisfied with the GYRTWIS service than the existing road and weather phone service.
4. Travelers will perceive the new GYRTWIS service provides useful weather, road condition, and safety information.
5. Maintenance personnel will perceive the pavement and weather forecasts as useful.
6. Maintenance personnel will perceive the pavement and weather forecasts as accurate.
7. The GYRTWIS Pavement Thermal Model will accurately predict pavement thermal conditions.

The following subsections provide a summary of the findings by study area and the key lessons learned.

System Usage

The GYRTWIS 511-telephone service was deployed on January 15, 2003. Despite starting late in the winter season, the number of calls to 511 indicated that travelers utilized the 511-telephone system more than they did the previous *ROAD and 800 information services. In terms of total number of calls, there were 198,068 callers to 511 versus the two baseline winter seasons, which had 163,411 (2000 – 2001) and 132,861 (2001 – 2002), respectively. Average usage per month also indicated more 511 calls (56,591) than pre-511 calls (24,690). The increased number of 511 callers is statistically reliable when the analysis takes into account the number of calls per storm events ($F(1,14)=9.42$, $p < 0.01$). The number of 511 callers per storm event is approximately 16 percent higher (926/797) than the per storm event calls in 2000 – 2001, and about 53 percent higher (926/607) than in 2001 – 2002.

March 2003 was a particularly active month for storm events with 123 events occurring across the state. This resulted in nearly 90,000 callers requesting road and weather information during March. One period in particular, March 5 – 9, 2003 – sustained 71 of the 123 storm events, resulting in over 55,000 callers, with nearly 18,000 calling on March 7, 2003 alone.

Although it was originally hypothesized that maintenance personnel would use the road and weather information provided through GYRTWIS more than existing systems, maintenance personnel did not use GYRTWIS. MDT modified its anti-icing practices because of safety, cost effectiveness, public perceptions, and environmental factors. Maintenance crews are now applying "just-in-time" anti-icing treatments to road surfaces and utilizing actual information (camera views, weather reports) and weather forecasts instead of road condition predictions based on sensor data.

Customer Satisfaction

The *2003 Montana Traveler Information Survey* indicated that a majority of Montana travelers were quite satisfied with the accuracy, availability, usefulness, and ease of understanding of the GYRTWIS road conditions and weather forecast information. For all measures of satisfaction, a higher percentage indicated they were satisfied with the GYRTWIS 511-telephone service when compared to the previous *ROAD and 800 telephone services. Table ES-2 displays a comparison of 2002 and 2003 customer satisfaction measures both Before and After GYRTWIS 511, and the percentages regarding the respondents' satisfaction level.

Table ES-2. Comparison of Satisfaction Before and After 511

Measure of Effectiveness	Before 511 (*ROAD & 800) (2002 Survey)	After 511 (2003 Survey)
Accuracy	Road Conditions & Weather Forecasts: – Somewhat Accurate/Very Accurate = 62%	Road Conditions: – Satisfied/Very Satisfied = 81% Weather Forecasts: – Satisfied/Very Satisfied = 73%
Availability	– Somewhat Available/Very Available =62%	– Satisfied/Very Satisfied = 77%
Usefulness	– Somewhat Useful/Very Useful = 88%	– Satisfied/Very Satisfied = 90%
Understandability	– Somewhat Easy/Very Easy = 73%	– Satisfied/Very Satisfied = 82%

Road condition and weather information continued to be very important to Montana travelers. The results of the *2003 Montana Traveler Information Survey* indicated a similar trend to the

1997 Rural Traveler Survey with participants rating road and weather information as more important than other types of information. In the 2003 survey, information about winter road conditions on highways and weather forecasts were the most important items (mean rating of 4.91 and 4.23, respectively, on a 5-point scale).

Pavement Thermal Model Accuracy

Montana State University (MSU) has successfully demonstrated the feasibility of the PTM process of forecasting road surface temperatures that is based on a physical model of energy transfer at the road surface and within the road. This process uses available terrain and weather forecast information to provide inputs to a thermal model of the road, from which road surface temperatures are estimated. Despite the complexity of this process – in particular, the complexity of generating small-scale weather forecasts and computing terrain-to-terrain radiant energy exchanges – MSU demonstrated the ability to generate a continuous stream of road surface temperature forecasts.

Validations of these forecast temperatures showed typical differences between forecast and measured values of about 5 °C. To be useful for estimating when icing might occur, much more accurate forecasts are needed. During initial validations, significant differences between the forecast and measured weather conditions were observed. It was proposed that these differences resulted in much of the errors in forecast road surface temperatures. Subsequent validation activities, during which *measured* instead of *forecast* weather data was used, confirmed this supposition and reduced the typical differences between forecast and measured temperatures to about 2.5 °C. (Similar observations about the limitations of forecast weather data were noted during validation activities for the road surface temperature model used for the Maintenance Decision Support System [MDSS].)

Thus, although the PTM process shows promise for forecasting road surface temperatures, limitations in the accuracy of small-scale, long-term weather forecasts currently limit the accuracy of the road surface temperature forecasts. These limitations may make it difficult to use the PTM to directly support anti-icing decision-making at this time – the overall accuracy of the model is not high enough at this time to make anti-icing decisions based primarily on the road surface temperatures forecast by the model. However, the forecast road surface temperatures could still assist maintenance managers in making anti-icing decisions – for example, allowing them to estimate the relative risks of icing at different locations – areas with high forecast road surface temperatures should be less likely to ice than areas with low forecast temperatures. Travelers might use the results in a similar way in deciding whether a trip should be postponed because the risk of icing was high.

Business Model Case Study

The Business Model Case Study focused on a qualitative investigation of the GYRTWIS business model, including how the services were being funded and maintained. The key findings are:

- The GRYTWIS 511-telephone service emphasizes providing readily available and accurate information to address traveler safety concerns. Therefore, the goal of the system is to provide accurate and timely weather and road condition information. This contrasts with urbanized areas where emphasis is most often placed on the need for congestion information over road condition.

- Project management does not favorably view promoting the 511 system to generate revenue in order to become a self-sustaining service. Since the 511 system replaced the *ROAD telephone service and was built on existing MDT maintenance processes and information, public opinion and support of the service is of higher priority than generating self-sustaining revenue.
- However, lodging and other tourist-related advertising on kiosks and other State-owned properties is a possibility due to recent changes to Montana state law.
- MDT used a low-cost (approximately $40,000) “grassroots” approach to raise State residents’ awareness regarding the 511-telephone service. The GYRTWIS 511 project management mobilized approximately 240 MDT employees who participate in the MDT Transportation Awareness Program to educate the public at county fairs and other public events. Based on the GYRTWIS marketing and outreach experiences, the least and most costly methods are shown in Table ES-3.

Table ES-3. Relative Costs for Marketing and Outreach Activities

Marketing / Outreach Method	Relative Cost
"Word of Mouth"	Free
Transportation Awareness Program	Low
Press Releases	Low
News Interviews	Low
Newspaper Articles	Low
1-800 Announcements	Low
Highway Signs	Low – Moderate
Billboard Advertising	Moderate
Public Service Announcements	Moderate

- Despite close relationships between the partners and having the Memorandum of Understanding (MOU) and Statement of Work (SOW) documents in place, the lack of formalized policies, procedures, and requirements in a systems engineering plan, and the lack of MDT staff availability for oversight made monitoring technical progress a challenge. The development effort would have benefited from creating and using a systems engineering plan that described the functional requirements, data flows, testing requirements, specific deliverables, and schedule.

Institutional Lessons Learned

The GYRTWIS project team was a close-knit, fairly small group of people; however, coordination became challenging over time. A number of factors contributed to coordination issues: a high level of trust between project team members resulted in the management team allowing the development effort to progress without a systems engineering plan to clearly define roles and communicate system requirements; the structure of the funding arrangement also contributed to some confusion as MSU/WTI received the Earmark funding and managed the Meridian contract, but the 511 system was being developed for MDT; and the lack of full time MDT staff devoted to the project resulted in part time monitoring and management of the development issues.

- **Information Sharing.** Sharing information and documentation about design decisions from conference calls and conversations was found to be more problematic than the sharing of technical data (such as RWIS or meteorological data). The emergence of this information-sharing gap led to MDT and MSU/WTI management team documenting important conversations. For important calls with Meridian, MDT and MSU/WTI both participated in the calls, and a call report documenting the key points of the meeting was developed and distributed by MSU/WTI.
- **Planning Documents.** Two planning documents had a positive impact on overcoming obstacles. The Greater Yellowstone Regional Intelligent Transportation System (GYRITS) Regional Architecture was cited as a useful planning tool for guiding the GYRTWIS deployment. The Montana DOT Strategic Business Plan was cited as being a useful tool to address job security issues and alleviate fear of job loss due to new technology.
- **State of Montana Experts.** The identification and use of in-house (State of Montana) experts to address complicated issues proved especially helpful in dealing with the companies operating telephone services in the region (both wireless and landline companies). The GYRTWIS management team identified and enlisted the help of an individual from the State of Montana Department of Administration that was experienced in dealing with telephone issues for the State. The individual was able to coordinate a meeting with all the phone companies and negotiate an agreement with no per call charges and minimal switching costs.
- **Benefits.** Working together to develop GYRTWIS provided several benefits and advantages for MDT. These benefits included the sharing of ideas and perspectives, working with others who have ITS experience, and learning about ITS without having to hire additional personnel.
- **Budget Challenges.** In terms of challenges, the lack of budget for meetings and workshops and geographic dispersion of the project team were perceived as more of an inconvenience than major challenge. The team now plans and designates a budget for travel in proposals to allow the team to travel to meet and discuss issues in person. Whether for meetings in Montana at MDT or WTI/MSU, in North Dakota at Meridian, or to attend workshops/conferences, traveling in-person to view progress and discuss issues was still viewed as productive and valuable for gaining knowledge and insight. The 511 Deployment Coalition was mentioned as doing a good job in providing travel funding for the GYRTWIS team.

- **Cellular Phone Providers.** Obtaining the participation of cellular phone providers was a major challenge for the GYRTWIS 511-telephone service. However, throughout the United States in 2002 (and into the first half of 2003) the wireless companies began participating and advertising the 511 service. By early June 2003 in Montana, an agreement was signed between the State of Montana and all the major wireless companies operating within the State.

511 Implementation Challenges, Guidelines, and Standards

Following are the 511 implementation challenges, guidelines, and standards observed throughout this project:

- **Challenges.** Three noteworthy implementation challenges and their outcomes were described. Two of these challenges were anticipated and the third was unexpected. First, concern about the willingness of wireless companies to support the GYRTWIS 511 service was identified as a potential implementation stumbling block. Although not an isolated case, MDT's concern was similar to 511 deployments in other parts of the country such as in Arizona and Northern Kentucky. The wireless companies did agree to participate and support Montana's 511-telephone service and the last major wireless company signed an agreement with MDT in late May 2003.

  Another implementation challenge was the legislative changes whereby the Montana Department of Administration became responsible for the purchase of computer and telephony equipment. This legislative requirement delayed the procurement of the telephone equipment, which in retrospect, was beneficial to MDT. MDT decided to lease, not buy, the telephony equipment from Meridian, thereby avoiding operations and maintenance costs. Depending on demand, additional phone lines may be leased if needed.

  The one unexpected challenge was directly related to the system development. Because the 511 system was developed by Meridian in North Dakota using a different version of the interactive voice response (IVR) telephone system, the 511 system did not initially function as expected due to technical difficulties, which delayed the deployment. However, the GYRTWIS 511-telephone service was successfully deployed on January 15, 2003. As a result of this challenge, Meridian put into place a duplicate of the real-time system to test system changes prior to deployment. The test system enables MDT to call a test number and hear how the system is working prior to implementation.

- **Guidelines.** The 511 Implementation Guidelines[5] were perceived to be fairly general, yet useful in providing a high-level understanding of the 511 service. The Guidelines were found to be helpful in explaining to higher levels of management the 511 design decisions. The content guidelines were also described as helpful in identifying the type of information from National Parks that could be included in 511. However, since GYRTWIS was developed

[5] 511 America's Traveler Information Number Implementation Guidelines for Launching 511 Services, Version 1.0 Published by the 511 Deployment Coalition, November 2001. Version 2.0 of the "*511 Implementation and Operational Guidelines*" is now available at: http://www.itsa.org/ITSNEWS.NSF/4e0650bef6193b3e852562350056a3a7/8f8183993d0f638985256db100783faf?OpenDocument.

using Meridian's #SAFE system, the Guidelines were not viewed as very helpful in terms of aiding actual development.

- **Standards.** The ITS Architecture Standards were viewed as useful for planning purposes. The ITS Architecture Standards provided a framework for the regional architecture, as well as the development of the overall GYRTWIS architecture. One limitation was noted regarding the ITS Architecture Standards. The ITS Architecture Standards for Advanced Traveler Information System (ATIS) were not viewed as very helpful in providing guidance on message sets for signs. However, participation in the 511 Deployment Coalition meetings and events provided MDT a means to learn from other 511 activities and discuss issues with other 511 implementers.

  The 511 Implementation Guidelines[6] were reviewed, and a variety of suggestions and comments yielded the following key points:
  - The national guidelines should not be limited to just one solution.
  - There should be a more definitive split between urban and rural areas.
  - Allowing users to provide feedback can help planners/developers to identify problems, obtain input on suggested improvements to content, menu design, etc., and can be a valuable public relations tool.
  - Flexibility in the selection of road segments, routes, or corridors is a desirable feature.
  - Providing route-specific weather and highway information provides travelers a complete view of the route.
  - Providing access to customer service center operators raises significant issues related to cost and service implications.
  - The guidelines should include interregional information as part of the basic information required along highways.
  - Implementing a system that allows callers to report incidents raises quality control issues.
  - Some personalized services should be provided by the private sector.
  - Accuracy, timeliness, and reliability are essential to maintaining users trust in the system.

Lessons Learned

The following lessons learned were derived from the GYRTWIS 511 deployment:

- Road condition and weather forecast information is more important to rural travelers in cold weather regions than other types of information. Travelers surveyed in 1997 and 2003 consistently rated road condition and weather forecast information as more important than other types of travel information. These results suggest that travelers on Montana's rural roads and highways are more concerned with the safety of road conditions and weather forecast information than another other types of information (e.g., city road conditions, accident information, public transit).

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[6] 511 America's Traveler Information Number Implementation Guidelines for Launching 511 Services, Version 1.0 Published by the 511 Deployment Coalition, November 2001. Version 2.0 of the "*511 Implementation and Operational Guidelines*" is now available at: http://www.itsa.org/ITSNEWS.NSF/4e0650bef6193b3e852562350056a3a7/8f8183993d0f638985256db100783faf?OpenDocument.

- **Low-cost methods of promoting the 511 service can be effective.** In Montana, raising public awareness of 511 was promoted using Transportation Awareness Program (TAP) staff at public events and other low cost methods such as press releases, TV news interviews, newspaper articles, highway signs, announcements on pre-511 telephone numbers, and "word-of-mouth" about road and weather information services. Based on the analyses of numbers of calls it appears the promotion methods were reasonably effective in raising public awareness.
- **Allocate adequate staff time for planning, development, and oversight of the 511 deployment effort.** In retrospect, this was one of the most overlooked issues for MDT staff. As a result of multiple duties and overwork, it was difficult to monitor progress, address issues, maintain coordination between team members, and keep open lines of communication.
- **Incorporate adequate budget for travel costs to project meetings, conferences, and other related activities.** This was especially important for the GYRTWIS team because not only were they geographically dispersed, but they also found conferences and in-person meetings to be very useful in discussing and addressing issues.
- **Clearly define roles, responsibilities, plans, and processes.** Detailed partnership agreements, SOW documents, and systems engineering plans are very important to define roles, responsibilities, and provide detailed descriptions of functional specifications, deliverable dates, and system test requirements.
- **Document calls, meetings, and discussions when they involve making important decisions.** As the GYRTWIS development effort progressed, details on design decisions (such as what was decided and by whom) became difficult to recall until the team began keeping records of important calls and discussions. The records were distributed and kept so they could be later referenced, if needed.
- Planning documents are important for providing guidance and information to upper-level management and any staff that might be threatened by the new technology. Having a Montana DOT Strategic Business Plan and a regional ITS architecture provided a framework for others to understand how GYRTWIS fit into the current MDT environment.
- **Identify and utilize experts to help solve complicated issues.** When confronted with the task of meeting and negotiating agreements between MDT and the region's telephone companies, MDT was able to identify and enlist the help of a telecommunications expert within the State of Montana Department of Administration to work with the telephone companies and negotiate an agreement for the 511 service.
- **Leasing, not buying, equipment and services can be an attractive alternative to avoid operations and maintenance costs.** MDT decided to lease the equipment to avoid operating and maintaining the telephone system, and if necessary, MDT has the ability to lease additional phone lines when needed.
- **Test the new 511 system and any upgrades on a system platform identical to the one being used in the field.** System testing on an identical system platform will reduce the risk of technical problems when attempting to deploy in the field.

- The 511 Guidelines and ITS Architecture Standards are useful for guidance, but implementers should also seek other sources of information for guidance. The GYRTWIS team found meetings and conferences provided opportunities to learn from others and discuss issues.

1.0 Introduction

1.1 ITS Integration Program

As sponsored by the U.S. Department of Transportation (USDOT) in conjunction with the Joint Program Office (JPO) and the Federal Highway Administration (FHWA), the Intelligent Transportation System (ITS) Integration Program is being conducted to accelerate the integration and interoperability of ITS in metropolitan and rural areas.[7] Projects approved for Federal funding have been assessed as supporting the improvements of transportation efficiency, promoting safety, increasing traffic flow, reducing emissions, improving traveler information, enhancing alternative transportation modes, building on existing ITS projects, and promoting tourism. A small number of these projects are selected for national evaluation. The Greater Yellowstone Regional Traveler and Weather Information System (GYRTWIS) in Montana was among the selected projects in Fiscal Year 2000.

Montana implemented the GYRTWIS to improve the road and weather information available to travelers and maintenance personnel. One facet of GYRTWIS replaced the *ROAD service (which is a non-interactive, recorded message system) with a 511-telephone information service that is based on Meridian Environmental Technology's #SAFE system. The 511-telephone system is an interactive system that uses road condition and weather forecasts and provides the information through landline or cellular phones via a 511-telephone access number.

The second facet of GYRTWIS developed a Pavement Thermal Model (PTM) to receive road weather information and forecasted weather condition information and generate a location-specific prediction of pavement conditions. Researchers at Western Transportation Institute/Montana State University (WTI/MSU) developed the model primarily to provide additional information to highway maintenance personnel to help support treatment decisions. WTI/MSU researchers have also been investigating how to best use PTM and other weather data for traveler information. Starting in 2004, these researchers will investigate the efficacy of integrating a Pavement Thermal Model (PTM) being developed by WTI/MSU into the 511 system.

A team led by Science Applications International Corporation (SAIC), under direction from the USDOT ITS/JPO, was selected to evaluate GYRTWIS. Three areas were investigated for this evaluation:

- System impacts of 511 on usage and customer satisfaction.
- Investigation of PTM Accuracy.
- Case study of the Business Model, Institutional Lessons Learned, and 511 Implementation Challenges, Guidelines, and Standards.

The purpose of the evaluation was to determine whether the project goals were met, and to assist others who may be considering similar deployments. This document focuses on the methods, results, and lessons learned from Phase III of the evaluation. As such, the results and lessons

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[7] See brochure *Intelligent Transportation Systems in the Transportation Equity Act for the 21st Century*[7] at http://www.itsdocs.fhwa.dot.gov/jpodocs/brochure/4p601!.pdf for a synopsis.

learned reported in this document are based on comparisons of data collected both Before and After GYRTWIS deployment.

1.2 Background

Montana is a large, rural state with a landmass of over 147,000 square miles and about 70,000 miles of public highways and roads. Although the State of Montana is larger than the combined areas of New York, Maryland, Delaware, Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, New Jersey, and Connecticut, it consists of only 2 percent of the combined population of those states.[8]

The mountainous corridors in Montana can be difficult to travel, especially during adverse weather conditions. Approximately 77.7 percent of Montana's vehicle miles traveled (VMT) take place outside of urban areas[9]. It is during the fall, winter, and early spring seasons that weather conditions can adversely impact traveler safety and security and be challenging to road maintenance operations. In 1998, Montana averaged 2.5 fatal crashes per hundred million vehicle miles (HMVM) versus the national average of 1.6 fatal crashes per HMVM[10]. In 1999, Montana Department of Transportation (MDT) crews plowed 3,067,406 miles of highway, applied 1,856,376 gallons of liquid anti-icing/deicing materials, and deposited nearly 302,595 cubic yards of sand.[11]

Annually, 3 million travelers visit Yellowstone National Park. Adjacent to the park are three states: Montana to the north and west; Idaho to the southwest; and Wyoming to the south and east. Yellowstone National Park and portions of the surrounding states and principal roadways are shown in Figure 1-1. The mountainous corridors in Montana can be difficult to travel, especially during adverse weather conditions. In winter, temperatures often hover near zero throughout the day, occasionally reaching highs in the 20s. Subzero nighttime lows are common. Annual snowfall averages nearly 150 inches in most of the park. At higher elevations, 200-400 inches of snow have been recorded[12]. Periods of high winds, fog, and heavy rain are also common to the region.

1.3 Problem Statement

MDT has been proactive in deploying road weather information systems (RWIS) to capture/interpolate road condition information and predict travel conditions. Surface and atmospheric conditions are also measured at various sites (e.g., airports, cities, etc.) and by other agencies (e.g., National Weather Service, National Oceanographic and Atmospheric Administration, Agrimet, avalanche organizations, etc.). Despite these efforts, in the past, the information often has been unavailable to travelers in a timely and consistent fashion. The information was also difficult for road maintenance decision makers to use in an effective manner to more effectively maintain the roadways.

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[8] Montana Fast Facts, http://www.mdt.state.mt.us/map/fastfact.htm.
[9] Ibid.
[10] USDOT National Center for Statistics and Analysis; http://www-fars.nhtsa.dot.gov
[11] Montana Fast Facts, http://www.mdt.state.mt.us/map/fastfact.htm.
[12] Yellowstone National Park Weather Page, http://www.nps.gov/yell/planvisit/orientation/weather/index.htm.

As a proposed solution to these challenges, MDT launched the GYRTWIS initiative. GYRTWIS was developed as a two-pronged approach to disseminating information to individuals who need it most: MDT maintenance operators and personnel and Montana's travelers. For MDT maintenance personnel, the system was expected to provide detailed weather forecasts and predictions of road conditions to facilitate maintenance operations and improve the utilization of personnel, snow removal equipment, and anti-icing activities. It was anticipated that the GYRTWIS system would result in fewer and less severe accidents related to poor road surface conditions and improved productivity and mobility. However, during the development of GYRTWIS, changes in MDT's winter anti-icing procedures made it unlikely that maintenance operators will use predictions of weather and road conditions.

For Montana's travelers, the system enables MDT to disseminate weather and road condition information to the traveling public. It was anticipated that travelers in Montana would find the 511-telephone service a more useful and satisfying means to obtain weather and road condition information over the previously used *ROAD telephone service.

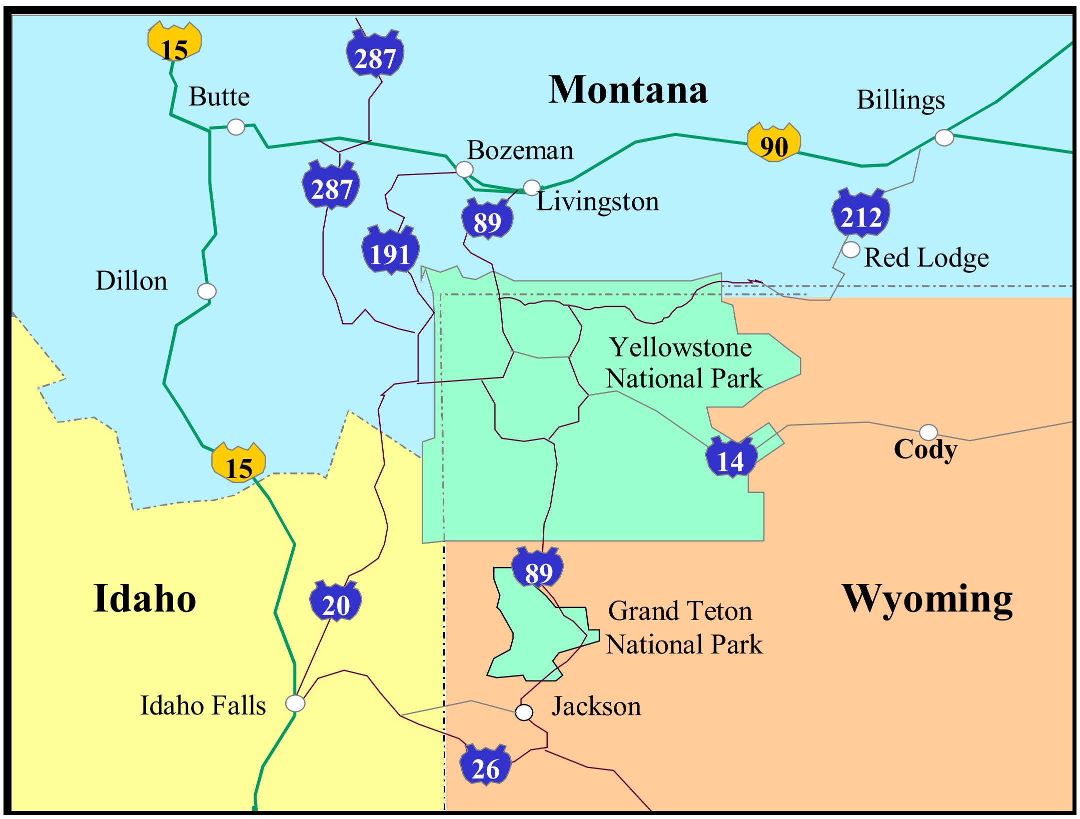

Figure 1-1. Greater Yellowstone Region

1.4 GYRTWIS Description

1.4.1 Project Goals and Objectives

The goals and objectives identified for the GYRTWIS project are shown in Table 1-1. The success of this project is evaluated by determining how well each of these goals and objectives are met. The Western Transportation Institute/Montana State University (WTI/MSU) team documented a procedure for evaluating the GYRTWIS project as described in "Greater Yellowstone Regional Traveler Weather Information System Evaluation Plan Version 1.0".[13]

Table 1-1. Project Goals and Objectives

Goals	Objectives
Inform the traveler of adverse weather conditions.	Provide accurate and timely road weather conditions to the traveler. Provide road and weather information in a format that is useful to the traveler. Inform the public that the information is available.
Improve information available for maintenance and ice and snow removal activities.	Provide accurate and timely road weather conditions to maintenance personnel. Provide road and weather information in a format that is useful to the maintenance user.
Improve coordination of road information dissemination across jurisdictional boundaries and project boundaries.	Provide easy access for the traveler to out-of-state information. Improve coordination between State information providers. Exchange data with other road information sources.

The GYRTWIS project consists of three components:

- #SAFE, the Regional Multi-Modal Traveler Information Service.
- Pavement Thermal Model.
- The 511-Telephone Information System.

The output from #SAFE is currently disseminated through the telephone to the public and over the Internet to MDT and GYRTWIS project personnel. In the future, the information may also be packaged for availability to kiosks, dynamic message signs (DMS), and other devices in Montana and adjoining states. The #SAFE, PTM, and 511 system are described in more detail in the following Sections 1.4.2, 1.4.3, and 1.4.4, respectively.

1.4.2 #SAFE

Meridian Environmental Technology (Meridian) of Grand Forks, North Dakota, developed #SAFE, the traveler information component of the GYRTWIS project in Montana. The #SAFE system provides the traveler weather forecasts and road conditions from mesoscale meteorological data via cellular, pavement condition survey (PCS), and landline telephone. The weather and road information is also available over the Internet[14].

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[13] Requests for additional information regarding this document should be forwarded to Mr. Michael Bousliman, MDT (mailto:Mbousliman@state.mt.us).
[14] Meridian Environmental Technology, Inc. Safe Travel USA, http://safetravelusa.com.

The telephone service (shown graphically in Figure 1-2) works by interfacing coded weather information with a computer telephony system located in North Dakota. The system provides location-specific information through an interactive process with the traveler. Under GYRTWIS, #SAFE was expanded into Montana and accessible to Montana travelers using the 511 system. Data from MDT's 59 RWIS stations were integrated and used to provide the weather *Nowcast/Forecast* and road condition information (see Section 1.4.3 Pavement Thermal Model for additional detail on this subject).

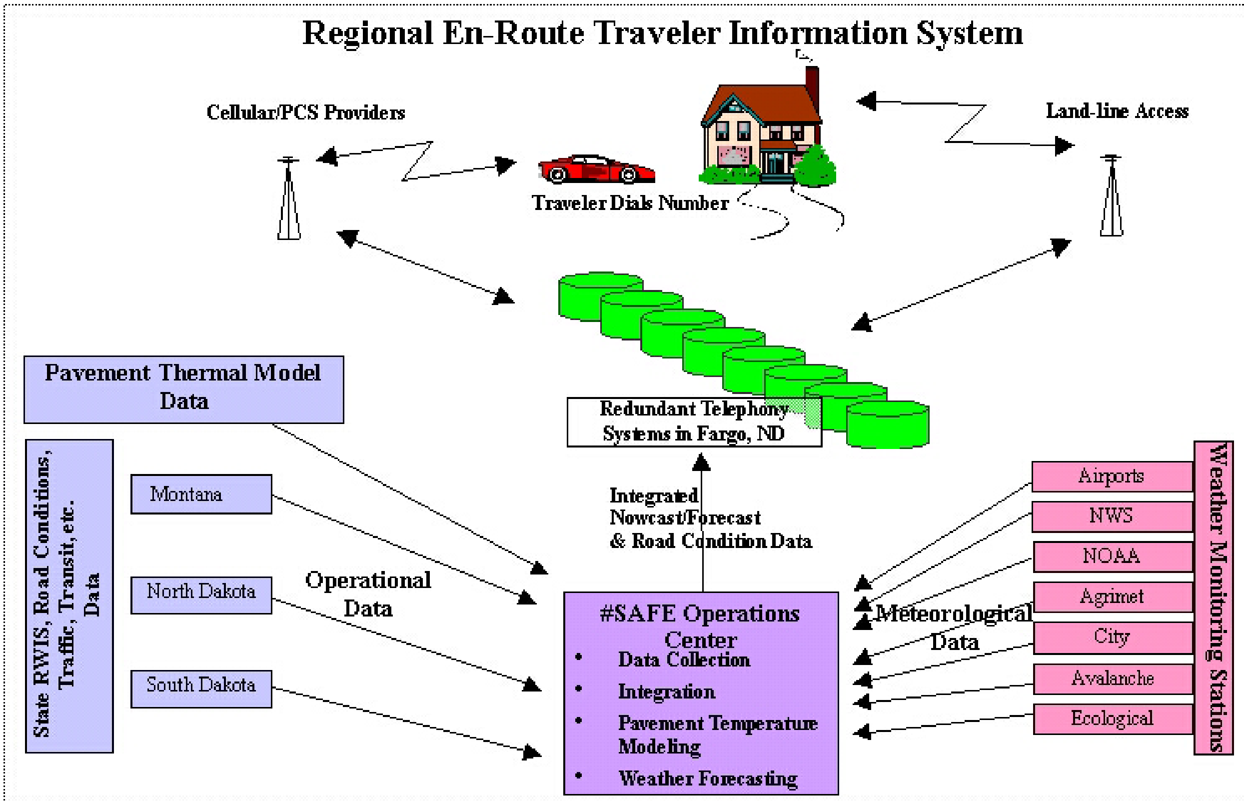

Figure 1-2. #SAFE System

After answering several questions about their location, Montana travelers calling the 511-telephone service hear a route-specific road conditions report and a 6-hour weather forecast.

In the late 1990s, both North and South Dakota implemented the #SAFE system from which cellular and PCS telephone users can access the information. After the deployment of the system in those states, the Federal government designated 511 as the National Traveler Information number.[15] Montana used the nationally designated telephone number for dissemination of weather and road condition information under the GYRTWIS project.

1.4.3 Pavement Thermal Model (PTM)

A second component of the GYRTWIS project is the PTM that provides predictions of the current road surface conditions. The PTM's pavement prediction information is being

[15] Approved and designated by the Federal Communications Commission in July 2000.

investigated to determine how best to integrate the information into #SAFE to provide forecasted road surface conditions to Montana travelers and MDT maintenance personnel. The PTM began in 1997 when WTI/MSU, in conjunction with MDT and FHWA, began work on a proof-of-concept study under the Montana Partnership for the Advancement of Research in Transportation Small Project Program. This led to the SAFE-PASSAGE project, which employed a road and weather condition prediction model integrated with several traditional ITS technologies (RWIS, DMS, and Highway Advisory Radio [HAR]) to improve the safety of travel through Bozeman Pass (between Bozeman and Livingston, Montana).

As part of GYRTWIS, researchers at WTI/MSU are developing a PTM that uses forecasted wind, air temperatures, humidity, and radiation, as well as the topography of the landscape, to predict pavement temperatures. This type of modeling has its greatest utility in areas with complex topography, such as mountain passes and coulees. The computer model has the potential of forecasting road surface conditions where no RWIS sites exist. In addition to Bozeman Pass, the thermal model was expanded to Lookout Pass in northwest Montana in January 2003. As a proof of concept study, the PTM was also used to model the 19th Street Bridge in Bozeman.

1.4.4 511 Traveler Information System

In March 1999, the USDOT petitioned the Federal Communications Commission (FCC) to adopt a new, national 3-digit telephone number to allow easy access to transportation and travel information. The nationally designated number provided travelers with a standard number to call in order to receive highway information (such as traffic conditions, construction, and road-weather); public transit information (such as transit buses, ferries, light rail); and other optional content (such as services and attractions, tourist information, special events, etc.).

The FCC ruling in July 2000 left nearly all implementation issues and schedules to state and local agencies and telecommunications carriers. As a result, the 511 Deployment Coalition was established to assist State and local agencies with the further development and integration of 511 systems. The Coalition consists of representatives from the American Association of State Highway and Transportation Officials (AASHTO), in conjunction with many other organizations, including the American Public Transportation Association (APTA), and the Intelligent Transportation Society of America (ITS America), with support from USDOT.

In November 2001, the 511 Deployment Coalition released a set of guidelines to assist state implementers in developing 511 systems and in reducing the potential for service confusion and inconsistency. The Coalition developed the "Implementation Guidelines for Launching 511 Services"[16] to assist implementers in their efforts to develop quality systems and to lay the foundation for ultimately establishing a consistent nationwide 511 service. The Coalition recognizes that 511 services will be developed in a bottom-up fashion, with services being established in areas and timeframes as determined by individual state and local transportation agencies.

[16] 511 America's Traveler Information Number Implementation Guidelines for Launching 511 Services, Version 1.0 Published by the 511 Deployment Coalition, November 2001.

The guidelines focus on two main areas: service content and service consistency. The service content describes basic and optional content. The *basic content* provides information that every 511 system should have, such as highway and public transportation information. The *optional content* provides information that is at the discretion of the system implementers and may be supported by public and/or private sector supported services. The service consistency guidance provides implementers a blueprint in the following areas:

- User Interface
- Initial Greeting
- Commercial Advertising and Sponsorship
- Fee Notification of Premium Services
- Multilingual Capabilities
- Time stamping of Information
- System Access Quality
- Hours of System Operation
- Americans with Disabilities Act (ADA) Implementation
- Environmental Justice
- Use of Standards
- Privacy
- 511 Branding
- Number Allocation and Service Coordination

1.5 GYRTWIS Project Participants

The GYRTWIS project participants are identified in Table 1-2, along with their accompanying roles and responsibilities.

Table 1-2. GYRTWIS Project Stakeholders, Roles, and Responsibilities

Participants	Roles/Responsibilities
Montana Department of Transportation	Project Management, Contract/Grant Administration
Montana State University/Western Transportation Institute	Project Lead, Lead for Local Evaluation, Co-Developer of Pavement Thermal Model
Meridian Environmental Technology	511 Developer, System Integration
ThermoAnalytics	Co-Developer of Pavement Thermal Model
Science Applications International Corporation	Independent Evaluator for National Evaluation

2.0 Methodology

2.1 Evaluation Objectives

This evaluation builds upon and complements the ongoing GYRTWIS evaluation being conducted by WTI/MSU. The WTI/MSU team's evaluation of GYRTWIS examines traveler perceptions of accuracy, availability, usefulness, and understandability, the accuracy and usefulness of the information for maintenance operations, and perceptions of project success.

This evaluation complements WTI/MSU's GYRTWIS evaluation by investigating three areas:

- System impacts of 511 on usage and customer satisfaction.
- Pavement Thermal Model accuracy.
- Case study of the business model, institutional challenges, and 511 implementation issues.

The three study areas and respective objectives are shown in Table 2-1. The System Impacts Study compares the baseline ("Before") usage of MDT's *ROAD and 800 road and weather information phone services to the "After" 511 usage. In addition, Before and After perceptions of customer satisfaction are also compared. The Before perceptions focus on traveler satisfaction with the travel information available and traveler-perceived needs. The After perceptions investigate satisfaction with the 511-telephone service and how well the pre-511 traveler information needs were satisfied.

The Pavement Thermal Model Accuracy Study examines the predicted versus actual pavement temperatures collected by WTI/MSU as part of its development effort. As of the date of publishing this Phase III document, the integration of the PTM data into the GYRTWIS is scheduled for mid-2004.

The objective of the Case Studies includes examining the GYRTWIS business model for MDT's 511-telephone service (what it is, how they are paying for the services, and where they hope to obtain funding for ongoing operations). A second objective is to identify the institutional benefits, challenges, and lessons learned from the effort to deploy 511 in Montana. The third objective is to investigate the challenges of integrating the technologies and the role of 511 guidelines and ITS Architecture standards in system design and implementation. Special consideration and emphasis on the advantages/limitations, and suggested changes will be noted. This document describes the methodology, baseline results, and conclusions for Phase III of the evaluation.

Table 2-1. Evaluation Study Areas and Objectives

Study Areas	Objectives
System Impacts Study:	
System Usage Test	Compare traveler usage of MDT's new 511-telephone service to existing road and weather information phone service.
	Compare maintenance personnel usage of the new pavement and weather forecasts to existing information.
Customer Satisfaction Test	Compare traveler satisfaction with MDT's new 511-telephone service to the existing road and weather information phone service.
	Compare maintenance personnel satisfaction with the new pavement and weather forecasts to the existing information available.
Pavement Thermal Model Study:	
PTM Test for Accuracy	Examine the accuracy of the Pavement Thermal Model to be used for MDT's new 511-telephone service.
Case Studies:	
GYRTWIS Business Model	Examine the GYRTWIS business model; what it is; how MDT is paying for the services; and where it hopes to obtain funding for ongoing operations.
Institutional Lessons Learned	Identify the institutional benefits, challenges, and lessons learned from the GYRTWIS project.
511 Implementation Challenges, Guidelines, and Standards	Develop a case history of implementation challenges; the role of 511 guidelines/ITS Architecture standards; and the advantages, limitations, and suggested changes.

The key hypotheses investigated for this evaluation are:

1. Travelers will use the new GYRTWIS service more than the existing road and weather information phone service.
2. Maintenance personnel will use the road and weather information provided through GYRTWIS more than existing systems.
3. Travelers will be more satisfied with the GYRTWIS service than the existing road and weather phone service.
4. Travelers will perceive the new GYRTWIS service provides useful weather, road condition, and safety information.
5. Maintenance personnel will perceive the pavement and weather forecasts as useful.
6. Maintenance personnel will perceive the pavement and weather forecasts as accurate.

7. The GYRTWIS Pavement Thermal Model will accurately predict pavement thermal conditions.

2.2 Evaluation Timeline

A draft Evaluation Plan was presented to the MDT project manager and key project personnel in February 2002 for review. A site visit to Montana was conducted during February 28 to March 1, 2002 to interview the key project personnel and learn about the Pavement Thermal Model and obtain qualitative information for the GYRTWIS Business Model, Institutional Lessons Learned, and 511 Implementation Challenges case studies "before" GYRTWIS deployment. An interim evaluation briefing was presented to the Performance Assessment Working Group (PAWG) in June 2002. The briefing included the evaluation status and preliminary findings based on the System Usage Test and Case Study interviews. The Phase II (pre-deployment) evaluation report was submitted to FHWA in September 2002.

For Phase III, data collection was performed from January 2003 through the summer of 2003. The case study interviews occurred on May 29 – 30, 2003. The final Phase III report (this document) was submitted to FHWA in December 2003.

3.0 Results

3.1 System Impacts Study

The objective of evaluating the system impacts was to assess the impact of the GYRTWIS deployment on both travelers and maintenance personnel. This study investigated impacts in terms of system usage and customer satisfaction. To assess system usage and customer satisfaction by travelers and maintenance personnel, six hypotheses were derived as shown in Table 3-1, along with the measures of effectiveness (MOE) and data sources for the System Usage and Customer Satisfaction tests.

Table 3-1. System Impacts Evaluation

Hypotheses	MOE	Data Source
System Usage Test:		
Travelers will use the new GYRTWIS service more than the existing road and weather information phone service.	Number of Calls	WTI/MSU/MDT call tracking
Maintenance personnel will use the road and weather information provided through GYRTWIS more than existing systems.	Number of Users	WTI/MSU/MDT call tracking
Customer Satisfaction Test:		
Travelers will be more satisfied with the GYRTWIS service than the existing road and weather phone service.	Perceived accuracy, availability	WTI/MSU Traveler Surveys
Travelers will perceive the new GYRTWIS service provides useful weather, road condition, and safety information.	Perceived usefulness, understandability	WTI/MSU Traveler Surveys
Maintenance personnel will perceive the pavement and weather forecasts as useful.	Perceived usefulness	WTI/MSU Maintenance Interviews
Maintenance personnel will perceive the pavement and weather forecasts as accurate.	Perceived accuracy, timeliness	WTI/MSU Maintenance Interviews

3.1.1 System Usage Test

The following sections describe the methods, results, and conclusions for the System Usage Test. The section focuses on system usage by travelers, not maintenance personnel. Although it was originally hypothesized that maintenance personnel would use the road and weather information provided through GYRTWIS more than existing systems, maintenance personnel did not use GYRTWIS. There were two reasons why this did not occur. First, during the development of GYRTWIS, changes in MDT's winter anti-icing procedures resulted in the decision to not rely on GYRTWIS road condition prediction information. MDT modified the timing of anti-icing applications on road surfaces because of concerns related to the following elements:

- Safety – depending on operational factors, such as chemical type, as well as environmental variables, such as pavement temperature and humidity, anti-icing treatments may make the road surface slippery.
- Cost effectiveness – applying anti-icing treatments too soon sometimes results in wasted treatment chemicals due changes in weather conditions.
- Public perceptions – treatments at the wrong time are sometimes perceived as not effective and a waste of resources.
- Adverse impact on the environment.

Consequently, maintenance crews are now applying "just-in-time" anti-icing treatments to road surfaces. In addition, MDT maintenance crews are using actual information (camera views and real-time weather and pavement condition information from the RWIS sites) and weather forecasts instead of predicted road conditions based on sensor data.

A second reason system usage by maintenance personnel were not included is because the Pavement Thermal Model was still under development in 2003 and is not expected to be fully integrated into GYRTWIS until the summer of 2004. Therefore, the road condition predictions were not available during 2003. This topic is discussed further in Section 3.2 of this report regarding the Pavement Thermal Model.

3.1.1.1 Methods

MDT collected the call volume data (number of calls) for the System Usage Test. MDT provided the telephone service call volume data for the past three winter driving seasons (November to April). The number of calls was defined as the number of callers requesting road condition information from the telephone information service. For this evaluation, the call volumes per month are used for the Before and After 511 comparisons. The November 2000 to April 2001 and November 2001 to April 2002 winter seasons are used as a baseline for this evaluation. Since GYRTWIS was deployed on January 15, 2003, the call volume data for the 511-telephone service includes only the 3.5-month period from January 15, 2003 through April 2003 for the 2002 – 2003 winter driving season.

3.1.1.2 Results

System Usage By Travelers

<u>Total Usage</u>

The call volume data showed that in terms of total number of calls, travelers used the GYRTWIS 511-telephone service more than the previous *ROAD and 800 road and weather information phone services. This was true despite having a shorter data collection period than the two baseline years. As shown in Figure 3-1, the total number of calls for the two baseline years encompasses a 6-month data collection period. The total number of calls to the GYRTWIS 511 service includes a 3.5-month period.

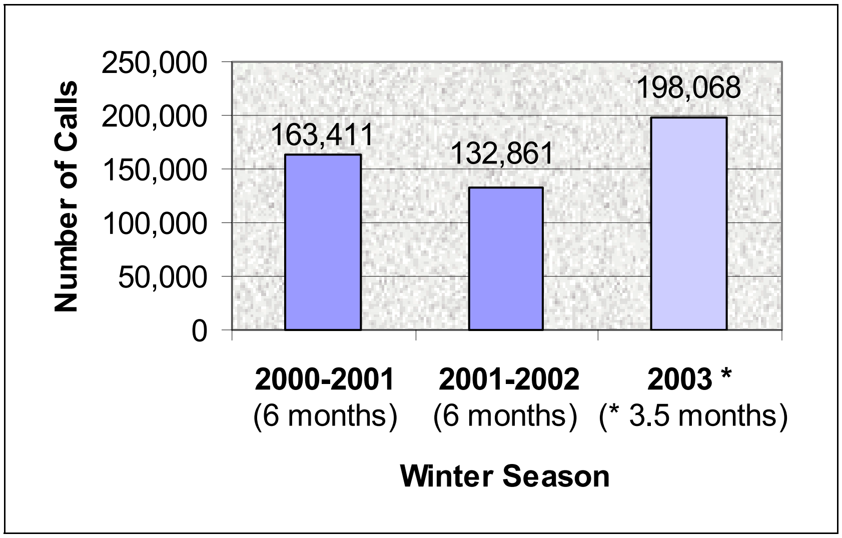

Figure 3-1. Total Number of Calls by Year per Winter Season

Average Usage Per Month

Although 2003 shows the greatest number of total calls, the differing length of data collection periods probably results in an underestimate of total calls for the 2002 – 2003 winter driving season. (The GYRTWIS 511-telephone service only includes 3.5 months of data versus 6 months for each of the baseline years.) Because of this, the Evaluation Team examined a comparison of the average number of calls per month to take into account the number of months included in the total number of calls.

The average number of calls per month is shown in Figure 3-2. The average number of GYRTWIS 511 calls per month was 56,591 or approximately twice the average number over the previous 2 years. The baseline winter periods have an average number of calls per month of 27,235 (2000 – 2001) and 22,144 (2001 – 2002). When averaged over both baseline years, the average number of baseline calls were approximately 24,690 calls per month.

However, investigating the average usage per month does not take into account the occurrence of weather-related storm events. Therefore, the next analysis examined the relationship of call volumes to storm events.

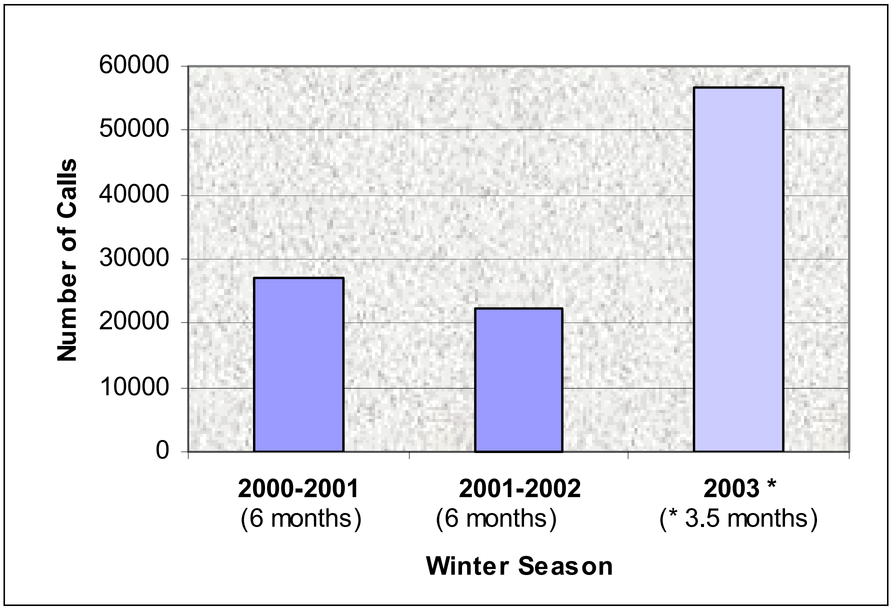

Figure 3-2. Average Number of Calls Per Month

Effect of Storm Events

The total usage and average usage per month analyses did not take into account the occurrence of weather-related storm events. Therefore, this section investigates the relationship of call volumes to storm events. The purpose of the analysis is to consider the number of storm events in determining if more callers used the 511 system than the previous telephone system.

Archived storm event data were obtained from the National Climatic Data Center (NCDC) [17] to examine the relationship between number of calls and number of storm events. All events that were believed to affect travel conditions were included. The events included in the counts were: snowstorms, ice storms, heavy rains, high winds, avalanche, extreme cold, flash flooding, hail, tornado, and high winds.

As expected, the analysis indicated that the numbers of calls per month are related (correlation, $r=0.76$) and statistically reliable ($p<0.005$) to the number storm events that occurred. Irrespective of the length of data collection periods, the total number of storm events was comparable for the Baseline and After 511 data collection periods. There were 205 weather-related storm events in Montana from November 2000 through April 2001, 219 events from November 2001 through April 2002, and 214 storm events in 2003. Figure 3-3 depicts number of calls by month and year, while Figure 3-4 presents the total number of storm events across the state during the same time periods.

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[17] National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) – Storm Events Website: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms.

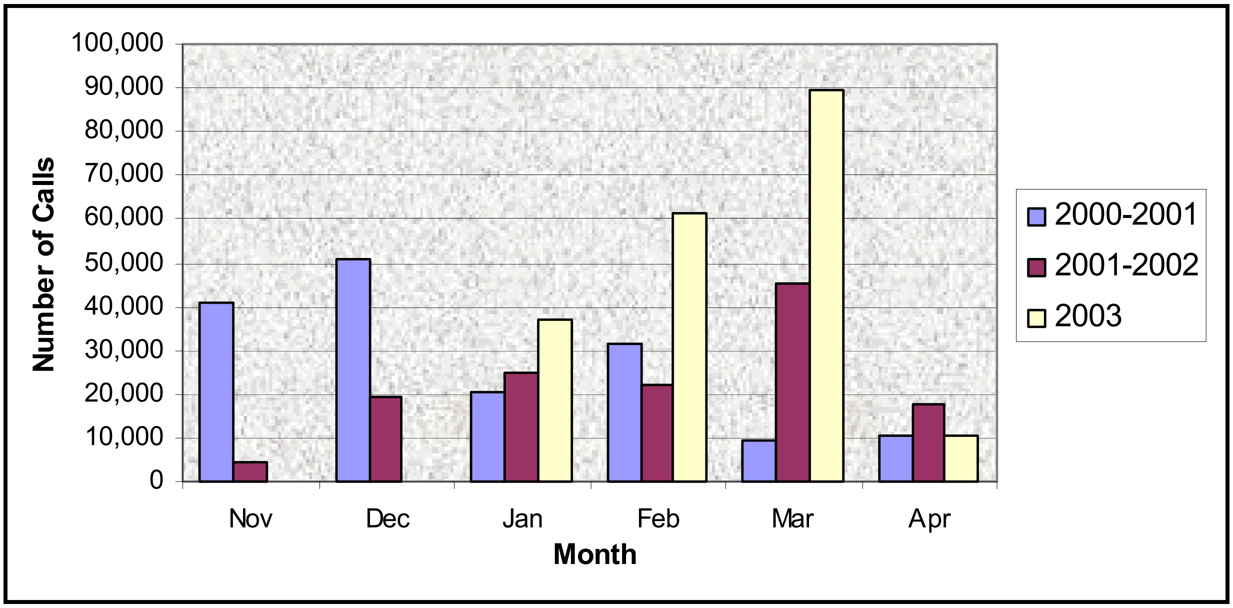

Figure 3-3. Number of Calls by Month and Year

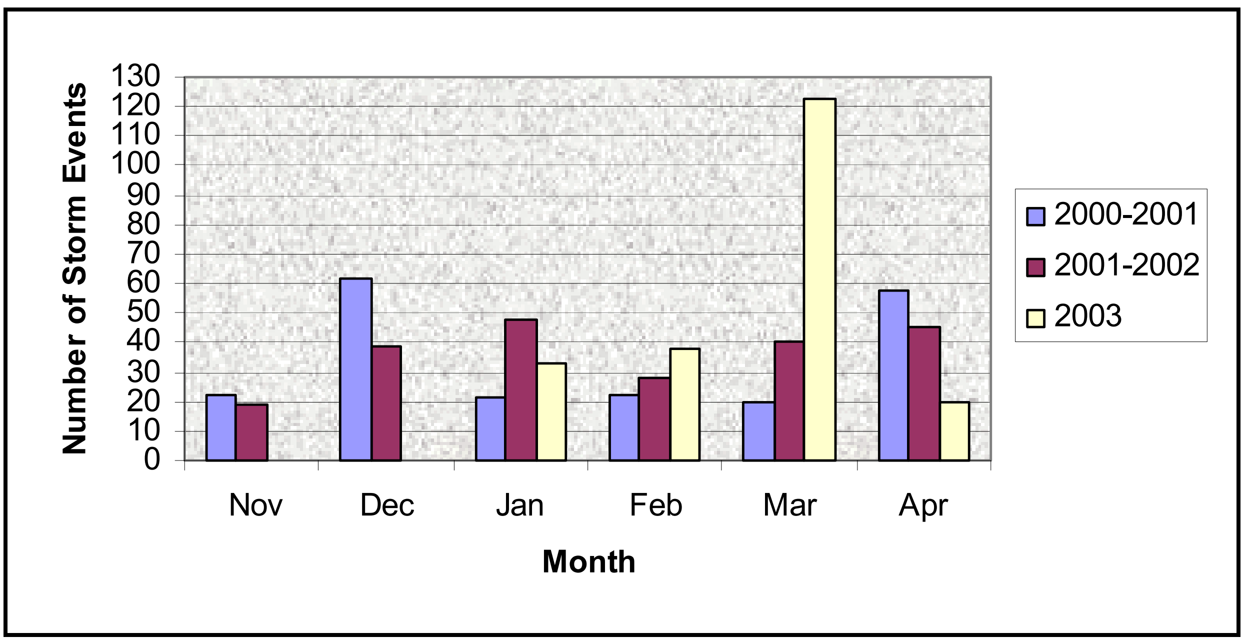

Figure 3-4. Number of Storm Events in Montana by Month and Year

An analysis of variance was performed on the number of calls by year taking into account the number of storm events. The results indicated that there was a statistically reliable difference in the number of calls between the Baseline and After 511 winter seasons, $F(1, 14)=9.42$, $p < 0.01$. Thus, it appears that taking into account the number of storm events more calls were made to the GYRTWIS 511-telephone service than to the previous road and weather information telephone service.

A final comparison was made to provide an indication of how many more callers used the 511-telephone system. First, the number of calls per storm event was calculated for each of the Before and After months. The average number of calls per storm event was 797 calls per event during 2000 – 2001, 607 calls per event during 2001– 2002, and 926 calls per event during 2003. Next, using these measures the ratios of 511 calls to pre-511 calls were compared to estimate a percentage increase in calls per average storm event. The number of 511 callers was approximately 16 percent higher (926/797) than the per storm event calls in 2000 – 2001, and about 53 percent higher (926/607) than in 2001– 2002.

To illustrate the impact of storm events on the number of 511 calls, the next section provides a detailed description of a winter storm that occurred in March 5 – 9, 2003.

Winter Storm - March 5 – 9, 2003

As shown in Figure 3-4, March 2003 was an extraordinary month for storm events in Montana. NCDC recorded 123 storm events between March 1 and March 31, 2003. Of these events, 71 occurred between March 5 – 9, 2003. This section provides a snapshot of the events that occurred and how the number of callers varied during the time period. Figure 3-5 shows a 2-km infrared satellite image of the storm system on March 7, 2003.[18] Figure 3-6 depicts the locations of Lookout Pass and Bozeman Pass in relation to the counties in Montana.[19] The storm first entered the northwest portion of Montana, and then proceeded to move eastward across the state.

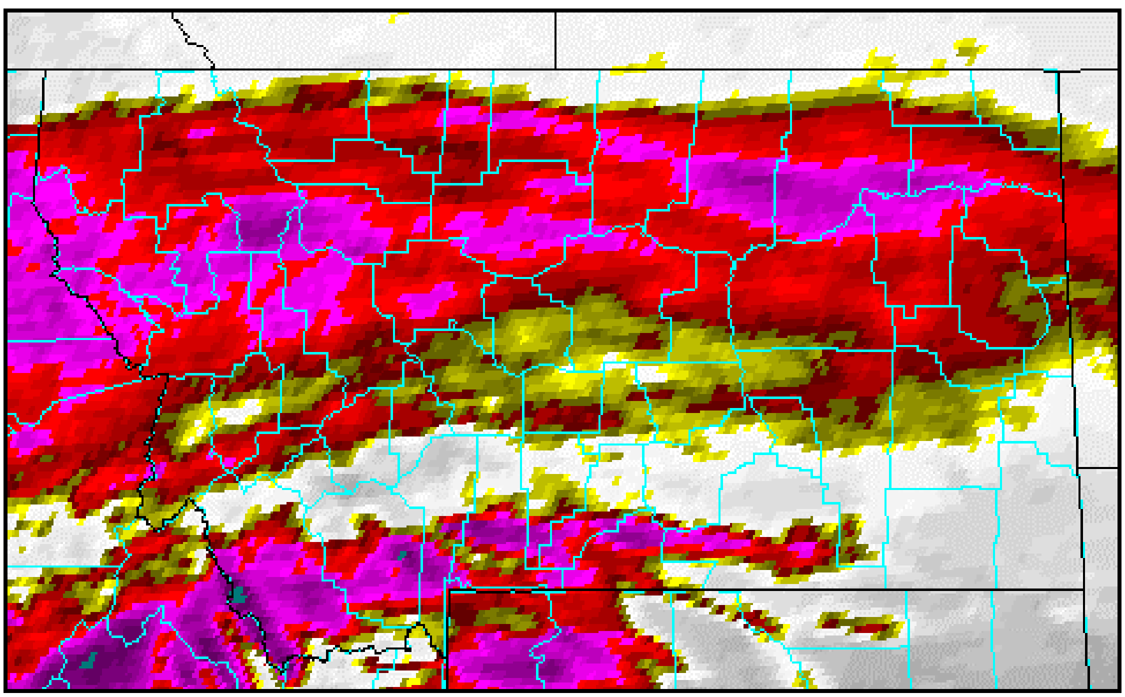

Figure 3-5. Satellite Image of Montana Winter Storm on March 7, 2003

[18] Satellite image courtesy of NOAA's National Weather Service Forecast Office Website (http://www.wrh.noaa.gov/Billings/satellite.shtml).

[19] Source: U.S. Census Bureau: State and County QuickFacts. (http://quickfacts.census.gov/qfd/maps/montana_map.html).

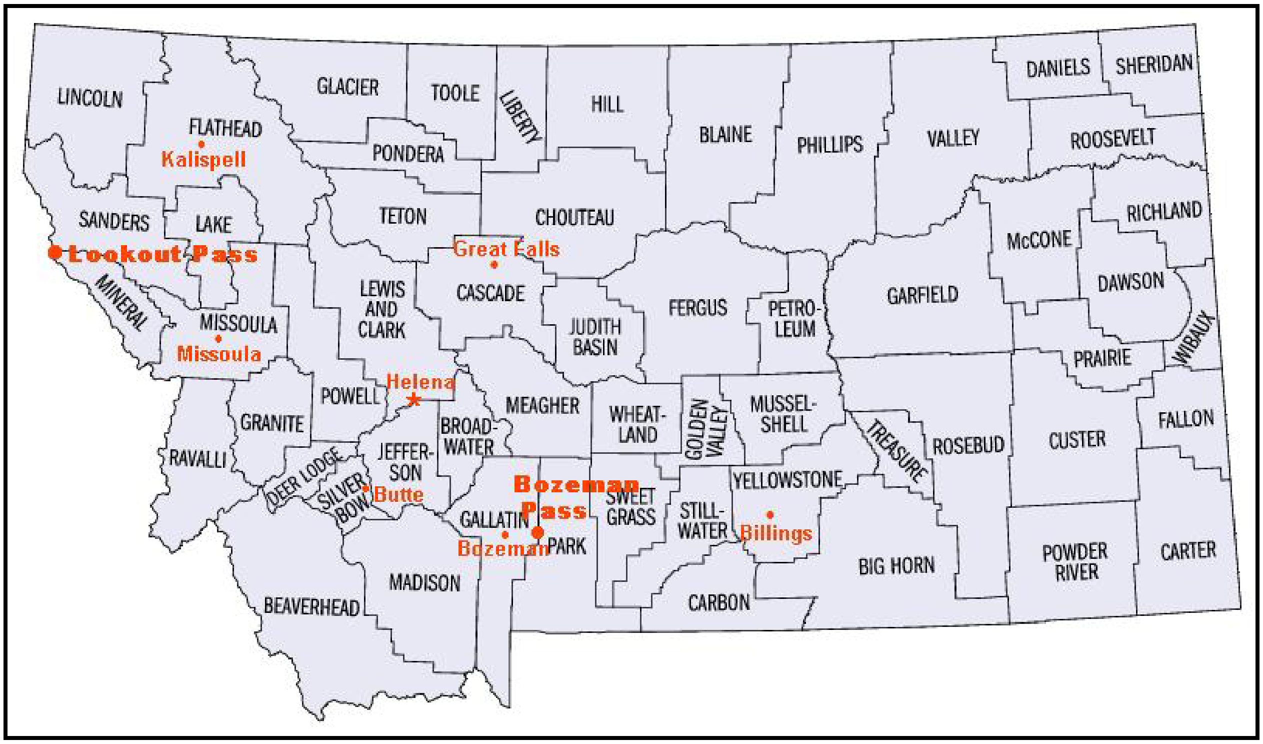

Figure 3-6. Counties and Major Cities in Montana

According to NCDC event records, a series of reports detailed snowstorm impacts from the upper northwest portions of Montana (Glacier, Pondera, and Teton Counties) beginning March 5, 2003:

> *A blizzard occurred over the entire Rocky Mountain Front on March 5th. Sustained winds near 35 mph, along with heavy snow fell from East Glacier south to Lincoln. Significant blowing and drifting snow occurred. One to two feet of snowfall was common over the Rocky Mountain Front in a 24-hour period ending by the early morning hours on the 6th.*[20]

As the storm continued, the reports from the Glacier/West Pondera/West Teton areas were updated:

> *Heavy snow fell over the entire Rocky Mountain Front from March 6th to March 10th. Snowfall amounts generally ranged from 6 to 10 inches per day. However, in a 24-hour period starting at 4:00 pm on the 7th, some areas did receive over 2 feet of snow. By the end of the storm, many locations above 5000 feet had received between 3 and 5 feet of snow.*[21]

[20] NCDC event record descriptions recorded March 5 – 6, 2003 from Glacier, West Pondera, and West Teton areas.
[21] Updated NCDC event record descriptions recorded March 6 – 10, 2003 from Glacier, Pondera, and West Teton Counties in the western portion of Montana.

Then, as the front continued moving, other portions of western Montana (Missoula, Lincoln, Ravalli Counties) reported similar events:

> *A long duration winter storm impacted a large portion of western Montana from March 5 through March 8. Pacific storm systems marched inland during the week as an Arctic cold front waffled back and forth along the Continental Divide…. The Department of Transportation declared emergency travel for different highways due to poor driving conditions during each day of the event.*[22]

By March 7, 2003 the counties around central Montana received very heavy snow. Helena, near central Montana, also received heavy snow:

> *Very heavy snow fell on the Helena Valley, and the nearby mountains on the 7th. Snowfall rates were 2 to 3 inches per hour for 12 hours…. In the city of Helena, snow amounts ranged from 18 inches on the East side, to 30 inches on the West side. Many roads were closed Friday afternoon and evening.*[23]

Finally, at the tail end of the storm on between March 8 and 9, 2003, the following report was filed:

> *Additional snow fell across areas of western Montana as the last storm system of the week impacted the region. Snow amounts in the period were mainly from 6 to 11 inches.*[24]

During the March 5 – 9, 2003 snowstorm, parts of southeastern Montana received from 8 to 24 inches of snow. By 11 p.m., Billings, the largest city in Montana, had received 16 inches of snow at the National Weather Service Forecast Office.

Figure 3-7 shows two RWIS camera views on March 7, 2003. The picture to the left is Bozeman Pass (southern Montana) at 9:45 a.m. The picture to the right was also taken at 9:45 a.m. at Lookout Pass in western Montana.[25]

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[22] NCDC event record descriptions recorded March 5 – 8, 3003 from Missoula, Lincoln, and Ravalli Counties, other reporting areas from the western portion of Montana.

[23] NCDC event record descriptions recorded March 7, 2003 from the Helena Valley area, near central Montana.

[24] NCDC event record description recorded March 9, 2003 from the National Weather Service Forecast Office in Billings, Montana.

[25] Photos from MDT's Mountain Pass Cameras link (http://rwis.mdt.state.mt.us/). SCAN Web® is a registered trademark of Surface Systems, Inc.

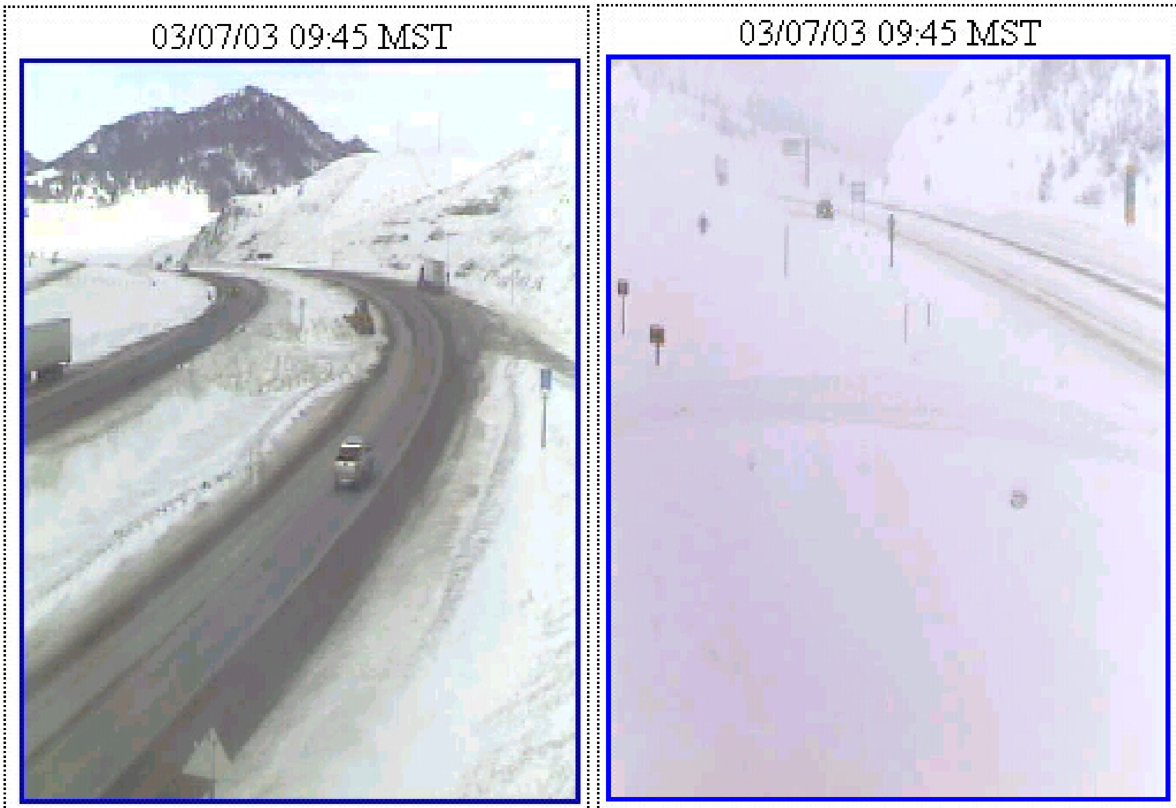

Figure 3-7. RWIS Camera View of Bozeman Pass and Lookout Pass on March 7, 2003

During the 5-day storm period the GYRTWIS 511-telephone service handled 55,367 callers. Figure 3-8 shows the number of calls per day for the March 5 – 9, 2003 period. The number of calls peaked on March 7, 2003 with 17,775 callers accessing road and weather information during the 24-hour period.

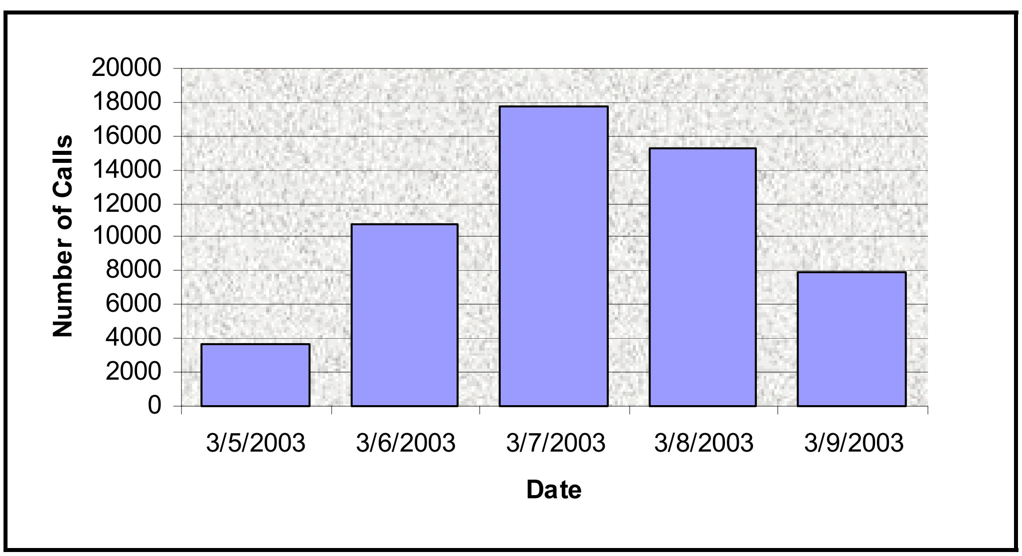

Figure 3-8. Number of Calls Per Day During March 5 – 9, 2003

3.1.1.3 Summary

The GYRTWIS 511-telephone service was deployed on January 15, 2003. Although the GYRTWIS 511-telephone service was not operational during the entire 2002 – 2003 winter driving season, more callers received information from the 511 system in 2003 than from the *ROAD and 800 telephone services during each of the previous two winter seasons. The number of storm events in 2003 resulted in nearly double the number of callers per month (56,591 callers per month on average).

March 2003 was a particularly active month for storm events with 123 events occurring across the state. This resulted in nearly 90,000 callers requesting road and weather information during March. One period in particular, March 5 – 9, 2003 – sustained 71 of the 123 storm events, resulting in over 55,000 callers, with nearly 18,000 calling on March 7, 2003 alone.

Maintenance personnel did not use GYRTWIS. MDT modified its anti-icing practices because of safety, cost effectiveness, public perceptions, and environmental factors. Maintenance crews are now applying "just-in-time" anti-icing treatments to road surfaces and using actual information (camera views, weather reports) and weather forecasts instead of road condition predictions based on sensor data.

3.1.2 Customer Satisfaction Test

As previously shown in Table 3-1, the Customer Satisfaction Test investigated traveler satisfaction with the GYRTWIS service and perceived usefulness of the GYRTWIS 511 service. The measures used included traveler perceptions of accuracy, availability, usefulness, and understandability. A second objective of the Customer Satisfaction Test was to investigate maintenance personnel satisfaction with the pavement and weather forecast information. However, as previously mentioned, changes in winter anti-icing procedures at MDT have resulted in MDT no longer planning to use GYRTWIS road condition prediction information. Therefore, no data were available (or expected to become available) to assess maintenance personnel perceptions of GYRTWIS usefulness, accuracy, and information timeliness.
The remainder of this section focuses on the methods, results, and findings from traveler surveys Before and After 511 implementation. Select questions from Before and After 511 traveler surveys conducted in Montana are compared. The Before 511 surveys include the 1997 WTI/MSU *Rural Traveler Needs Survey*[26] and the 2002 WTI/MSU *Montana Traveler Information Survey*. The After 511 survey is the 2003 WTI/MSU *Montana Traveler Information Survey*.

In 1997, WTI/MSU conducted the *Rural Traveler Needs Survey* as part of the Greater Yellowstone Rural ITS Priority Corridor project. The overall purpose of the survey was to determine the concerns and information needs of rural drivers/passengers when traveling in Montana, Wyoming and Idaho. This survey provided baseline results in identifying the types of information that were important to Montana travelers.

WTI/MSU administered the *Montana Traveler Information Survey* during the summer of 2002 (before GYRTWIS 511) and the spring of 2003 (after GYRTWIS 511). The purpose of the

[26] "Greater Yellowstone Rural Intelligent Transportation System Priority Corridor Project Rural Traveler Needs Survey, Volume I," October 1997.

surveys were to investigate users' perceptions of MDT's road and weather information phone services before and after the GYRTWIS 511-telephone service deployment. Four survey items provide a comparison of users' perceptions of perceived accuracy, availability, usefulness, and understandability.

3.1.2.1 Methods

Rural Traveler Needs Survey. For the Rural Traveler Needs Survey, 481 responses were collected at 14 locations throughout Montana, Idaho, and Wyoming. Respondents consisted of Montana, Wyoming, and Idaho residents (30 percent), and tourists or individuals from other states (68 percent).

The respondents consisted of 55 percent males and 42 percent females, the majority being between the ages of 45 and 64 (38 percent), with 56 percent reporting that they live in an urban area versus 42 percent who reported living in a rural area. Additional demographic information reported that 56 percent were employed full time, had a college degree (30 percent), had an income between $40,000 and $79,000 (34 percent), and 97 percent had a current driver's license. The majority of respondents (78 percent) reported their normal mode of travel as the driver of an automobile; 36 percent normally traveled 0 to 49 miles per day; 27 percent normally traveled on two-lane highways; and their normal trip purpose is for recreation (47 percent).

Montana Traveler Information Survey. Although the sample sizes for the 2002 and 2003 surveys differed, respondent demographics appeared to be comparable.

For the 2002 Montana Traveler Information Survey, 1,500 surveys were divided equally between the MDT districts. The percentage of responses by MDT District was fairly uniform and ranged from 6.4 to 15 percent of the total. Overall, approximately 23 percent or 348 surveys were returned.

The respondents consisted of 60 percent males and 40 percent females, with the majority (51 percent) being between the ages of 45 and 64 years old. Nearly all the respondents (96 percent) reported they primarily drive automobiles on Montana highways with 37 percent traveling 100 – 300 miles per trip; 21 percent traveling less the 24 miles; 16 percent traveling 25 – 49 miles; and 14 percent traveling 50 – 99 miles per trip. The primary purpose for the majority of highway vehicle travel was for: work (53 percent); visiting family or friends (14 percent); recreation (13 percent); or shopping (11 percent).

For the 2003 Montana Traveler Information Survey, 3,000 surveys were distributed to Montana residents based on the distribution of population within the state. Overall, approximately 23 percent or 676 surveys were returned. Figure 3-9 shows the percentage of responses returned per MDT district.

The respondents consisted of 62 percent males and 37 percent females, with the majority (49 percent) being between the ages of 45 and 64 years old. Nearly all the respondents (92 percent) reported they primarily drive automobiles on Montana highways with the primary purpose for the majority of highway vehicle travel was for: personal trips (63 percent); business trips (25 percent); tourism (2 percent); or other (7 percent). When asked, 63 percent indicated that they owned a mobile phone.

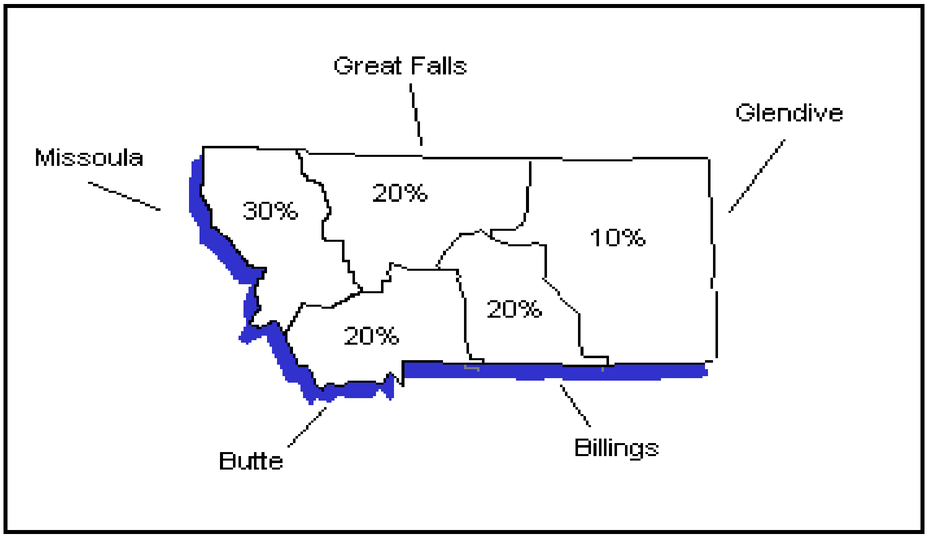

Figure 3-9. Percentage of Responses by MDT District[27]

3.1.2.2 Results

Traveler Perceptions of Information Accuracy. A majority of 511 callers indicated they were satisfied with the accuracy of GRYTWIS 511 road condition information and weather forecasts. In 2002, survey participants were asked the question "*How accurate is this service's road condition reports and weather forecasts? (Check only one)",* and used a 5-point rating scale ranging from "Very Accurate" to "Very Inaccurate". Nearly two-thirds of the respondents indicated the service was "Somewhat Accurate" (46 percent) to "Very Accurate" (16 percent). Leaving about one-third of the respondents who indicated "Neutral" or "Somewhat Inaccurate". These results are shown in Figure 3-10.

In 2003, after the 511-telephone service was deployed, survey participants were asked two separate questions related to their satisfaction with the accuracy of reported road conditions and accuracy of the weather forecasts. Using a 5-point rating scale (ranging from "Very Unsatisfied" to "Very Satisfied"), participants were asked *"How satisfied are you with the following 511 capabilities?"* (*Accuracy of Reported Road Conditions)."* Approximately 81 percent of the respondents rated their satisfaction with the accuracy as "Satisfied" (42 percent) to "Very Satisfied" (39 percent). When asked *"How satisfied are you with the following 511 capabilities? (Accuracy of the Weather Forecasts)"*, approximately 73 percent of the respondents rated their satisfaction with the accuracy as "Satisfied" (40 percent) or "Very Satisfied" (33 percent). The response distribution is shown in Figure 3-11.

Although the 2002 and 2003 questions are not directly comparable because the 2002 survey asked "*How accurate"* and the 2003 survey asked "*How satisfied"*, the high proportion of

[27] Figure courtesy of MSU/WTI.

"Satisfied" and "Very Satisfied" respondents in 2003 suggests that callers to MDT's 511 service were quite satisfied with the accuracy of the road condition information and weather forecasts.

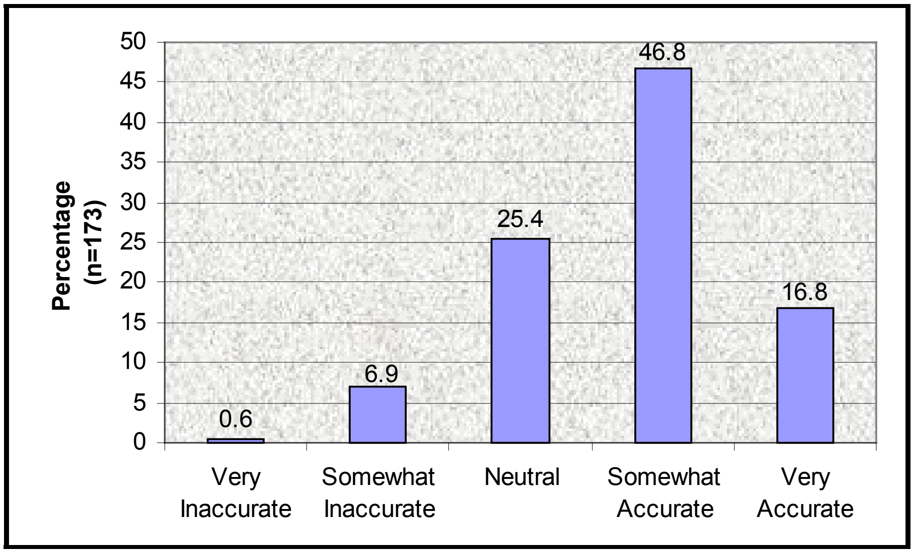

Figure 3-10. Accuracy Ratings for *ROAD and 800 Phone Service

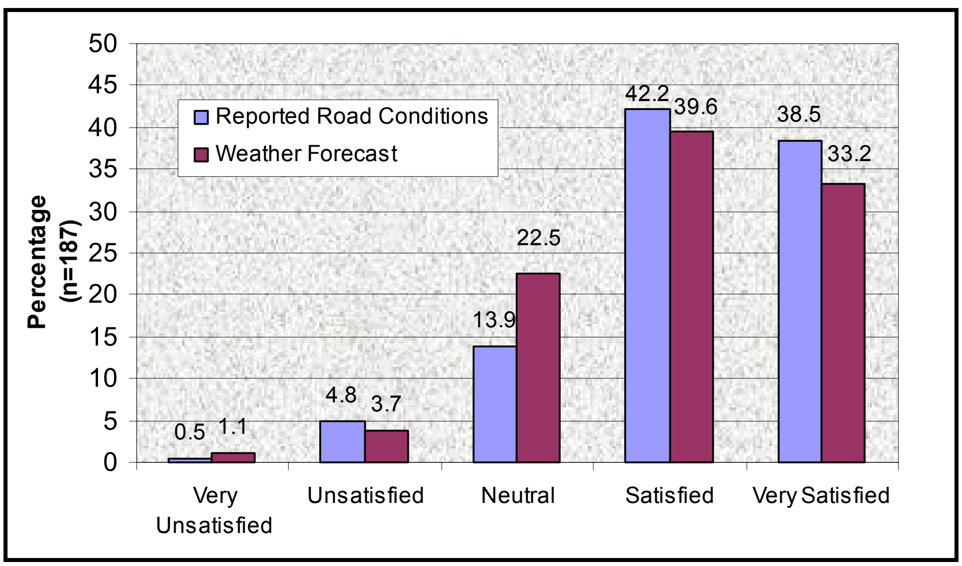

Figure 3-11. Accuracy Ratings for GYRTWIS 511 Phone Service

Traveler Perceptions of Service Availability. A majority of 511 callers indicated they were satisfied with the availability of the GRYTWIS 511-telephone service. For the 2002 survey, participants were asked the question "*When trying to access this service, HOW AVAILABLE is it? (Check only one).*"

Using a 5-point rating scale (ranging from "Very Available" to "Very Unavailable"), the majority of respondents indicated that the service was "Very Available" to "Somewhat

Available". The most frequently selected choice was "Somewhat Available" with nearly 33 percent of the respondents choosing this option. The second most common choice, "Very Available" (29 percent), was followed closely by 24 percent responding with "Neutral". The response distribution is shown in Figure 3-12.

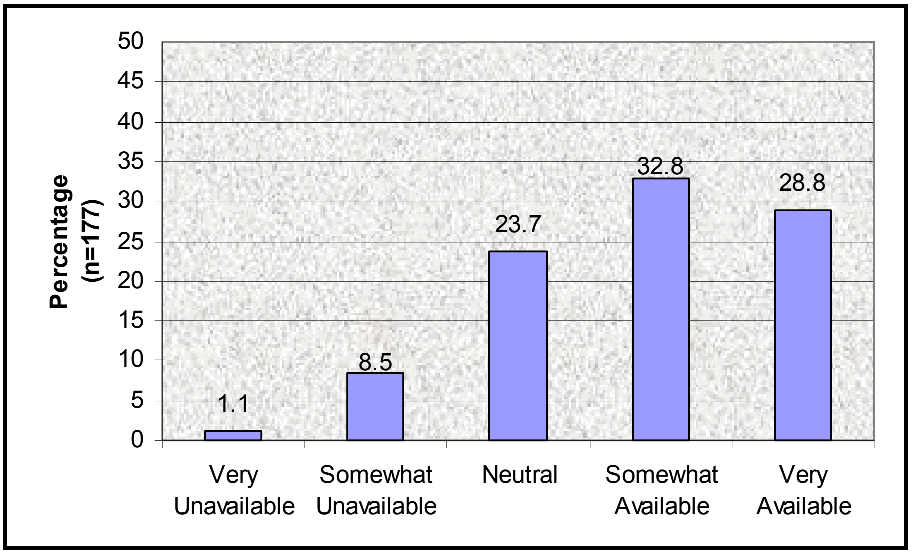

Figure 3-12. Availability Ratings for *ROAD and 800 Phone Service

In the 2003 survey, participants used a 5-point rating scale (ranging from "Very Unsatisfied" to "Very Satisfied") and were asked *"How satisfied are you with the following 511 capabilities? (Availability of the system [system is working/no busy signals])?"* Over 77 percent of the respondents rated their satisfaction with the availability of the service as "Satisfied" (31 percent) to "Very Satisfied" (47 percent). About 18 percent were "Neutral" and less than 5 percent were "Unsatisfied" or "Very Unsatisfied" with the availability of the 511 service. These results are shown in Figure 3-13.

Although the 2002 and 2003 questions are not directly comparable because the 2002 survey asked "*How available*" and the 2003 survey asked "*How satisfied*", the high proportion of "Satisfied" and "Very Satisfied" respondents in 2003 suggests that callers to MDT's 511 service were quite satisfied with the availability of the 511 system.

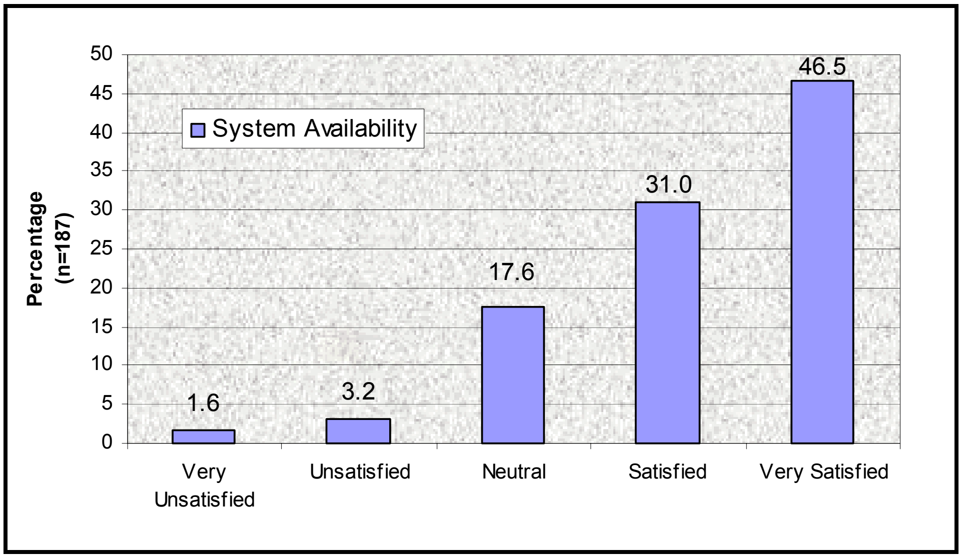

Figure 3-13. Availability Ratings for GYRTWIS 511 Phone Service

Traveler Perceptions of Usefulness. A majority of 511 callers indicated they were satisfied with the usefulness of the GRYTWIS 511-telephone service. The 2002 survey investigated the overall perception of the usefulness of the *ROAD and 800 phone service. Participants were asked, "*Overall, HOW USEFUL is this service's road condition reports and weather forecasts? (Check only one).*" On a 5-point rating scale (ranging from "Very Useful" to "Very Useless"), most respondents felt that the service was very to somewhat useful. Nearly 46 percent of the respondents indicated the phone service was "Very Useful" and 42 percent selected "Somewhat Useful". These results are shown in Figure 3-14.

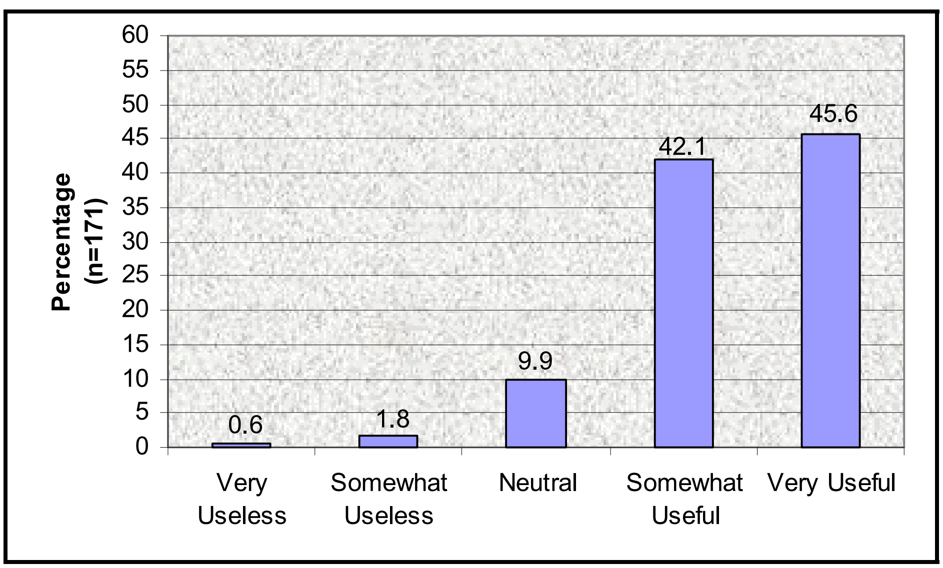

Figure 3-14. Usefulness Ratings for *ROAD and 800 Phone Service

In the 2003 survey, participants used a 5-point rating scale (ranging from "Very Unsatisfied" to "Very Satisfied") and were asked *"HOW SATISFIED are you with the following 511* *capabilities? (Usefulness of the service)."* Nearly 90 percent of the respondents rated the usefulness of the 511-telephone service as "Satisfied" (33.3 percent) or "Very Satisfied" (56.5 percent). Less than 10 percent were neutral with the usefulness and fewer than 2 percent were unsatisfied. These results are shown in Figure 3-15.

Once again, the 2002 and 2003 questions are not directly comparable because the 2002 survey asked "*How useful"* and the 2003 survey asked "*How satisfied."* However, the high proportion of "Satisfied" and "Very Satisfied" respondents in 2003 suggests that callers to MDT's 511 service were quite satisfied with the usefulness of the 511-telephone service. Nearly 90 percent are satisfied and well over half (56 percent) of the respondents were very satisfied.

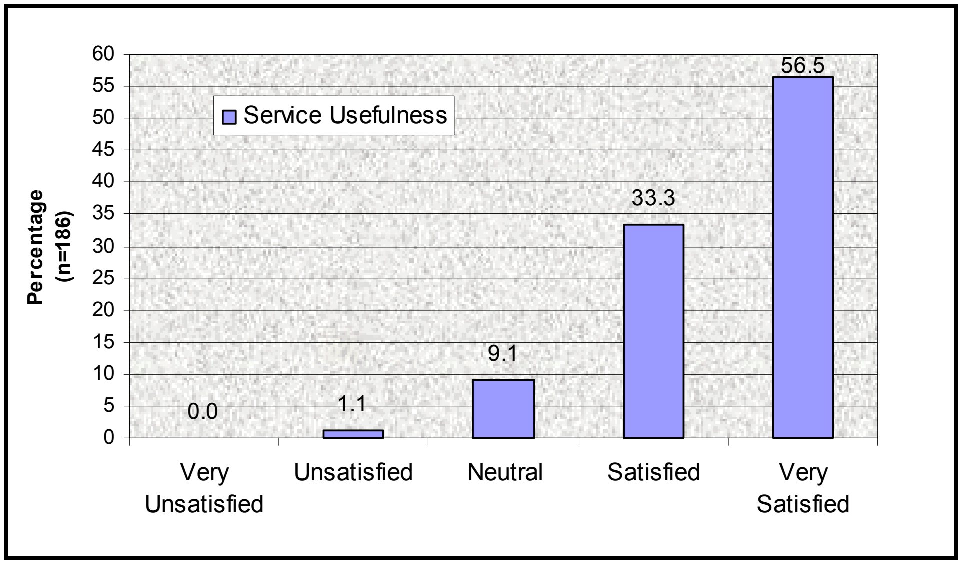

Figure 3-15. Usefulness Ratings for GYRTWIS 511-Telephone Service

Traveler Perceptions of Easy to Understand. A majority of 511 callers indicated they were satisfied with the usefulness of the GRYTWIS 511-telephone service. In the 2002 survey, participants were also asked the question "*HOW EASY to understand, are the road condition reports and weather forecasts provided by this service? (Check only one)."* On a 5-point rating scale (ranging from "Very Easy" to "Very Difficult"), most of the respondents indicated the service was very to somewhat easy to understand. Approximately 44 percent indicated the phone service was "Very Easy" and 42 percent selected "Somewhat Easy". Just over 8 percent of the respondents indicated the phone service was "Somewhat Difficult" (6.8 percent) or "Very Difficult" (1.7 percent). The results are shown in Figure 3-16.

For the 2003 survey, participants again used a 5-point rating scale (ranging from "Very Unsatisfied" to "Very Satisfied") to rate *"How satisfied are you with the following 511 capabilities?* (*Ease of understanding the information)."* Approximately 82 percent of the respondents rated the ease of understanding the 511information as "Satisfied" (32.4 percent) or "Very Satisfied" (50 percent). About 14 percent were "Neutral" with the "understandability" and fewer than 4 percent were "Unsatisfied". The response distribution is shown in Figure 3-17.

Once again, the 2002 and 2003 questions are not directly comparable because the 2002 survey asked "*HOW EASY to understand"* and the 2003 survey asked "*How satisfied"*. However, the high proportion of "Satisfied" and "Very Satisfied" respondents in 2003 suggests that callers to MDT's 511 service were quite satisfied with the "understandability" of the 511-telephone service. About 32 percent were "Satisfied" and 50 percent of the respondents were "Very Satisfied".

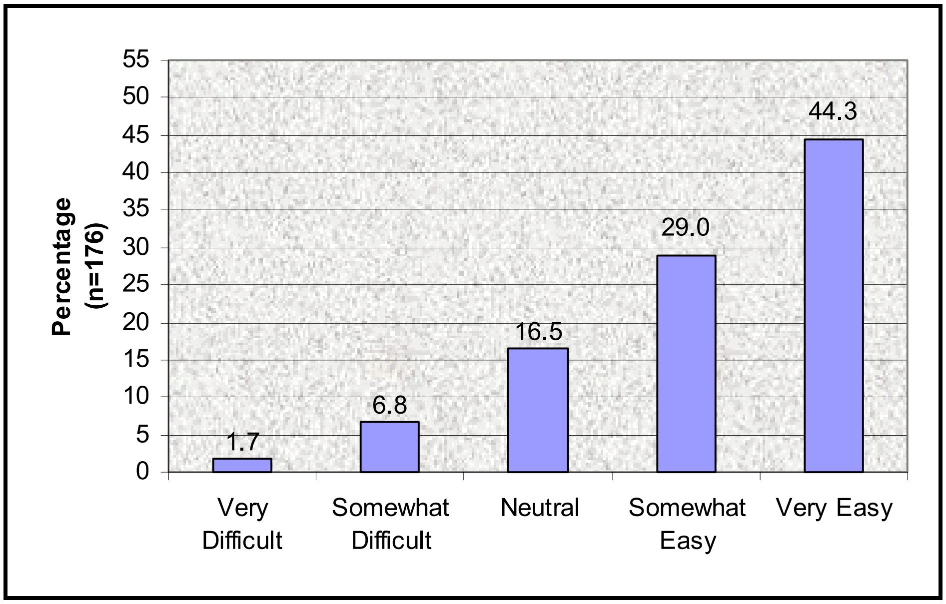

Figure 3-16. Easy to Understand Ratings for *ROAD and 800 Phone Service

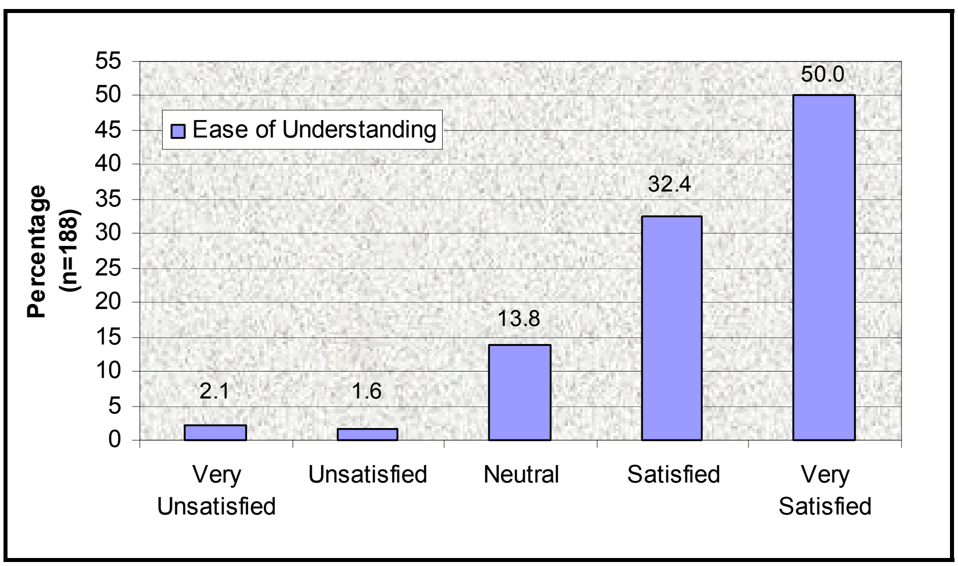

Figure 3-17. Easy to Understand Ratings for GYRTWIS 511 Phone Service

Types of Information Important to the Traveler. Road condition and weather information remain very important to Montana travelers. The results of the *1997 Rural Traveler Survey* indicated that travelers rated road conditions and adverse weather condition information as very important. The Rural Traveler Survey participants were asked to rate the importance of "T*ypes of information…before you start your trip by motor vehicle on rural roads and highways*." The types of pre-trip information were each rated using a 5-point scale, where 1 was "Not At All Important", to 5, which was "Very Important". Information about road condition problems due to weather (mean = 3.91) and adverse weather conditions (mean = 3.87) were two of the highest rated items falling just behind information about the best route to the destination (mean = 3.92). Figure 3-18 shows the pre-trip information categories and importance ratings from the Rural Traveler Survey.

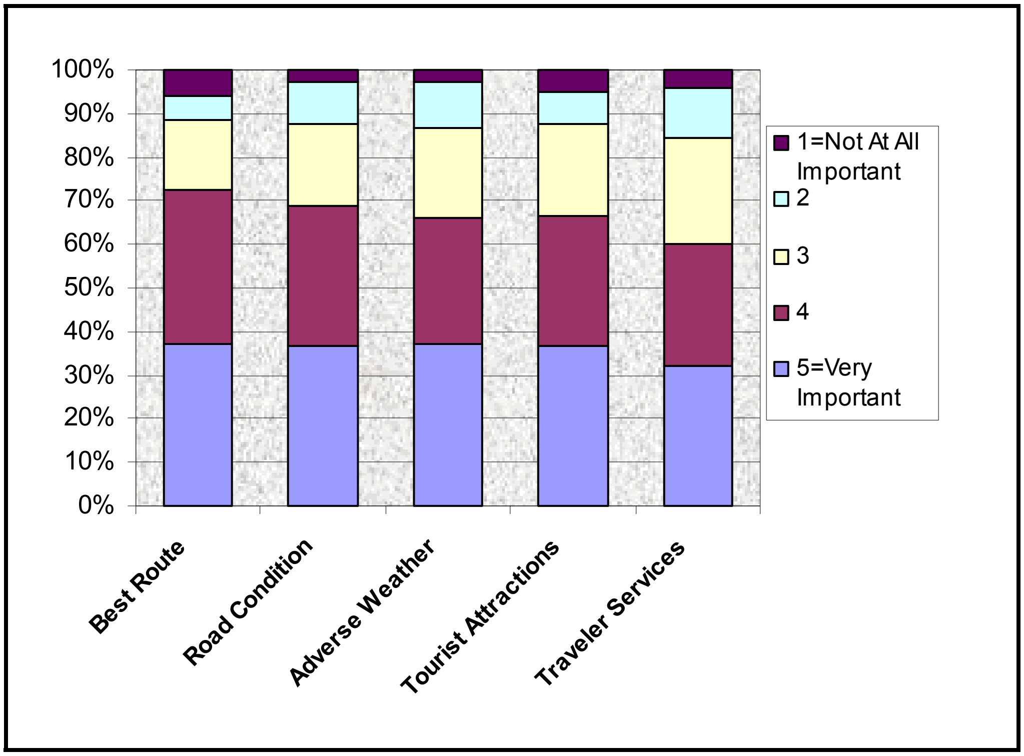

Figure 3-18. 1997 Rural Traveler Survey: Pre-Trip Information Importance

The results of the *2003 Montana Traveler Information Survey* indicated a similar trend with participants rating road and weather information as more important than other types of information. When survey participants were asked: "*If you were to call a travel information phone number, how important are the following features?",* they rated the types of information using a 5-point scale, where 1 was "Very Unimportant", to 5, which was "Very Important". Information about winter road conditions on highways (mean = 4.91) and weather forecasts (mean = 4.23) were the highest rated items. These 2003 survey results suggest that road and weather condition information are still very important to travelers. The information categories and importance ratings are shown in Figure 3-19.

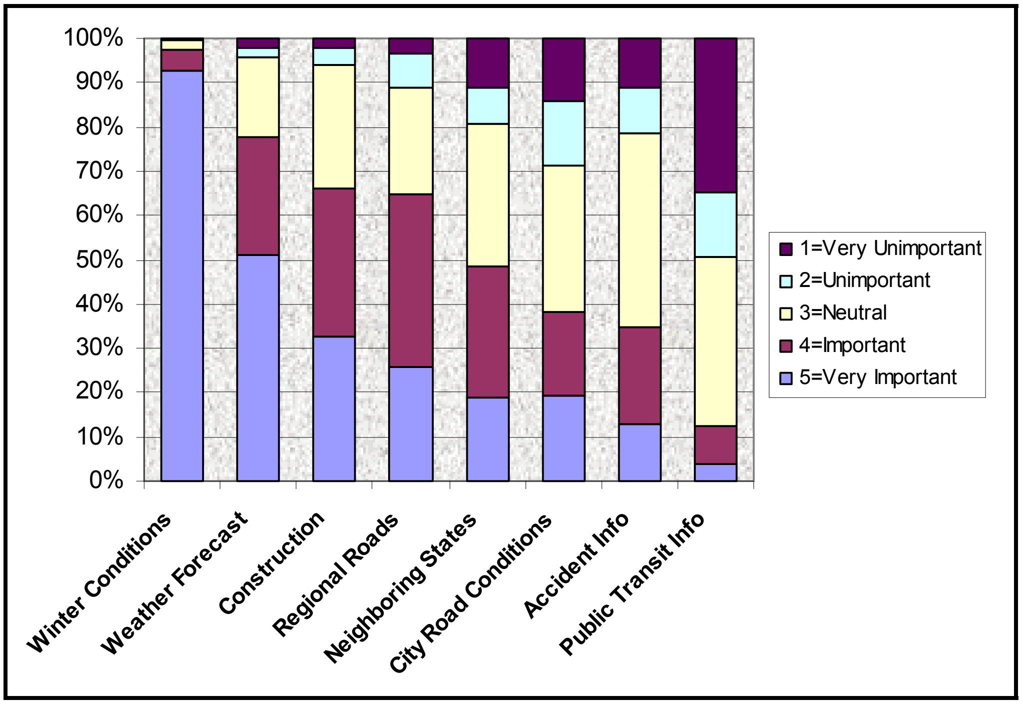

Figure 3-19. 2003 Montana Traveler Information Survey: Important Information

3.1.2.3 Summary

The *2003 Montana Traveler Information Survey* indicated that a majority of Montana travelers were quite satisfied with the accuracy, availability, usefulness, and ease of understanding the road conditions and weather forecast information. For all measures of satisfaction, a higher percentage indicated they were satisfied with the GYRTWIS 511-telephone service when compared to the previous *ROAD and 800 telephone services. Table 3-2 displays a comparison of 2002 and 2003 customer satisfaction measures both Before and After GYRTWIS 511 and the percentages regarding the respondents' satisfaction levels.

Table 3-2. Comparison of Satisfaction Before and After 511

Measure of Effectiveness	Before 511 (*ROAD & 800) (2002 Survey)	After 511 (2003 Survey)
Accuracy	Road Conditions & Weather Forecasts: – Somewhat Accurate/Very Accurate = 62%	Road Conditions: – Satisfied/Very Satisfied = 81% Weather Forecasts: – Satisfied/Very Satisfied = 73%
Availability	– Somewhat Available/Very Available =62%	– Satisfied/Very Satisfied = 77%
Usefulness	– Somewhat Useful/Very Useful = 88%	– Satisfied/Very Satisfied = 90%
Understandability	– Somewhat Easy/Very Easy = 73%	– Satisfied/Very Satisfied = 82%

Road condition and weather information continue to be very important to Montana travelers. The results of the *1997 Rural Traveler Survey* indicated that travelers rated road conditions and adverse weather condition information as very important (mean = 3.91 and 3.87, respectively). The results of the *2003 Montana Traveler Information Survey* indicated a similar trend with participants rating road and weather information (mean = 4.91 and 4.23, respectively) as more important that other types of information.

3.1.3 Conclusions

Despite starting late in the winter season, the number of calls to 511 indicated that travelers utilized the 511-telephone system more than they did the previous *ROAD and 800 information services. In terms of total number of calls there were 198,068 callers to 511 versus the two Baseline winter seasons, which had 163,411 (2000 – 2001) and 132,861 (2001– 2002). Average usage per month also indicated more 511 calls (56,591) than pre-511 calls (24,690). A statistically reliable difference in the number of calls to 511 was found when the analysis took into account the number of calls per storm events, $F(1,14)=9.42$, $p < 0.01$. The number of 511 callers per storm event was approximately 16 percent higher (926/797) than the per storm event calls in 2000 – 2001, and about 53 percent higher (926/607) than in 2001 – 2002.

Several factors contributed to the success of GYRTWIS 511 in 2003. First, the 511-telephone system was capable in handling the volume of callers during winter storm events. If the system had not been capable in handling many callers, the customer satisfaction survey would have indicated a lower satisfaction with the accuracy, availability, usefulness, and ease of understanding. Second, the traveling public must be aware of the changeover from *ROAD and 800 numbers to the 511-telephone service for the system to be utilized. Without public awareness of the system, no one would be able to access 511 to obtain the information. Apparently, the GYRTWIS public awareness campaign was successful in reaching the traveling public. Third, the number of storm events resulting from the March 5 – 9, 2003 winter storm provided the need for road condition and weather forecast information. If there had been no winter storms, no one would have called.

The role of customer satisfaction should not be understated as a factor in the number of calls to the 511 system. If callers had not been satisfied with the 511-telephone service, they probably would have not used the service and would have sought the information they wanted from other sources. The Customer Satisfaction Test investigated caller satisfaction with the road condition and weather forecast information by comparing the telephone services both Before and After 511 in terms of the accuracy, availability, usefulness, and ease of understanding. For all four satisfaction measures the 511 system received high satisfaction ratings.

3.2 Pavement Thermal Model Accuracy Study

The PTM Accuracy Study examined the accuracy of the Pavement Thermal Model when used for Montana's new 511-telephone service and to support MDT's Maintenance Department activities. The overall purpose of the PTM is to use readily available information, such as National Weather Service weather predictions and topographic data about the earth's surface, to estimate current and future pavement surface temperatures. The approach of the PTM is to use fundamental laws of physics – the heat and mass balance at the road surface (as depicted in

Figure 3-20) – along with engineering approximations of the important heat and mass flows to estimate the conditions at the roads surface.

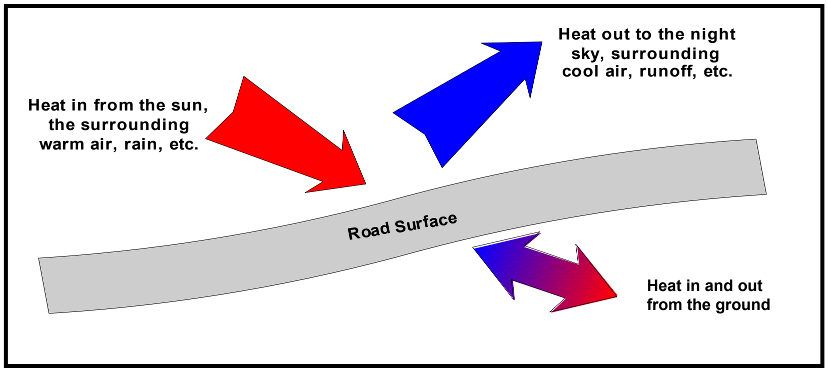

Figure 3-20. Simplified PTM Diagram

The PTM was designed to estimate road surface temperatures to enable the MDT Maintenance Department to apply prophylactic chemical treatments to reduce bonding between the road ice that forms and the road surface.

During 2004, the PTM will be investigated to determine what PTM information may be useful to travelers and incorporated into the 511 system.

Section 3.2.1 describes the PTM process of modeling pavement surface temperatures and reports on testing the accuracy of the PTM in estimating these temperatures.

3.2.1 Factors that Affect the Road Surface Temperature

The basic concept behind the PTM is that changes in the road surface temperature result from differences in the heat arriving at and leaving a road surface. Heat can arrive through solar radiation, from relatively warm air over the road, from relatively warm ground in winter, etc. Heat can leave the road surface through radiation to the cold, night sky, through transfer to cold air over the road, through transfer to relatively cool ground in summer, etc. These concepts are well known and provide a proven approach for modeling thermal changes in all sorts of systems, with the most important factors in implementing a model being:

- Estimating the significance of each heat source and sink, for heat transfer to and from the road surface.
- Including all-important sources and sinks in the heat transfer model.
- Estimating the temperature change of the road because of the differences in the amount of heat received from sources and lost to sinks.

While this is a proven approach to modeling thermal changes, implementing a model is still difficult because one must balance two contradictory sets of constraints:

- To ensure the model is accurate might require using complicated modeling equations that are difficult to solve and rely on difficult to find data.

- To ensure the model is useable might require using equations that are solvable in real-time and can make use of readily available data.

In balancing these constraints, a modeler must make compromises that dictate under what circumstances a model is and is not accurate. These compromises naturally affect the circumstances under which a model should be used.

For example, snow on a road can effect the temperature of the road surface in several ways – by reflecting much of the solar radiation that might be received by the road, by serving as an insulating layer that shields the road from the air temperature, by extracting heat from the road to melt snow at the road surface, to mention just a few. Any model that does not consider the effect of snow cover on a road would not be appropriate to use when snow is on the roads, assuming the effects of the snow cover are significant relative to the other factors that affect the road temperature.[28] Such a model might be an excellent source of information on whether ice was likely to form on roads on most days, but would be less useful on snowy days.

The remainder of this section describes some of the factors that affect road surface temperatures. The purpose of this information is to serve as a basis for understanding the description of the WTI/MSU PTM, which follows.

Solar Radiation[29]
Outside of the earth's atmosphere, the sun delivers heat at a fairly constant rate of 1,367 Watts per square meter. On a cloudless day with the sun directly overhead, about 75 percent of the solar radiation passes directly through the atmosphere to reach the earth; some of the rest scatters back into space and some of it reaches the earth indirectly by radiating from the atmosphere. With clouds overhead, more of the solar radiation is reflected back into space, while more of the ground radiation is reflected back to the ground. With snow on the ground, more of the radiation that reaches the earth's surface is reflected back into the atmosphere; Part of this radiation passes through the atmosphere back into space, and part of it returns to earth through scattering or absorption and re-radiation.

The primary seasonal and hourly difference in the amount of solar radiation reaching the earth's surface is due to the angle of the earth's surface relative to the sun: the closer the incoming solar rays line up to the normal direction of the earth's surface, the greater the amount of solar radiation that is received, per unit surface area of the earth. With the sun at a 45-degree angle, a square meter of the earth's surface receives only about 70 percent of the radiation it would receive if the sun were directly overhead. This effect is depicted in Figure 3-21. As a secondary effect, when the sun is closer to the horizon, the solar radiation passes through a thicker layer of atmosphere and more radiation is scattered and absorbed by the atmosphere.

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[28] Unfortunately, changes in snow cover on roads due to human activities, such as snowplows and traffic, cannot be easily accounted for in forecast models. WTI/MSU researchers identified several options to account for such activities, such as obtaining estimates for these activities (e.g., traffic counts, snowplow schedules) and modifying the model to account for these activities or performing multiple model runs to bracket the range of probable outcomes due to possible variations in these activities. WTI/MSU is considering these as an option for their PTM.
[29] Much of the information about solar radiation is summarized from information published by the University of Oregon Solar Radiation Monitoring Laboratory at http://solardat.uoregon.edu/SolarRadiationBasics.html.

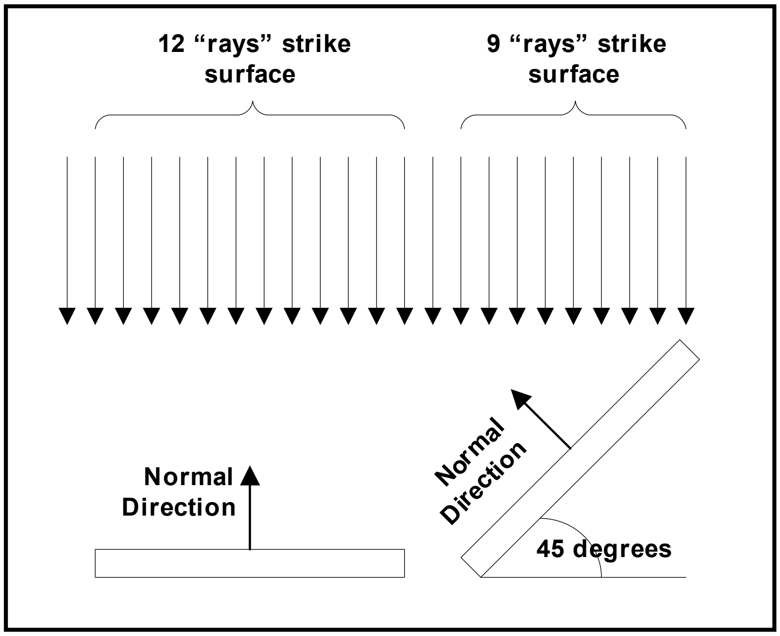


Figure 3-21. The Effect of Angle on Solar Radiation

Following are some factors to be considered when modeling the effect of solar radiation on road temperature:

- The *annual variation in the sun's intensity* outside the earth's atmosphere – a variation of only about 3 percent over the course of a year.
- The *seasonal and time-of-day variation* in the sun's angle relative to the earth's surface at a given latitude
- *Cloud cover* that may reflect solar radiation.
- The *thickness of the atmospheric layer* through which the solar radiation passes and the rate of absorption and scattering of the atmosphere (e.g., humid air absorbs more and scatters less solar radiation than dry air).
- *Shadowing of the road* from the sun and sky by terrain features.
- The *road surface condition* (e.g., the color of the pavement, whether the pavement is icy, wet, or snow-covered).
- The different frequencies of direct, scattered, and absorbed and re-radiated radiation and the differences in the rate of absorption of these different frequencies at the road's surface.

Other Forms of Radiation

While solar radiation is often the dominant form of radiation, other forms of radiation can also be important, which are listed as follows:

- *Diffused atmospheric radiation* comes diffusely from across the sky. On clear days, diffused atmospheric radiation is primarily a combination of solar radiation scattered by the atmosphere and solar radiation absorbed by the atmosphere, then re-radiated back to the earth. On cloudy days, these sources are combined with radiant energy reflected or radiated from the earth that re-reflects off the bottom of the clouds back to the earth's surface.

- *Ground radiation* is heat radiation that is exchanged directly between different parts of the earth. This type of radiation is a combination of solar and atmospheric radiation reflected from the ground, and long-wave radiation generated by the ground and dependent upon its temperature.

Heat Exchange with the Atmosphere

A second source of heat exchange from the road's surface is heat exchange with the atmosphere directly over the road – cold air tends to absorb heat from a warm road, and vice-versa. A typical approach for estimating the rate of heat exchange is to use a boundary-layer approach as shown in Figure 3-22. This exchange occurs where the heat transfer with the atmosphere per road surface area is equal to a heat-transfer coefficient *h* times the temperature difference between the road and the atmosphere. Thus, this rate of heat exchange depends primarily on the temperature difference between the road and the ambient air and the properties of the ambient air that go into computing the heat-transfer coefficient *h*.

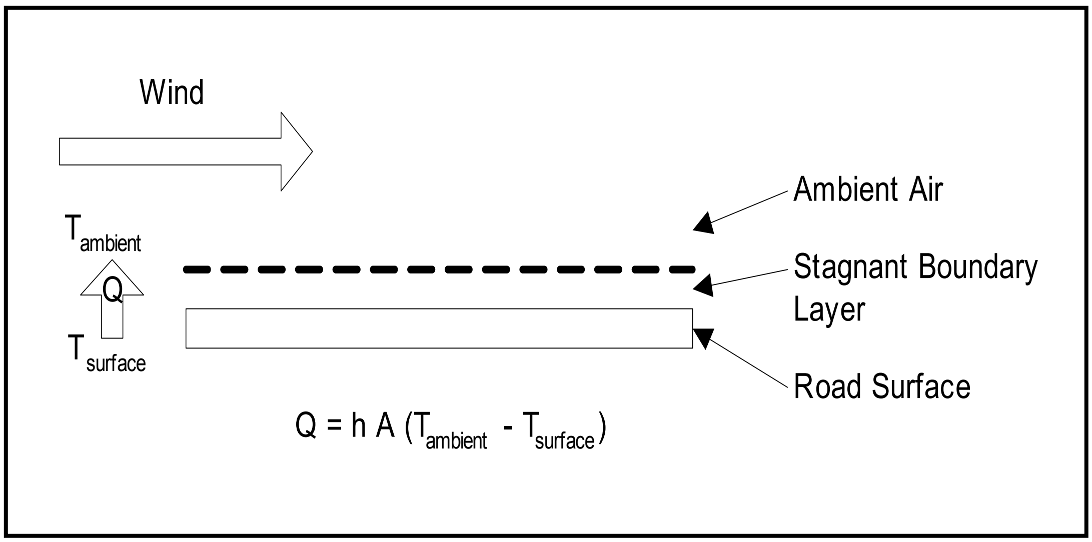


Figure 3-22. Heat Exchange with the Atmosphere

Some factors that can affect these calculations include:

- The *wind speed* has a major effect on *h*, with higher wind speeds being associated with higher heat transfer rates.
- The *wind direction* can have a significant impact on the heat transfer rate. If the wind is running in the direction of the road (or the wind speed is very low), then the heat from the road stays over the road and $T_{ambient}$ is increased over that expected purely from the local weather conditions.
- The *thermal properties of the air* affect the value of *h* – higher heat capacities, densities, and thermal conductivity's in the air lead to higher values of *h*.

- *Wind channeling* (e.g., where raised banks channel the flow of cool air along a roadway) and other weather effects associated with roadways can result in different ambient conditions over the roadway than over the terrain outside of the roadway.
- *Higher traffic volumes and speeds* can significantly increase *h* because each passing vehicle induces local wind speeds that are higher than the ambient wind speeds.
- All of these effects are also accounted for to some degree except for human factor influences associated with traffic volumes.

<u>Mass Exchange with the Atmosphere</u>
Thermal effects due to mass exchange with the atmosphere should also be considered in a pavement thermal model. These effects can take two primary forms. First, mass exchange between the roads surface and the atmosphere can carry heat with it – cold rain falling on a warm road absorbs heat as it hits the road, evaporation from the road surface may cool the road as heat is absorbed to evaporate the liquid. The second effect is that accumulated water or snow on the road surface adds a new layer that should be considered in the model for the road surface – the water/snow surface coating can change the way radiant heat is exchanged (e.g., white snow reflects most solar radiation), runoff can remove heat from the road surface. This second effect will be considered separately below.

Some factors that should be considered when estimating this rate of heat exchange are:

- The rate at which precipitation is falling, the type of precipitation (e.g., rain, snow), and the temperature of the precipitation.
- The slope of the road and other factors that affect the rate at which the precipitation runs off the road.
- The humidity of the air, the road surface temperature, and other factors that affect the rate at which snow melts and water evaporates from the road surface.

<u>Mass Accumulation on the Road Surface</u>
Water and snow accumulating on the road surface affects the temperature of the road surface in two different ways. First, any accumulation on the surface acts as an insulating layer, making the road surface temperature less dependent on the temperature of the air and more dependent on the temperature of the ground under the road. Second, any accumulation of material on the road surface changes radiant exchanges with other bodies. A white, snow-covered road can reflect up to 95 percent of direct solar radiation, while a clear, blacktop road will reflect only 5 to 10 percent of the radiation. Some factors that should be considered when analyzing the affect of mass accumulation on the road surface temperature are:

- The *rate* at which material (e.g., snow, ice) is accumulating on the road.
- The *temperature of the road* and other factors that affect how quickly the material melts and runs off the road surface.
- *Maintenance operations* that can remove accumulations (e.g., snow plows), change surface conditions (e.g., sanding), or change physical characteristics (e.g., de-icers) of the surface material.

- *Traffic* that can change surface conditions (e.g., darkening snow) or change physical characteristics (e.g., convert lose snow to slush) of the surface material.

Heat Exchange with the Ground

The temperature of the road surface is, in general, determined by balancing the energy gained from or lost to the atmosphere and the ground under the road. The most important factors that influence the heat exchange between the road surface and the ground are:

- The *type of roadbed and ground under the road* affect the rate at which heat is exchanged between the ground and the road.
- The *ground temperature* at some point deep enough underground to be relatively immune to short-term (i.e., daily, hourly) temperature changes.

Other Factors

Several other factors exist that can, in some circumstances, significantly affect road surface temperatures, including the following:

- *Bridges affect road surface temperature* by removing the interaction of the road with the ground, replacing that interaction with interactions with the atmosphere under the bridge and whatever the bridge is crossing.
- The *various effects of traffic on the road surface temperature*, including the effect of exhaust heat on the air temperature over the road, thermal radiation from vehicle engines, frictional heat between the tires and the road, shading of the road by the more reflective surfaces of the car, and enhanced heat transfer between the road and the atmosphere because a passing car mixes the air over the road.
- *Shade* from trees, signs, and other features near the road other than the local terrain.
- *Different rates of absorption, reflection, and transmission for radiation* of different wavelengths. For example, snow reflects most short-wave radiation (e.g., most direct solar radiation), but reflects much less long-wave radiation (e.g., radiation from the road).
- *Heat conduction along the road* helps equalize temperatures across a road, but can also reduce heating of a road after a snowstorm if plowed snow on the side of the road keeps temperatures outside the road lower.

3.2.2 The Pavement Thermal Model

As shown in Figure 3-23, the PTM is an application of a commercial RadTherm/RT software product developed by ThermoAnalytics, Inc., and Montana State University. This product combines the use of a weather model to generate weather data as input and a Web interface to provide access to the resulting road condition estimates.

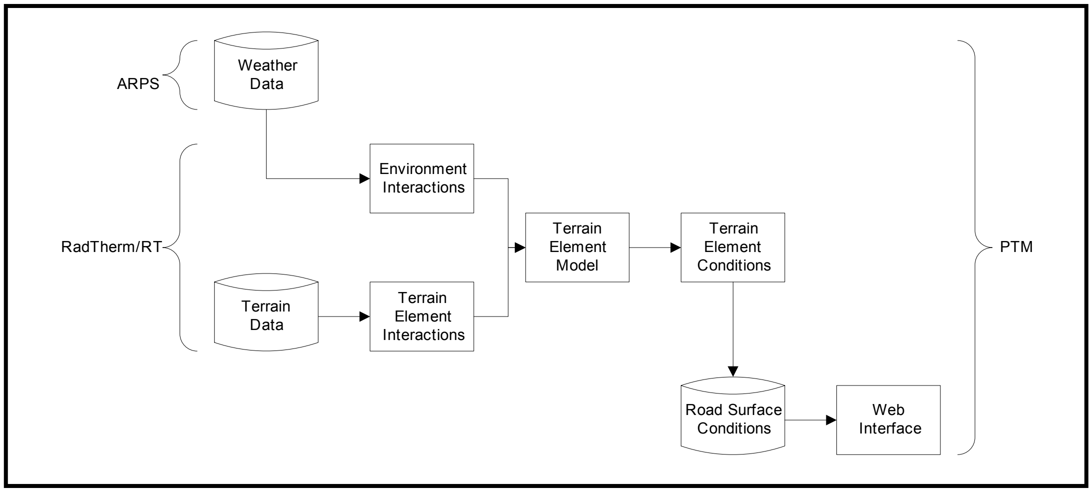


Figure 3-23. The Pavement Thermal Model

The RadTherm/RT application provides the core functionality of the PTM. There are two primary inputs to the RadTherm/RT application:

- *Terrain data* defines elevation and orientation of the terrain being modeled and the type of "cover" (e.g., asphalt, concrete, foliage, snow). Terrain is defined by overlaying a grid of terrain elements on selected site and defining the elevation, orientation, and cover for each terrain element. Figure 3-24 shows sample terrain elements near I-90 at Bozeman Pass.

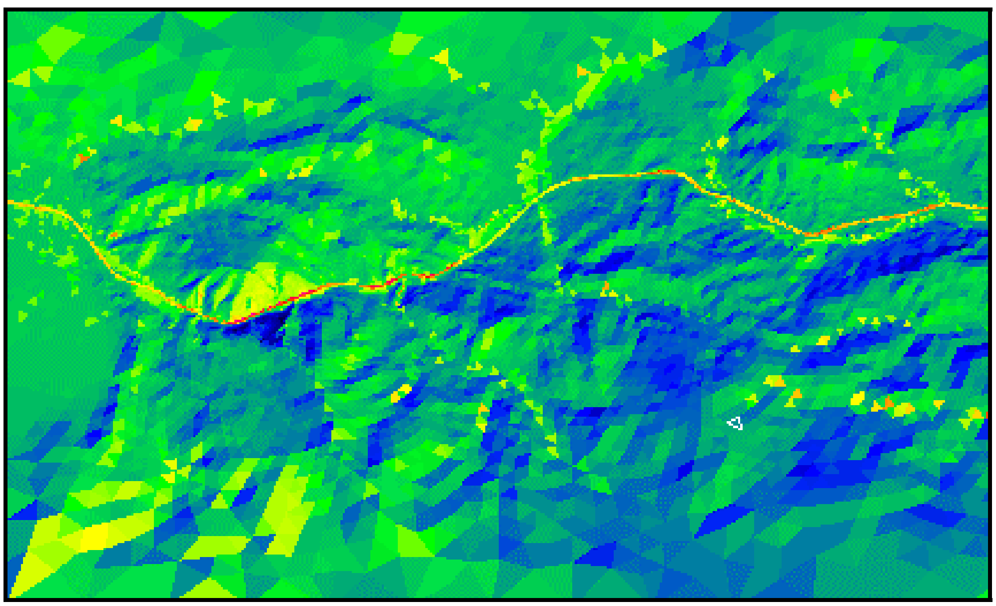


Figure 3-24. Example of Terrain Elements for Modeling Bozeman Pass

- *Environmental/weather data* for each terrain element. These elements include: total solar radiation; atmospheric long wave radiation; and cloud cover (primarily used for estimating atmospheric radiation when long wave data is unavailable). Also used are air temperature; wind speed; wind direction, and humidity (primarily used for estimating convective heat transfer with the environment). In addition, the rate of rainfall is used (primarily for estimating heat transfer effects of rainfall).

The RadTherm/RT application uses the terrain cover data to establish a thermal model for each terrain element. Each terrain element is modeled as a series of layers, such as snow on asphalt. Each base layer consists of several sub-layers. Figure 3-25 depicts an example of a snow on asphalt RadTherm/RT terrain element. An energy balance is used to compute the temperature changes for every sub-layer. This energy balance considers heat conducting through the sub-layers; moisture moving through soil and retained as dew on foliage; and interactions with the sub-layers above and below it. At the top layer, the energy balance considers the interactions with the layer below it and with the environment via convective heat transfer with the air over the terrain element. Additional energy balance considerations include: radiation exchange with the sun, the sky, and other terrain elements; and heat transfer due to rainfall.

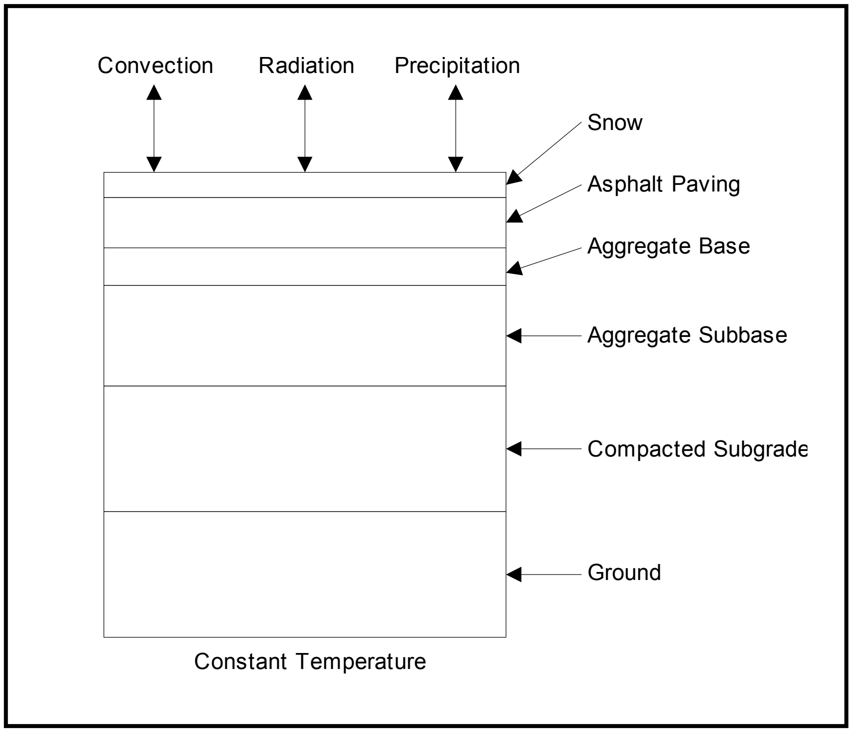


Figure 3-25. RadTherm/RT Terrain Elements

The radiation exchange depicted here considers a number of factors. First, view factors[30] are used to define the interaction between each terrain element, the sun, and the sky. These factors are computed from the terrain elevation and orientation data and information about the sun's position. Second, the amount of solar and long-wave radiation received from the sun and sky is evaluated. This incoming radiation is adjusted according to the view factors between the terrain element and the sun and sky and the amount of cloud cover. Part of the resulting incoming radiation is then absorbed and part is reflected, according to the type of terrain cover. Third, radiation received from other terrain elements via reflection and that exchanged between the elements because of temperature differences is considered.

[30] A view factor indicates the fraction of diffuse radiation leaving one surface that arrives at a second surface.

The convective heat transfer considers the effects of the ambient air temperature, the wind speed and direction, and the humidity on the rate of convective heat transfer. Heat exchange due to precipitation considers factors such as the rate of rainfall and the effect of the air temperature and humidity on the temperature of the rain. These factors are also considered in computing the effect of dew.

Weather Component

To provide the necessary estimates of weather and environmental variables, the PTM also includes a weather component. The initial PTM implementation was to combine data from RWIS and other meteorological stations to provide a grid of current weather conditions and use this data, interpolated as necessary, as input to RadTherm/RT. Plans were for later PTM implementations to use forecast weather data to produce forecasted PTM data. However, technical difficulties with obtaining the necessary data from the RWIS and meteorological stations resulted in accelerating these plans and using continental-scale weather forecasts from the estimated time of arrival (ETA) model of the National Centers for Environmental Prediction (NCEP) as input to RadTherm/RT. The Advanced Regional Prediction System (ARPS), a license-free meteorological forecast model maintained by the University of Oklahoma Center for Analysis and Prediction of Storms, is used in several steps to refine these large-scale forecasts to produce weather estimates with a 1-km resolution. The 1-km ARPS weather forecasts are interpolated to provide the 30-m weather data input used for the PTM. RadTherm/RT uses this forecasted weather data to produce estimates of road surface conditions.

Because each of the steps in this sequence requires considerable time to complete, it is also necessary to consider the timing of these events in order to understand the nature of the PTM forecasts. The forecast process used in 2003 is depicted in Figure 3-26. (Because the forecast timing depends on the available computer hardware, processing speeds, and data transfer speeds, the forecast schedules change from year to year.)

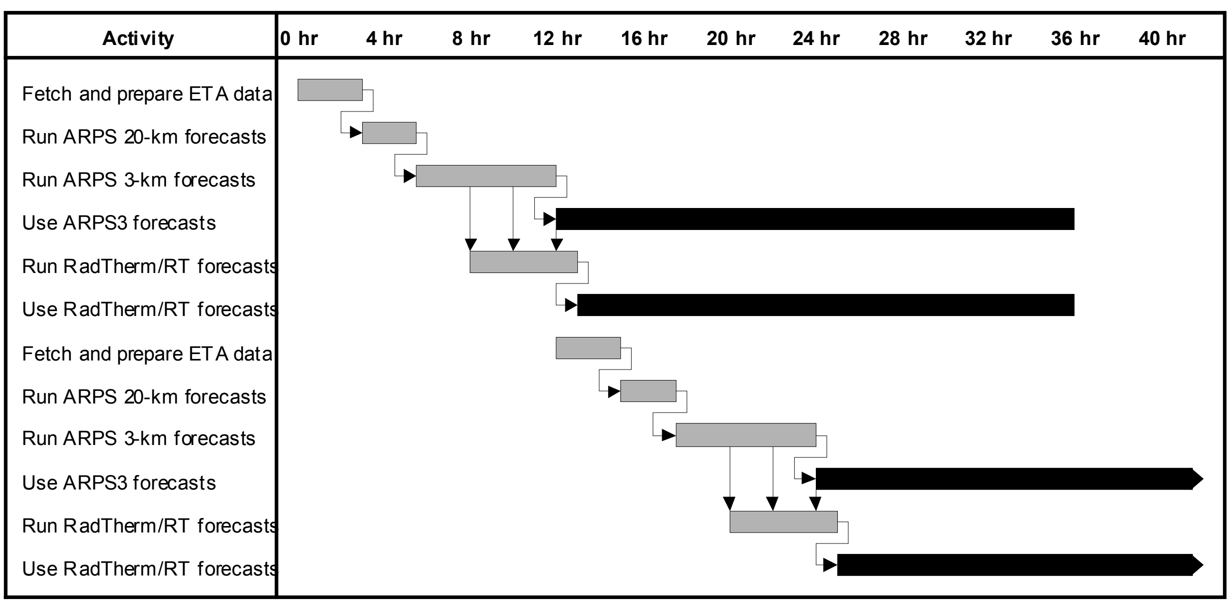


Figure 3-26. The PTM Forecast Timeline

Since the combined computation time for the ETA, ARPS, and RadTherm/RT forecasts is about 12 hours, the first PTM forecasts are available 12 hours after the forecast process begins. The first set of PTM forecasts are for 23 hours and rely on measured data compiled12 hours earlier. By repeating this process on a 12-hour cycle, PTM forecasts are continuously available, though some inconsistencies may occur when transitioning between RadTherm/RT forecast sets. In Figure 3-26, the PTM forecasts at Hour 25 change from depending on meteorological data measured 24 hours prior, to data measured 12 hours prior.

This process results in detailed meteorological forecasts for the region of interest and road condition data for the road segment of interest. MSU worked on several methods for making this information available to end users, including the methods depicted in Figures 3-27 and 3-28.

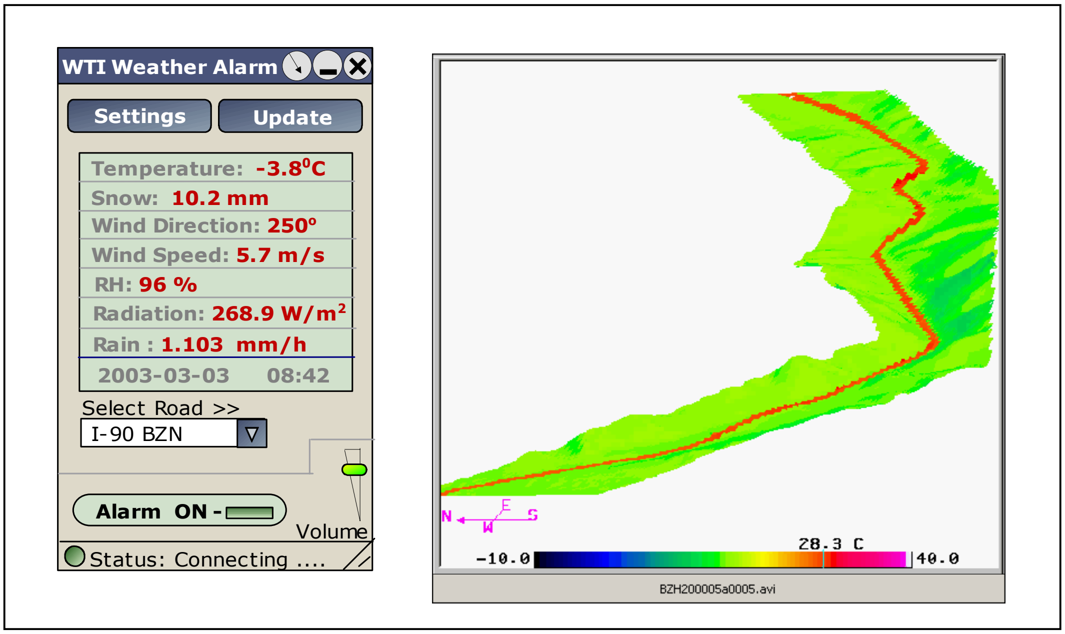


Figure 3-27. PTM Information: Weather Alarms and Thermal Maps

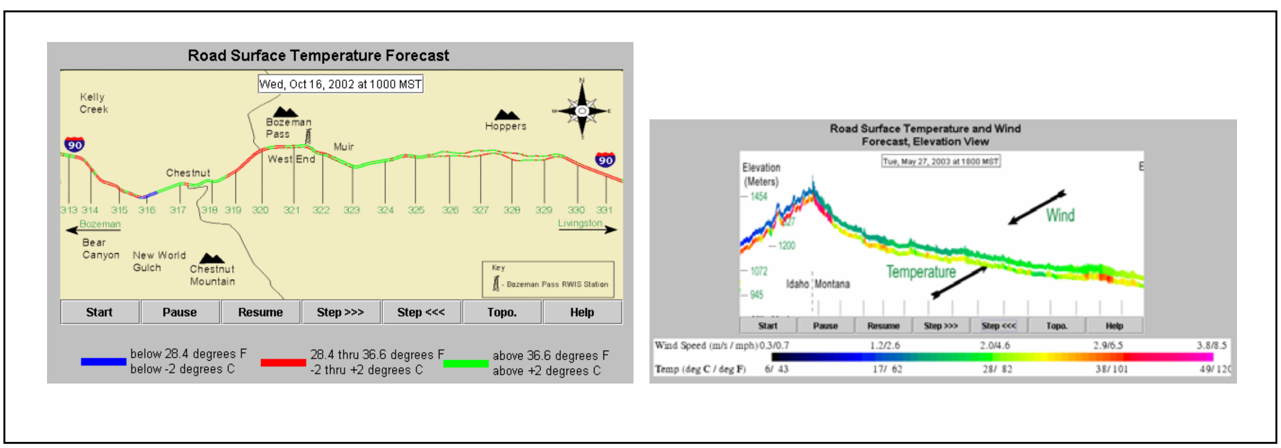


Figure 3-28. PTM Information: Temperature Maps and Elevation Views

While the preceding description describes the PTM process as it was used in 2003, MSU continues to investigate new opportunities to improve the process, including the following:

- The RadTherm/RT grid includes a large number of elements that are far from the road and have little impact on the road surface temperature. MSU is exploring an automated process to remove unnecessary terrain elements to reduce the RadTherm/RT computation time required.
- The PTM process does not currently compute snowmelt. It also does not take into account differences in the properties of snow as the snow ages, as chemicals and sand are applied, or as vehicles travel through it. While the PTM can represent differences in snow cover, the current model requires that the user specify the type of snow cover to use rather than computing it. MSU is investigating models to compute snowmelt on roads.
- The PTM does not consider the effect of bridges on road surface temperature, yet it is well known that the freezing properties of bridges are much different from those of the roadway. MSU is investigating methods for using RadTherm/RT to estimate road surface temperatures on bridges.

3.2.3 Evaluating the Accuracy of the PTM

A review of the PTM process described in Section 3.2.3 indicates that there are a number of factors that could affect the accuracy of the PTM model. Some of these factors are:

- **Weather Forecasts.** The PTM process uses a sequence of weather models that take approximately 12 hours to complete. Thus, the road condition forecasts are based on meteorological data measured approximately 12 hours prior. Inaccuracies in any model in the sequence will decrease the accuracy of the final RadTherm/RT forecasts.
- **Weather Data Interpolation.** The PTM process begins with national weather forecasts that are on a relatively coarse grid. The PTM process then uses the ARPS application to produce forecasts on a finer grid, then interpolates between those fine-scale forecasts to produce forecasted weather data for the 30-m grid used by the PTM. In general, this process of refining the weather forecasts to finer levels of detail produces fine-scale weather forecasts that are more accurate than applying the coarse-scale forecasts on a fine scale. However, these fine-scale forecasts may not always reproduce actual fine-scale variations.
- **Terrain Elevation and Orientation.** One element of the terrain data is the elevation and orientation of the terrain. Because this data is derived from geographic information system sources of good accuracy, this is not likely to be a significant source of error in the PTM process.
- **Terrain Cover.** Terrain cover can affect road surface temperatures, such as directly shading the road changing amounts of radiation reflected on the road because of snow and ice. Although the PTM assigns different values to the terrain cover to different areas, it does not take into account changing conditions during snowfall or when snow or ice is melting, without manual interaction.
- **Road Cover.** The effect of snow and ice cover on a road has a strong effect on the road surface conditions. However, modeling snow and ice cover on a road is much more difficult than modeling it for the terrain. Factors such as traffic, snowplows, and chemical de-icers change conditions on roads much more quickly than they typically change for the surrounding terrain. While PTM can use a snow-over-asphalt terrain element, it does not

currently include the capability to consider the dynamics of human activities and their influence on road-cover snow.

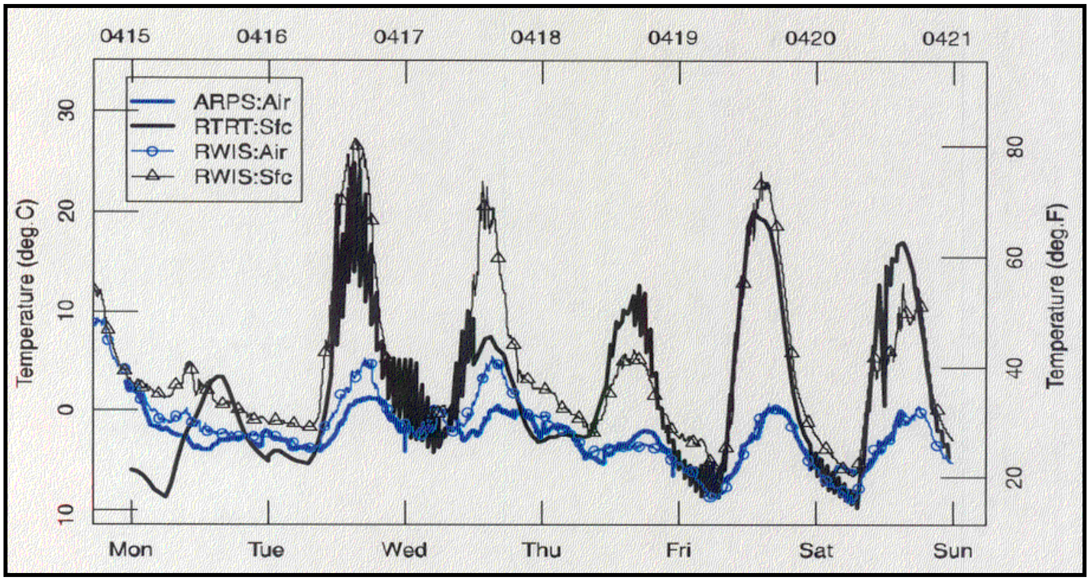
- **RadTherm/RT Estimates.** The last step in the PTM process is using RadTherm/RT to combine weather and terrain data in order to estimate road surface temperatures. This RadTherm/RT model may operate differently under different circumstances. For example, the model might produce better results on cloudless days than on cloudy days if the part of the RadTherm/RT model that considers cloud cover is less accurate than other parts of that application. Thus, it is important to test the model under different types of conditions.
- **Missing and Approximate Factors.** As indicated in Section 3.2.1, there are a number of factors that can influence road surface temperature, and the current PTM process considers those that are typically most significant. There may be some situations where the typically less significant factors are important, in which case, the PTM process will produce less accurate results. For example, the model has built-in assumptions regarding physical factors, such as the specific heats and reflectivity of the surface terrain and any snow cover on it. Better data on these values and how they vary would improve PTM forecasts.

The first systematic efforts to evaluate the accuracy of the PTM were conducted in 1998 during proof-of-concept testing of the PTM.[31] At that time, the PTM primarily considered solar radiation, long-wave radiation, terrain shadowing, and conduction through the layers making up each terrain element. Solar radiation and air temperature measurements were taken at an RWIS station and used to estimate road surface temperatures. These measurements were then compared to road surface temperature measurements taken at the station. The results for September 2, 1998 showed a road surface temperature range of about 12 °C to 30 °C, with a maximum discrepancy of 2 °C. The maximum discrepancy observed for all the tests was 5 °C.

After that proof-of-concept testing, PTM development continued, and results of a second round of validation was reported in the October 2002 SAFE-PASSAGE report.[32] This report, whose results are summarized below, tested the accuracy of the PTM along an 18-mile section of Bozeman Pass during two 6-day periods, from April 15 – 21, 2002 and from April 21 – 29, 2002. During this period, ETA data was obtained on a regular 12-hour interval, as previously described. From that point on, the PTM process used for the validation was different.

To minimize contributions from more extended forecast inaccuracies on the RadTherm/RT portion of the PTM process, only the first 12 hours of ETA data and corresponding ARPS data was used – the weather forecasts further into the future were presumed to be less accurate. Output from the ARPS model was fed to the RadTherm/RT application to generate road surface temperature forecasts for that 12-hour period. This process was repeated to gather data for two weekly periods. The results were compared to temperatures taken at an RWIS station at the top of Bozeman Pass. The resulting road surface temperature comparisons are depicted in Figures 3-29 and 3-30.

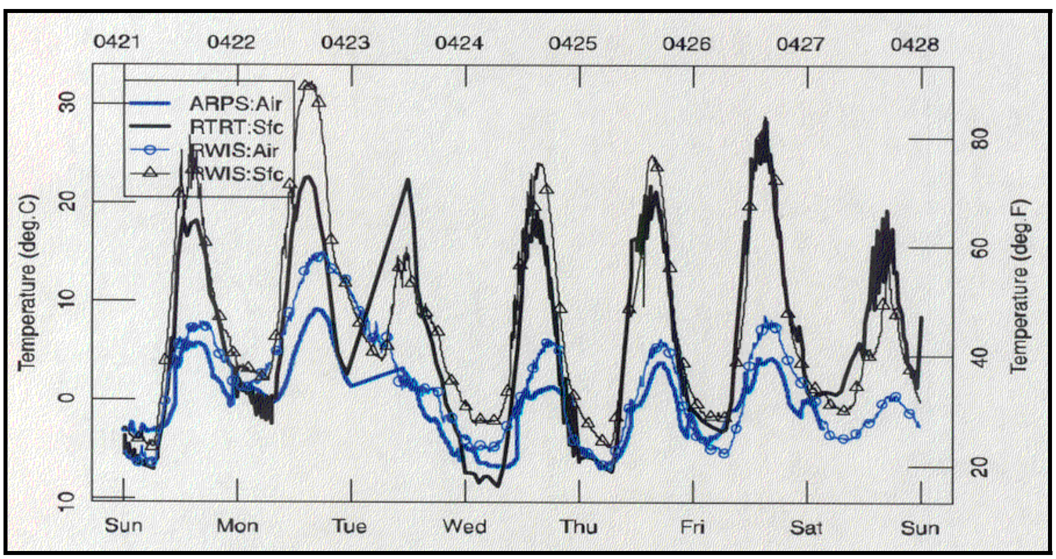
[31] These results were published in the July 1999 report *Proof of Concept for Prediction of Pavement Temperature* (Report FHWA/MT-99-003/9117-6).
[32] *Development and Demonstration of a Rural Weather Prediction Model and Motorist Communication System for Safe and Efficient Traffic Management/Infrastructure Maintenance, SAFE-PASSAGE report, October 2002.*



Source: Figure 6 from the SAFE-PASSAGE Fourth Year Report.

Figure 3-29. Forecast and Measured Road Surface Temperature, 4/15/2003 to 4/21/2003

Note that the large difference in forecast and measured road surface temperature at the beginning of the above figure is due to initialization error. Because there was no RadTherm/RT model run for the preceding week, approximate surface temperature profiles were used for the initial pavement temperatures. In this case, it appears that these approximate values were too low, and it took some time for the effect of these low estimates to damp out of the results.



Source: Figure 20 from the SAFE-PASSAGE Fourth Year Report.

Figure 3-30. Forecast and Measured Road Surface Temperature, 4/15/2003 to 4/21/2003

In these figures, the measured road surface temperatures ranged from roughly -5 °C to 32 °C, with a difference between measured and forecast ranging from roughly -17 °C to 12 °C. This yielded a root mean square difference of about 4°C during the first week, and about 6 °C during the second. The PTM explained about 60 percent of the variation in the observed road surface temperatures during the first week, and about 65 percent during the second.

Another pair of charts, shown in Figure 3-31, demonstrates what appears to be one of the weaknesses in the PTM process. There is a strong correlation between the times when the errors in the road surface temperature forecasts are high (RTRTRWIS:Sfc) and when the errors in the solar short-wave radiation forecasts are high (ARPSRWIS:SW). It appears that differences in the levels of solar radiation estimated by ARPS and the amount of solar radiation measured at the RWIS station is a significant contributor to errors in the forecasted road surface temperatures.

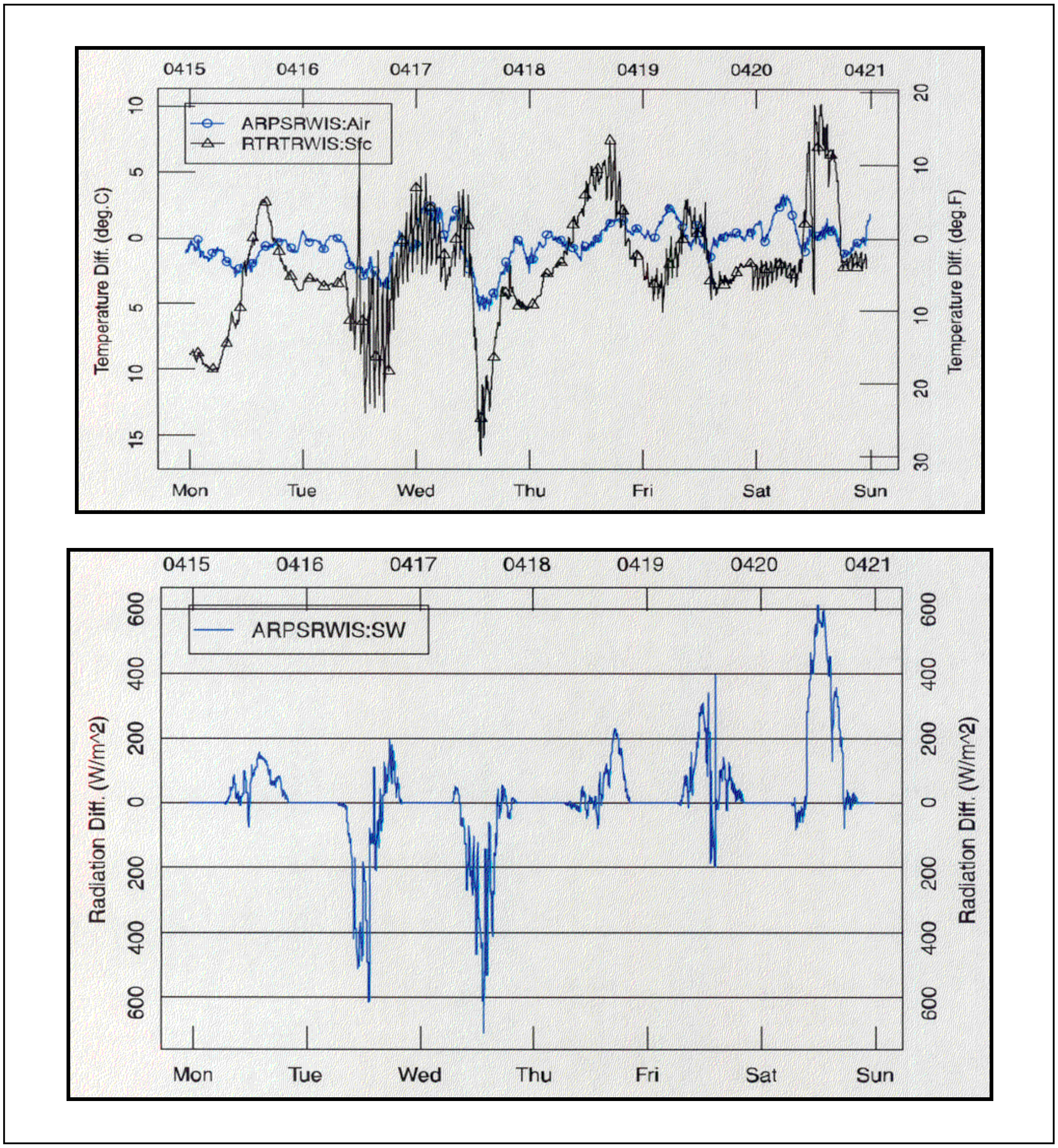


Figure 3-31. Differences in Forecast and Measured Temperatures and Solar Radiation

The SAFE-PASSAGE report also noted differences between the forecast and measured wind speed, wind direction, relative humidity, and precipitation rates. The primary conclusion concerning the PTM model drawn by that report was that "…in summary, the accuracy of the road surface temperature forecast is highly dependent on the accuracy of the ARPS forecast."[33]

The next round of validation focused on the RadTherm/RT portion of the PTM process by avoiding the use of ARPS weather forecast data. Instead, a small terrain model was made of the stretch of highway neighboring the RWIS station at the top of Bozeman Pass. RWIS data was collected from that station for a 24-hour period, and the meteorological conditions from that station were used for each of the terrain elements in the RadTherm/RT model for that 24-hour period. In that way, actual weather conditions were used, and the accuracy of the RadTherm/RT model could be evaluated by comparing the measured road surface temperature data versus those estimated by the RadTherm/RT model based on the measured weather conditions. Figures 3-32 through 3-35 compare the estimated to measured road surface temperatures for 4weeks in the Winter and Spring of 2003.

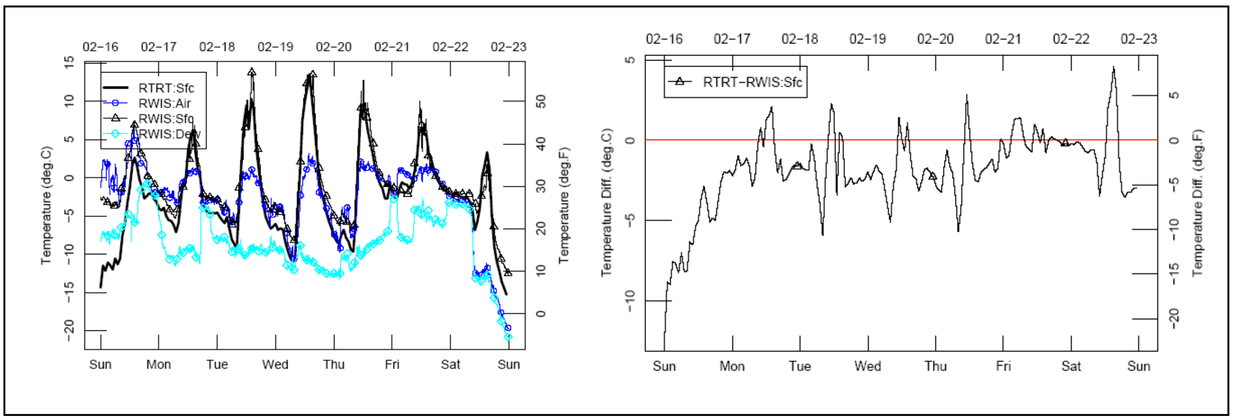


Figure 3-32. Forecast and Measured Road Surface Temperatures, 2/16/2003 to 2/23/2003

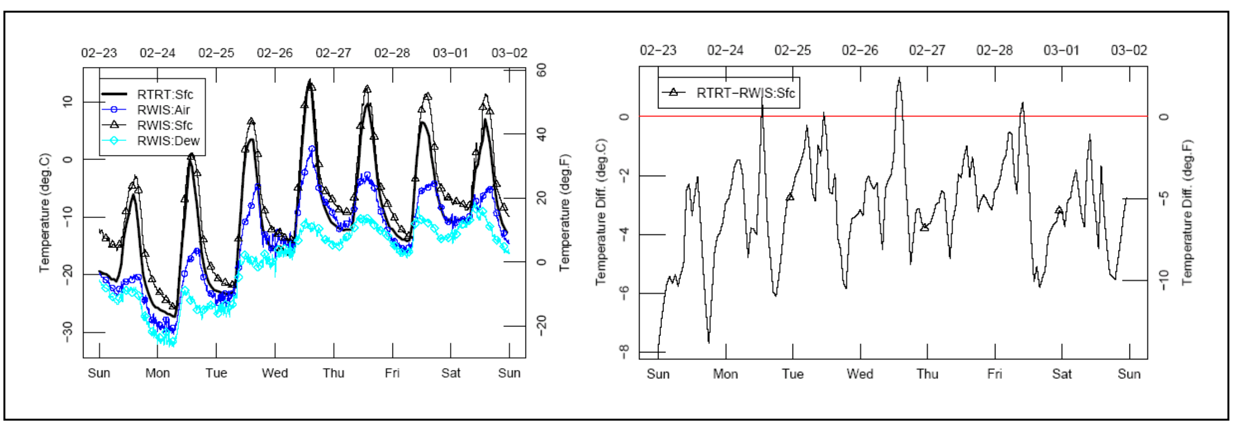


Figure 3-33. Forecast and Measured Road Surface Temperatures, 2/23/2003 to 3/2/2003

33 *Development and Demonstration of a Rural Weather Prediction Model and Motorist Communication System for Safe and Efficient Traffic Management/Infrastructure Maintenance,* SAFE-PASSAGE Report, October 2002.

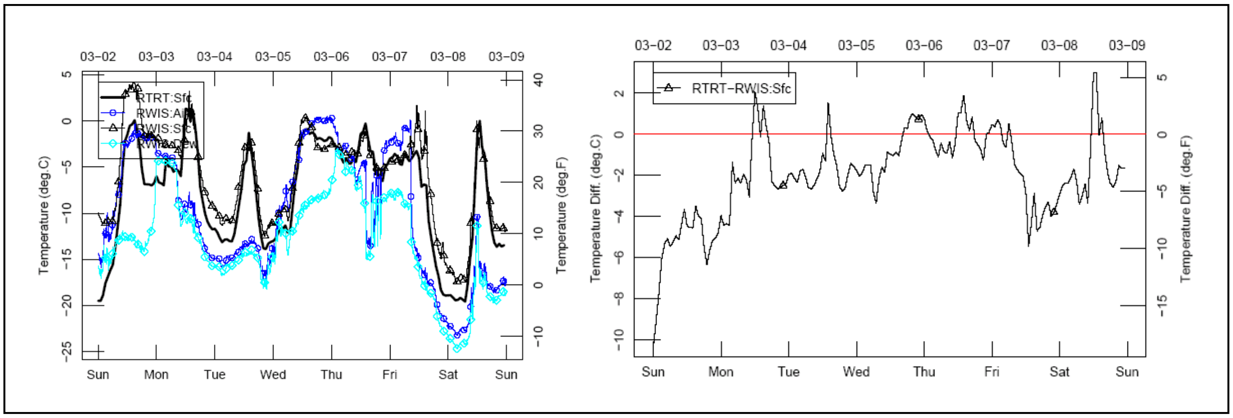


Figure 3-34. Forecast and Measured Road Surface Temperatures, 3/2/2003 to 3/9/2003

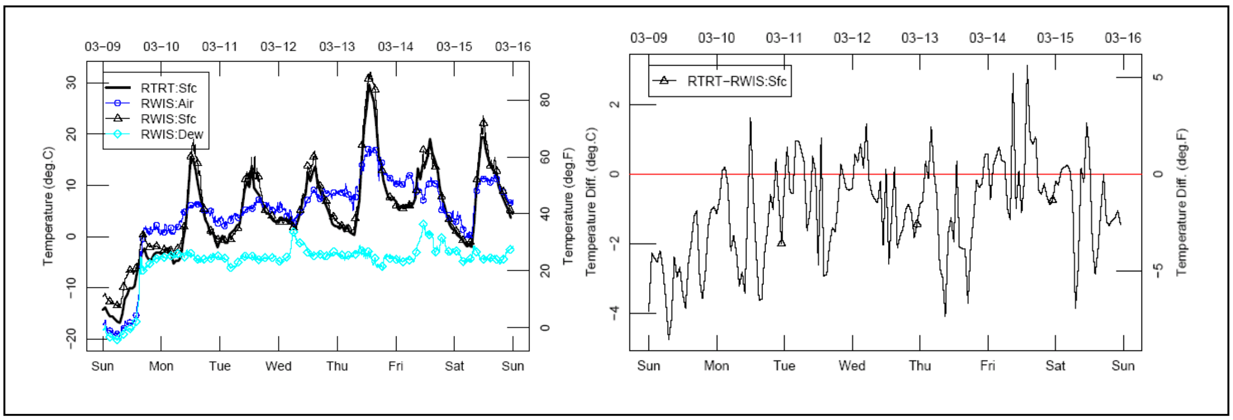


Figure 3-35. Forecast and Measured Road Surface Temperatures, 3/9/2003 to 3/16/2003

Figure 3-36 shows a similar comparison for a summer month in 2003.

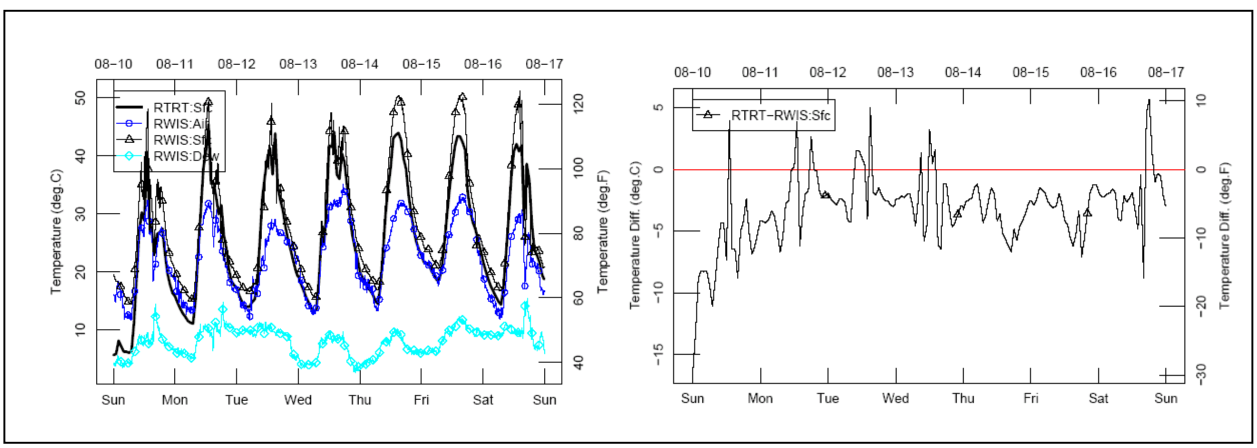


Figure 3-36. Estimated and Measured Road Surface Temperatures, 8/10/2003 to 8/17/2003

The results of an analysis of the differences between the estimated and measured temperatures are listed in Table 3-3. These results indicate that the RadTherm/RT model tended to under-estimate the road surface temperature by about 2 °C (i.e., the "Average" values were about

-2 °C). The typical difference between the measured and estimated values was about 2.5 °C. These differences are less than the 5 °C typically observed when ARPS data was used.

Table 3-3. Differences Between Estimated and Measured Road Surface Temperatures

Date Range	Average	Root Mean Square
2/16 to 2/23	-1.9 °C	2.7 °C
2/23 to 3/2	-3.1 °C	2.3 °C
3/2 to 3/9	-2.0 °C	3.1 °C
3/9 to 3/16	-1.0 °C	2.4 °C
8/10 to 8/17	-3.2 °C	2.9 °C

3.2.4 Using the PTM Data

Originally, the primary purpose of the PTM for GYRTWIS was to provide maintenance personnel with forecasts of road surface temperatures to support anti-icing decision-making. At the time, MDT maintenance practices called for applying anti-icing chemicals prior to ice or snow accumulating on the road. These actions were designed to prevent ice from forming and to eliminate bonding between ice and snow and the road surface, making it easier to plow. However, the following concerns about this practice were raised:

- Anti-icing treatments may make the road surface slippery (depending on the operational factors, such as chemical type, as well as environmental variables, such as pavement temperature and humidity).
- Early application of anti-icing treatments sometimes results in wasted treatment chemicals when weather conditions change.
- The public sometimes perceives early application of anti-icing treatments as wasteful.
- Anti-icing treatments could adversely impact the environment, so minimizing the number of treatments used became a priority.

Consequentially, MDT maintenance crews are now applying "just-in-time" anti-icing treatments by using actual information (camera views, road and weather reports) and weather forecasts instead of road condition predictions based on sensor data. Until these practices change, MDT is unlikely to use PTM results for maintenance anti-icing decision-making.

A secondary purpose of the PTM is to provide additional traveler information to the public. The road surface temperature information might enable the public to make more informed decisions about the safety of travel through regions that are prone to ice. Because MSU has been working on improving and validating the PTM, the PTM results have not yet been made available to the public. Current plans call for this information to be available over the Internet sometime during 2004.

3.2.5 Alternate Approaches to Estimating Road Surface Temperatures

FHWA is sponsoring development of a Maintenance Decision Support System (MDSS) prototype, which is a guidance tool for wintertime maintenance operations that includes road surface temperature models that consider both weather conditions and maintenance operations. The basic approach currently used for MDSS road surface temperature estimates is similar to the PTM in that it implements a 1-dimensional energy balance to estimate road surface temperatures based on known atmospheric data. However, the MDSS approach does not include the detailed terrain modeling inherent in RadTherm/RT and, therefore, is likely to be less accurate in areas were terrain plays a significant role in road surface temperatures. In general, MDSS road surface temperature trials have experienced similar problems as those of the PTM trials, with the accuracy of weather forecasts limiting the abilities of the energy balance to estimate accurate road surface temperatures.

An alternate approach to estimating road surface temperatures is proposed by Vaisala, a company that relies on field measurements of road surface temperatures rather than on energy and mass balances. Using this approach, the region of interest is first divided into climatic domains, which are regions that experience similar weather conditions. The roads in each climatic domain are considered separately. Then, surveys of road surface temperatures are taken under different weather conditions to produce thermal maps of the variation in road surface temperatures. The assumption is that, under similar weather conditions, similar variations in the road surface temperatures will occur.

Based on this assumption, estimates of road surface temperatures are produced by evaluating the current weather conditions and identifying a thermal map that applies to those weather conditions. (For example, trials in England used three classes of weather conditions with different thermal maps applied to each of these three classes.) The thermal map, which denotes differences in road surface temperatures, gives a method for estimating road surface temperatures for an entire road based on temperature estimates at a few points on the road.

As with the PTM and MDSS approaches for estimating road surface temperatures, this approach is still being developed and tested. To date, the trials of this approach have focused on estimating nighttime road surface temperatures during the winter. Because the effect of the sun can vary differently throughout the day for different sections of road, applying this approach to estimate daytime road surface temperatures may be difficult.

3.2.6 Summary of Findings

Several approaches exist for estimating road surface temperatures, one of which is the PTM process developed by WTI/MSU. (Two other approaches are described in Section 3.2.5.) This PTM process was refined and tested during the GYRTWIS project.

As a result, MSU successfully demonstrated the feasibility of the PTM process of forecasting road surface temperatures that is based on a physical model of energy transfer at the road surface and within the road. This process uses readily available terrain and weather forecast information to provide inputs to a thermal model of the road, from which road surface temperatures are estimated. Despite the complexity of this process – in particular, the complexity of generating small-scale weather forecasts and computing terrain-to-terrain radiant energy exchanges – MSU demonstrated the ability to generate a continuous stream of road surface temperature forecasts.

However, validations of these forecast temperatures showed typical differences between forecast and measured values of about 5 °C. To be useful for estimating when icing might occur, much more accurate forecasts are needed. During initial validations, significant differences between the forecast and measured weather conditions were observed, and it was proposed that these differences resulted in much of the errors in forecast road surface temperatures. Subsequent validation activities, during which measured instead of forecast weather data was used, confirmed this supposition and reduced the typical differences between forecast and measured temperatures to about 2.5 °C. (Similar observations about the limitations of forecast weather data were noted during validation activities for the road surface temperature model used for the MDSS.)

Although the PTM process shows promise for forecasting road surface temperatures, limitations in the accuracy of small-scale, long-term weather forecasts currently limit the accuracy of the road surface temperature forecasts. These limitations may make it difficult to use the PTM to directly support anti-icing decision making at this time. The overall accuracy of the model is not high enough at this time to make anti-icing decisions based primarily on the road surface temperatures forecast by the model. However, the forecast road surface temperatures could still assist maintenance managers in making anti-icing decisions by allowing them to estimate the relative risks of icing at different locations – areas with high forecast road surface temperatures should be less likely to ice than areas with low forecast temperatures. Travelers might use the results in a similar way in deciding whether a trip should be postponed because the risk of icing was high. Up until this time, MSU has been concentrating its efforts on developing, improving, and validating the PTM. During 2004, MSU plans to make the forecast road surface temperature, along with some of the small-scale weather forecast data needed to run the PTM, available over the Internet.[34] Perhaps the usefulness of the PTM forecasts can be judged at that time by the degree to which MDT maintenance and the public make use of them.

3.3 Case Studies

3.3.1 General Methodology

The general approach for the Case Study interviews included reviewing relevant documents, such as the GYRTWIS meeting minutes and the Memorandum of Understanding (MOU); discussing the current project status; preparing and distributing interview questions; and scheduling and conducting interviews. The Before interviews were conducted between February 28 and March 1, 2002 in Montana, and between March 19 and 21, 2002 at the 2002 511 Deployment Conference in Scottsdale, Arizona. The After interviews were conducted May 29 – 30, 2003 at MSU/WTI in Bozeman, Montana.

The following sections provide a brief description of the methodology and comparison of Before/After results for each of the Case Studies.

[34] As of late 2003, the PTM forecasts information was available at http://www.coe.montana.edu/wti/snow_ice/, though the site was labeled "Under Construction".

3.3.2 GYRTWIS Business Model

Advanced Traveler Information System (ATIS) business models are studied in many urban ITS deployment areas (e.g., San Francisco, Seattle, Phoenix, New York, Miami, and New England). However, information about rural ATIS business models for the 511-telephone service has just started to emerge within the past 2 years.

This evaluation focused on a qualitative investigation of the GYRTWIS business model, how the services were being funded, and from where funding for ongoing operations would be obtained. The goal is to present the findings and lessons learned to other regions considering similar systems. Table 3-4 presents the evaluation approach including the objective, measures of effectiveness (MOE), data sources, and analysis.

Table 3-4. Rural 511 Business Model Evaluation

Objective	MOE	Data Source	Analysis
Examine the rural ATIS business model, how services are being paid for, and the source of funding for ongoing operations.	For GYRTWIS what are the: – Revenue sources. – Level and type of financial support. – Marketing/outreach plans. – P-P partnership agreements. – Sharing infrastructure or services.	GYRTWIS documents: – MOUs – Contracts – Policy Statements – Before/After interviews with key project personnel.	Case study analysis of interviews and documents.

The data collection for the case study began with a review of relevant project documents (MOUs, policy statements, and meeting minutes) to understand the following elements:

1. The nature of the public-private (P-P) partnership agreements.
2. Agency policies and procedures.
3. Business model topics/issues discussed during project meetings.

Next, the Evaluation Team developed a series of questions for interviews with key project personnel. The key project personnel were comprised of project management personnel from both public agencies and private entities.

The interview results reported in this Phase III document identify deployment concerns/issues based on both the Before and After interviews, and provide guidance or lessons learned where applicable. Both Before and After interviews provided insight into the unique GYRTWIS 511 business model. Four areas were investigated:

- Revenue sources to implement and sustain the service.
- Marketing/outreach plans.
- Nature of the public-private partnership agreements.

- Shared infrastructure or services.

3.3.2.1 Results

Revenue Sources to Implement and Sustain the Service

The GYRTWIS 511 system was built using the existing RWIS that was originally developed for MDT maintenance operations. The business model can be viewed as both a public-private partnership and a traditional fixed-price contracting relationship. During the development phase, the funding sources to implement the system were FY2000 ITS Congressional Earmark appropriations bill, Highway Trust funds, State of Montana funds, and either cash or in-kind partnership contributions. MDT's agreement with Meridian and ThermoAnalytics can also be considered a fixed-price contracting relationship. As part of the financial arrangement, both companies are paid for their services. Meridian expanded the #SAFE weather model, provided mesoscale meteorological forecasts, and 511 telephony support. ThermoAnalytics is improving the Pavement Thermal Model and providing a user interface for maintenance users.

Since system deployment, the source of funding to sustain the GYRTWIS 511 system has not changed. However, organizational changes have resulted in GYRTWIS oversight moving from the Planning to Engineering Departments within MDT. As a result, some 511-telephone service funds are still available to cover contingencies such as handling increased call volumes, marketing, or 511 equipment upgrades.

The means to sustain the service beyond 2005 (the end of the earmark funding period) are still being explored and considered. The intent is to keep the 511 service operational and a number of options are available. In addition to budgetary constraints in relying on State funding, it can be challenging to anticipate funding needs for technology 2 years in advance of submitting budget requests. However, there are State exigency measures (e.g., emergency or other urgent funding sources) that can be used to maintain service while MDT seeks to secure final funding.

The public sector did not have the goal of generating revenue to enable the 511-telephone service to become self-sustaining. Since the 511 system replaced the *ROAD telephone service and was built on existing MDT maintenance processes and information, public opinion and support of the service is of higher priority than generating self-sustaining revenue.

However, advertising may be a potential revenue source in the future. Before the deployment, Montana state law prohibited advertising on state property. As a result, advertising revenues were not a possibility without changes to the State regulations. As of July 1, 2003, the State legislature approved rules allowing commercial activities on the highway right-of-ways. This has opened the possibility for lodging and other tourist-related advertising on kiosks and other State-owned properties. The current public sector viewpoint is that advertising through the 511-telephone service would be viewed negatively by users and will probably not occur.

Marketing/Outreach Plans

The MDT Public Information Office was responsible for outreach activities. Marketing and outreach activities began in the summer of 2002, several months ahead of a ribbon-cutting event for the 511 service. An application for grant money from the FHWA was submitted and the grant funding was used to pay some of the marketing and outreach costs. The planned budget for marketing and outreach was approximately $20,000 to $30,000. However, this amount will probably be approximately $40,000 by the end of the GYRTWIS earmark project in 2005.

In comparison with many other 511 deployments, the GYRTWIS marketing and outreach budget appears to be considerably smaller. For example, at the 2002 511 Deployment Conference in Scottsdale, Arizona, it was reported that Kentucky had a "shoestring" budget-spending approximately $50 thousand dollars per year promoting its 511 service. Boston, on the other hand, reportedly spends approximately $1 million dollars per year on marketing and outreach.

MDT uses a low-cost "grassroots" approach to raise awareness of the 511-telephone service to State residents. There are approximately 240 MDT employees who actively participate in the MDT Transportation Awareness Program (TAP). The TAP allows time-off (with pay) to MDT employees who participate in approved public events to distribute information and educate the public about current MDT programs and initiatives. These public events are often informal settings such as manning a booth at county fairs, trade shows, or local festivals. During the summer of 2002, TAP participants began educating the public and promoting the 511 service. During 2003, TAP participants will bring snowplows to fairs, display 511 signs, and distribute advertising "giveaways" (ice scrapers, pins, etc.) while talking with the public.

The consensus of the GYRTWIS team is that utilizing TAP for marketing and outreach is successful because the state population is smaller than most states. Additionally, personal communication via "word of mouth" is effective for important information such as road and weather information services.

Other low-cost methods used to promote 511 to both State residents and out-of-state travelers included press releases, TV news interviews, newspaper articles, highway signs at select locations, and announcements on MDT's pre-511 telephone numbers. Soliciting broadcast news media personnel (such as the local television meteorologists) and gaining their interest in the new service to periodically promote the 511 system in their weather broadcasts was also a very low-cost (but effective) means to reach the public.

Overall, the two most costly methods were for billboard advertising (approximately $12,000) and radio public service announcements (approximately $8,000).

Public-Private Partnership Agreements

In June 2001, the MDT entered into an MOU agreement with Western Transportation Institute/Montana State University, Meridian Environmental Technology, and ThermoAnalytics, Incorporated. The purpose of the MOU was *"To identify the parties that are collectively interested in entering into an agreement for demonstration and evaluation of the Greater Yellowstone Regional Traveler and Weather Information System (GYRTWIS)."*[35] The MOU defined the general agreement between the different public and private organizations and described the roles, responsibilities, and contributions (cash or in-kind) for the GYRTWIS

[35] Memorandum of Understanding for Greater Yellowstone Regional Traveler and Weather Information System, June 2001.

developers. In addition to the MOU, a Scope of Work (SOW) document, *Greater Yellowstone Regional Traveler and Weather Information System Scope of Work,*[36] was developed by MSU/WTI in June of 2001 to clearly define the scope of the project, schedule, and budget.

Despite the close-knit relationships between the GYRTWIS partners and having the MOU and SOW documents in place, the lack of a systems engineering plan describing formalized policies, procedures, and requirements made monitoring progress a challenge. This, in conjunction with the lack of MDT staff time available for oversight, resulted in technical issues remaining unresolved (and largely unknown to MDT) until the scheduled deployment date. Consequently, a last-minute rescheduling of the deployment date was necessary due to unresolved technology challenges. Additional staff oversight and more formalized requirements may have preempted the need for a 3-month delay in deployment.

Shared Infrastructure or Services

MDT provides the data collected from its RWIS sites to support the GYRTWIS 511-telephone service. Originally, the RWIS information was primarily used to collect data to support winter maintenance operations; however, the data is now integrated with meteorological information and forecasts to provide the 511weather information to callers.

WTI/MSU is also sharing infrastructure and services. The development of the PTM and processing system is being led by WTI/MSU. To support the computational-intensive PTM, WTI/MSU will provide some of the needed computing resources.

3.3.2.2 Summary

The follow-up interviews conducted after the GYRTWIS 511 deployment investigated four topic areas:

- Revenue sources to implement and sustain the service.
- Marketing/outreach plans.
- Nature of the public-private partnership agreements.
- Shared infrastructure or services.

The revenue sources used to implement and sustain the GYRTWIS 511-telephone service have not changed in the past year. The continuing revenue sources include the FY2000 ITS Congressional Earmark funding, Highway Trust funds, State of Montana funds, and cash or in-kind partnership contributions. Beyond 2005, MDT's intent is to keep 511 operational and to further explore additional funding resource(s) to sustain the service. Currently, the project management team does not favorably view or promote the 511 system to generate revenue in order to become a self-sustaining service. However, lodging and other tourist-related advertising on kiosks and other State-owned properties is a possibility due to recent changes to Montana State law.

[36] Greater Yellowstone Regional Traveler and Weather Information System Scope of Work, June 2001.

MDT used a low-cost (approximately $40,000), "grassroots" approach to raise State residents' awareness regarding the 511 service. The GYRTWIS 511 project management mobilized approximately 240 MDT employees who participate in the MDT Transportation Awareness Program to educate the public at county fairs and other public events. Other low-cost methods used included press releases, TV news interviews, newspaper articles, highway signs, and announcements on the pre-511 telephone numbers. The two most expensive methods were billboard advertising and public service announcements.

The MOU defined the general agreement between the different public and private organizations and described the roles, responsibilities, and contributions (cash or in-kind) for the GYRTWIS developers. The SOW document further defined the scope of the project, schedule, and budget. Despite close relationships between the partners and having the MOU and Scope of Work documents in place, the lack of formalized policies, procedures, and requirements in a systems engineering plan and the lack of MDT staff availability for oversight made monitoring technical progress a challenge.

MDT and WTI/MSU both provide infrastructure and service. MDT provides the data collected from their RWIS sites to support the GYRTWIS 511-telephone service. MSU/WTI is providing some of the computing resources to support the computational-intensive Pavement Thermal Model.

3.3.2.3 Conclusions

The GRYTWIS 511-telephone service emphasizes providing readily available and accurate information to address traveler safety concerns. Therefore, the goal of the system is to provide accurate and timely weather and road condition information. This contrasts with urbanized areas where emphasis is most often placed on the need for congestion information over road condition. Since the GYRTWIS is, in a sense, an upgrade of existing services (i.e., *ROAD telephone service and maintenance information system), the public sector is more concerned about providing the service than generating revenue.

In comparison with the reported budgets in Kentucky and Massachusetts, the GYRTWIS project has a small marketing and outreach budget. However, the low-cost "grassroots" methods used to educate resident travelers appears to be successful due to the importance of road and weather information and the effectiveness of personal communication via "word of mouth".

Based on the GYRTWIS marketing and outreach experiences, the least and most costly methods are shown in Table 3-5.

Table 3-5. Relative Costs for Marketing and Outreach Activities

Marketing / Outreach Method	Relative Cost
"Word of Mouth"	Free
Transportation Awareness Program	Low
Press Releases	Low

Marketing / Outreach Method	Relative Cost
News Interviews	Low
Newspaper Articles	Low
1-800 Announcements	Low
Highway Signs	Low – Moderate
Billboard Advertising	Moderate
Public Service Announcements	Moderate

Despite close relationships between the partners and having the MOU and SOW documents in place, the lack of formalized policies, procedures, and requirements in a systems engineering plan, and the lack of MDT staff availability for oversight made monitoring technical progress a challenge. The development effort would have benefited from a systems engineering plan that described the functional requirements, data flows, testing requirements, specific deliverables, and schedule.

3.3.3 Institutional Lessons Learned

GYRTWIS is a rural project in Montana that implemented a 511-telephone service utilizing the #SAFE system located in North Dakota and WTI/MSU's Pavement Thermal Model. Because GYRTWIS is a public-private partnership with the #SAFE operation center in North Dakota, it is important to document the institutional benefits and challenges that were encountered during GYRTWIS development and implementation. Problems arising during a deployment are not only technical, but also institutional, especially when the project involves participants from multiple states. The goal of this evaluation is to present findings and lessons learned to provide insight and guidance to others. Areas explored include:

- Project team coordination and cooperation.
- Information sharing and how gaps were accommodated.
- Management approach to overcoming obstacles.
- Benefits, advantages, challenges, and drawbacks.

Table 3-6 summarizes the evaluation approach including the objective, measures of effectiveness (MOE), data sources, and proposed analysis.

Table 3-6. Institutional Lessons Learned Evaluation

Objective	MOE	Data Source	Proposed Analysis
Identify the institutional benefits, challenges, and lessons learned	Perceptions of: – Coordination issues. – Information sharing/gaps.	Review GYRTWIS documents: – Meeting minutes	Case study analysis of interviews and documents.

Objective	MOE	Data Source	Proposed Analysis
regarding the 511 deployment.	– Approach to overcoming obstacles. – Benefits, advantages, challenges, and drawbacks.	– Other relevant docs Before/After interviews with key project personnel.	

3.3.3.1 Results

Project Team Coordination and Cooperation

The project team developing GYRTWIS was a close-knit, fairly small group of people; however, coordination became challenging over time. Project team cooperation, on the other hand, was not an issue. Early in the development process communication and coordination was not viewed as a major challenge. Project team consensus was reached early on with all project participants (MDT, MSU/WTI, Meridian, and ThermoAnalytics) reviewing, commenting, and discussing the MOU and SOW documents to ensure coordination and cooperation. However, the documents were not specific enough about the roles and responsibilities. Also, a systems engineering plan to guide the development process would have been beneficial in specifying data, functional, and testing requirements.

The roles and responsibilities of MDT and MSU/WTI were not always clear because of the high level of trust between the project team and the structure of the funding. The high level of trust resulted in the management team allowing the development effort to progress without a systems engineering plan to clearly define roles and communicate system requirements. The structure of the funding arrangement also contributed to some confusion as MSU/WTI received the Earmark funding and managed the Meridian contract, but the 511 system was being developed for MDT. Consequently, when development issues arose, MDT and MSU/WTI had to coordinate their management of the effort.

The lack of full time MDT staff devoted to the project resulted in part time monitoring and management of the development issues. The management team used several methods to maintain open lines of communication: scheduled telephone calls; reporting requirements; and project "team" meetings.

Scheduling weekly telephone calls helped project personnel maintain contact and remain in touch with current developments. However, as the development effort progressed, schedule conflicts and the demands of working on multiple projects reduced communication opportunities, which in turn, reduced the ability to monitor progress.

Project "team" meetings, where project personnel got together in-person to discuss issues helped coordination and cooperation among project personnel. Some opportunities to meet occurred at conferences, such as ITS America, Rural Applications of ITS Technologies, and the 511 Deployment Conference. The in-person meetings were preferred over telephone calls because schedule conflicts and geographic separation prevented frequent face-to-face meetings.

Information Sharing and How Gaps were Accommodated

After technical challenges delayed the October deployment of GYRTWIS, information sharing became an important issue for Montana DOT and MSU/WTI. It was not technical data (such as RWIS or meteorological data) required for the system to operate that created issues, but documentation and information about design decisions made during prior conference calls and conversations. Given the high level of trust and management structure (MSU/WTI providing management assistance to Montana DOT), conversations between Montana DOT, MSU/WTI, and Meridian often went undocumented. Interestingly, it was the same high level of trust that enabled the three organizations to resolve the development issues. Further, the emergence of this information-sharing gap has since led to a greater understanding between the MDT and MSU/WTI management team. For important calls with Meridian, MDT, and MSU/WTI both participate in the calls and a call report documenting the key points of the meeting is developed and distributed by MSU/WTI.

Management Approach to Overcoming Obstacles

In addition to what has already been mentioned, GYRTWIS management relied on planning documents and the use of in-house experts to address and overcome obstacles. MDT utilized two planning documents to provide a framework for the development and to address job security issues. The Greater Yellowstone Regional Intelligent Transportation System (GYRITS) Regional Architecture and the Montana DOT Strategic Business Plan provided high-level guidance and a framework to follow in the development. The GYRITS Regional Architecture is a useful planning tool for guiding the regional ITS deployments and ensuring compatibility with the National ITS Architecture and ITS Standards.[37] The regional architecture assists agencies and stakeholders to identify and plan the integration of ITS components and needed data exchanges. The GYRTWIS project architecture was developed based on the GYRITS Regional Architecture and identifies the components being used and information sharing requirements.

The Montana DOT Strategic Business Plan

Another useful tool to address job security issues and alleviate fear of job loss due to new technology was accessed from the Montana DOT Strategic Business Plan.[38] The Plan serves as the basis for business actions and performance measurement, both at the department and individual level. Employees have performance plans developed from 12 strategic initiatives and performance criteria that are tied to their division, district administrator, and overall departmental performance.

Management also utilized the help of in-house (State of Montana) experts to address complicated issues. This proved especially helpful in dealing with the companies operating telephone services in the region (both wireless and landline companies). The successful deployment of the GYRTWIS 511-telephone service depended on the participation of the various telephone companies operating in the State of Montana. However, the management team (comprising of Montana DOT and MSU/WTI) had very little knowledge and experience in dealing with the

[37] The GYRITS Regional Architecture planning tool information can be accessed via http://www.coe.montana.edu/wti/wti/pdf/GYRITS1_Task_11.pdf.

[38] The Montana DOT Strategic Business Plan can be accessed via http://www.mdt.state.mt.us/general/matrix/businessplan.html.

various telephone companies. Consequently, the GYRTWIS team was at a disadvantage in trying to negotiate the switch to 511 with the telephone companies.

Fortunately, the management team identified and enlisted the help of an individual in the State of Montana Department of Administration, who had experience in resolving telephone issues for the State. The individual was able to coordinate a meeting with all the phone companies and negotiate an agreement with no per call charges and minimal switching costs.

Benefits and Advantages

From the discussions both during and after the development of GYRTWIS, it was felt that working together provided several benefits and advantages for Montana's travelers and maintenance personnel. Obviously, working together has resulted in the sharing of ideas and perspectives. This also allowed MDT to work with others who have ITS experience and learn about ITS without having to hire additional personnel. This, in turn, has resulted in a greater knowledge and trust in ITS technologies at MDT.

Challenges and Drawbacks

As with any development project, there are challenges – both expected and unexpected. During the development phase, procuring telecommunications equipment was expected to be a challenge to the project schedule due to changes in Montana State law. The new laws require that all acquisitions of computer and telecommunications equipment to be handled by the Department of Administration. In retrospect, the changes to the equipment acquisition process delayed the GYRTWIS telephony equipment, but also opened up opportunities for GYRTWIS that were probably better for MDT. The decision was made to lease, not buy, the telephony equipment from Meridian. This, in effect, relieved MDT from buying and maintaining the equipment. Further, if the need arises, MDT has the option to pay for additional lines.

The lack of budget for meetings and workshops was perceived as a challenge. Post deployment, this was identified to be more of an inconvenience. Although GYRTWIS involves a small close-knit group, they are geographically dispersed (MDT and MSU/WTI are approximately 90 minutes apart via car). The team now plans and designates a budget for travel in proposals to allow the team to travel to meet and discuss issues in person. Whether for meetings in Montana at MDT or WTI/MSU, in North Dakota at Meridian Environmental Technology, or to attend workshops/conferences, traveling in-person to view progress and discuss issues was still viewed as productive and valuable for gaining knowledge and insight. Along these lines, the 511 Deployment Coalition was mentioned as doing a good job in providing travel funding for the GYRTWIS team.

An anticipated (and actual) challenge was getting the participation of cellular phone providers. MDT's concerns were related to experiences that have occurred with 511 deployments in other parts of the country such as in Arizona and Northern Kentucky. During the time of the GYRTWIS development, some wireless carriers raised objections to a national deployment of 511 services citing issues such as costs to operate and support the service and losing opportunities to provide the information as a value-added service. Throughout the United States in 2002 (and into the first half of 2003), the wireless companies began participating and advertising the 511 service. By early June 2003 in Montana, an agreement was signed between the State of Montana and all the major wireless companies operating in the State.

3.3.3.2 Summary

Four areas were explored for the institutional lessons learned case study:

- Project team coordination and cooperation.
- Information sharing and how gaps were accommodated.
- Management approach to overcoming obstacles.
- Benefits, advantages, challenges, and drawbacks.

Despite the GYRTWIS project team being a close-knit, fairly small group of people, coordination became challenging over time. A number of factors contributed to coordination issues: a high level of trust between project team members resulted in the management team allowing the development effort to progress without a systems engineering plan to clearly define roles and communicate system requirements; the structure of the funding arrangement also contributed to some confusion as MSU/WTI received the Earmark funding and managed the Meridian contract, but the 511 system was being developed for MDT; and the lack of full time MDT staff devoted to the project resulted in part time monitoring and management of the development issues.

The sharing of information and documentation about design decisions made during prior conference calls and conversations was found to be more problematic than technical data (such as RWIS or meteorological data) required for the system to operate. The emergence of this information-sharing gap led to a greater understanding between the MDT and MSU/WTI management team. For important calls with Meridian, MDT and MSU/WTI both participate in the calls and a call report documenting the key points of the meeting is developed and distributed by MSU/WTI.

Two planning documents had a positive impact on overcoming obstacles. The Greater Yellowstone Regional Intelligent Transportation System (GYRITS) Regional Architecture was cited as a useful planning tool for guiding the GYRTWIS deployment. The Montana DOT Strategic Business Plan was cited as being a useful tool to address job security issues and alleviate fear of job loss due to new technology.

The identification and use of in-house (State of Montana) experts to address complicated issues proved especially helpful in dealing with the companies operating telephone services in the region (both wireless and landline companies). The GYRTWIS management team identified and enlisted the help of an individual in the State of Montana Department of Administration who was experienced in dealing with telephone issues for the State. The person was able to coordinate a meeting with all the phone companies and negotiate an agreement with no per call charges and minimal switching costs.

Working together to develop GYRTWIS provided several benefits and advantages for MDT. The sharing of ideas and perspectives, working with others that have ITS experience, and learning about ITS without having to hire additional personnel.

In terms of challenges, the lack of budget for meetings and workshops and geographic dispersion of the project team were perceived as more of an inconvenience than major challenge. The team now plans and designates a budget for travel in proposals to allow the team to travel to meet and discuss issues in person. Whether for meetings in Montana at MDT or WTI/MSU, in North Dakota at Meridian, or to attend workshops/conferences, traveling in-person to view progress and discuss issues was still viewed as productive and valuable for gaining knowledge and insight. The 511 Deployment Coalition was mentioned as doing a good job in providing travel funding for the GYRTWIS team.

Obtaining the participation of cellular phone providers was a major challenge for the GYRTWIS 511-telephone service. However, throughout the United States in 2002 (and into the first half of 2003) the wireless companies began participating and advertising the 511 service. By early June 2003 in Montana, an agreement was signed between the State of Montana and all the major wireless companies operating in the state.

3.3.3.3 Conclusions

Coordination can become an issue if the roles and responsibilities are unclear. This is found to be true even though the project team developing GYRTWIS was close-knit and involved a fairly small number of people. The development and use of a systems engineering plan that specifies data, functional, and testing requirements would provide some relief. Having a full-time MDT staff member devoted to the development effort would have also improved the development effort.

Having all key members participate in important discussions about design decisions and documenting the discussion and decisions was an important process in the development effort. Documenting the discussion and design decision provides a written record that can later be reviewed and referenced if needed.

Planning documents such as the Greater Yellowstone Regional Intelligent Transportation System (GYRITS) Regional Architecture and Montana DOT Strategic Business Plan are useful as a planning tool for guiding the GYRTWIS deployment and to address job security issues and alleviate fear of job loss due to new technology.

Identifying and using experts to address a complicated issue can help in resolving the issue. MDT was able to identify and enlist the help of a telecommunications expert within the State of Montana Department of Administration to work with the telephone companies and negotiate an agreement for the 511-telephone service.

Working together promotes the sharing of ideas and perspectives and can be beneficial to agencies not able to hire additional staff. MDT was able to work with others that had ITS experience and learn about ITS without having to hire additional personnel.

For the GYRTWIS project team, the lack of budget for meetings and workshops and geographic dispersion of the project team were perceived as more of an inconvenience than major challenge. The team now plans and designates a budget for travel in proposals to allow the team to travel to meet and discuss issues in person. The 511 Deployment Coalition was mentioned as doing a good job in providing travel funding for the GYRTWIS team.

3.3.4 511 Implementation Challenges, Guidelines, and Standards

This study investigates the GYRTWIS implementation challenges and the role of 511 guidelines and ITS architecture standards in system design and implementation. The implementation challenges encountered during system development and the outcome or resolution are also provided here. The role of 511 Content and Consistency guidelines and ITS architecture standards and the advantages, limitations, and suggested changes are also explored and reported. Table 3-7 summarizes the evaluation approach including the objective, measures of effectiveness (MOE), data sources, and proposed analysis.

Table 3-7. 511 Implementation Challenges, Guidelines, and Standards Evaluation

Objectives	MOE	Data Source	Proposed Analysis
Develop a case history of implementation challenges, the role of 511 guidelines/ITS architecture standards, and the advantages, limitations, and suggested changes.	Usefulness of 511 content/ consistency guidelines. Advantages/limitations. Suggested changes.	System engineering and architecture documents. Before/After interviews with key project personnel.	Case study analysis of: – Implementation challenges. – Role of guidelines and standards. – Guidelines / standards advantages, limitations, suggested changes.

Data Collection and Analysis

The data collection for the Implementation Challenges, Guidelines, and Standards case study involved reviewing systems engineering documents and interviewing key personnel developing GYRTWIS. Pre-deployment interviews provided an opportunity to capture implementation challenges and perceptions of the 511 Guidelines and ITS Architecture Standards. The After interviews captured additional insights or challenges and focus on the system developers' perceptions of the role of guidelines and standards, advantages, limitations, and any suggested improvements.

A series of questions were developed for interviews with GYRTWIS key personnel. The Before interviews were conducted between February 28 and March 1, 2002 in Montana and between March 19 and 21, 2002 at the 2002 511 Deployment Conference in Scottsdale, Arizona. The After interviews occurred on May 29 and 30, 2003 at MSU/WTI in Bozeman, Montana.

3.3.4.1 Results

Implementation Challenges

There were three noteworthy implementation challenges; two were anticipated and the third was unexpected. The unexpected challenge, in conjunction with other factors (such as coordination issues, lack of a systems engineering plan, new equipment procurement processes), resulted in the system being deployed about 3 months later than expected. However, in retrospect, the 511-telephone system was deployed in time for the major winter storms that occurred in Montana during 2003.

In terms of anticipated implementation challenges, the willingness of wireless companies to support the GYRTWIS 511 service was identified as a potential implementation stumbling block. During the development effort and up until June 2003, a great deal of uncertainty existed about how willing Montana’s regional cellular providers would be to participate in the GYRTWIS 511 service. Although not an isolated case, MDT’s concern was similar to 511 deployments in other parts of the country such as in Arizona and Northern Kentucky where issues such as costs to operate and lost opportunities for value-added services have been raised. In retrospect, the wireless companies did agree to participate and support Montana's 511-telephone service and the last major wireless company signed an agreement with Montana DOT in late May 2003.

A second anticipated challenge, previously discussed in the Institutional Lessons Learned section, was the legislative changes whereby the Montana Department of Administration became responsible for the purchase of computer and telephony equipment. This requirement and the activities, discussions, and so forth that ensued, to convey MDT's special requirements related to the ITS Earmark funding, delayed the acquisition of the telephone equipment. Fortunately, the delay resulted in a decision for MDT to lease the telephony equipment and lines from Meridian Environmental Technology. Meridian now runs and maintains the system for MDT, who no longer has to deal with the technology, avoids operations and maintenance costs, and can lease additional phone lines if needed.

The one unexpected challenge directly related to the development of the system. Meridian developed Montana's 511-telephone system by modifying the #SAFE system. Montana's system was being developed and tested in Grand Forks, North Dakota, which had a different version of the interactive voice response (IVR) telephone system than the new IVR to be implemented in Montana. When the 511 system was to be deployed in Montana, the system did not initially function as expected. Although it took a couple of months to work out the technical issues, the GYRTWIS 511-telephone service was successfully deployed on January 15, 2003. As a result of this implementation challenge, Meridian has put in place a duplicate of the real-time system to test system changes prior to deployment. Meridian's full-time test system allows all changes to be implemented on the test system and enables MDT to call a test number and hear how the system is working prior to implementation.

Guidelines and Standards

The 511 Guidelines were perceived to be fairly general, yet useful in providing a high-level understanding of the 511-telephone service. In addition, the guidelines were helpful in explaining to higher levels of management the design decisions for the 511-telephone service. The content guidelines were described as a helpful tool to identify the types of information from National Parks that could be included in 511. However, since GYRTWIS was developed using Meridian's #SAFE system, the Guidelines were not viewed as very helpful in terms of aiding actual development.

The ITS Architecture Standards were viewed as useful for planning purposes. As noted in the Institutional Lessons Learned evaluation, the ITS Architecture Standards provided a framework for the regional architecture as well as the development of the overall GYRTWIS architecture. The GYRTWIS architecture, based on the GYRITS regional architecture, is based on the ITS Architecture Standards.

One limitation was noted regarding the ITS Architecture Standards. The ITS Architecture Standards for ATIS were not viewed as very helpful in providing guidance on message sets for signs. However, participation in the 511 Deployment Coalition meetings and events provided Montana DOT a means to learn from other 511 activities and discuss issues with other 511 implementers.

Suggested Changes and Other Comments

In a review of the 511 Content and Consistency Guidelines a variety of suggestions and comments were provided to improve the 511 Guidelines. Following are some of the key points and comments suggested during project meetings with MSU/WTI and Meridian between February 2002 and May 2003:

- **The national guidelines should not be limited to just one solution.** *"The 'Providing route-specific…' guideline is great for Montana, but may not apply to all systems. Most of the guidelines sound too much like #SAFE."*
- **There should be a more definitive split between urban and rural areas.** As indicated in the 2003 Montana Traveler Information Survey and 1997 MSU/WTI Rural Traveler Survey, travelers in rural states were most interested in road condition and weather information versus other types of information.
- Allowing users to provide feedback can help planners/developers to identify problems, obtain input on suggested improvements to content, menu design, etc., and can be a valuable public relations tool. *"At a minimum, each 511 system should provide a comment, questions, or feedback line to record input from users and allow the state to respond to questions and comments in a timely manner."*
- **Flexibility in the selection of road segments, routes, or corridors is a desirable feature.** This was mentioned because, *"…while longer routes do need to be divided to facilitate detailed reporting of conditions along that segment of the route, Interstates should provide both an entire state route by interstate and a segment report across the interstate."* Since commercial vehicles routinely travel the interstate through an entire state, providing a "complete route" report option allows the commercial vehicle operator time to make route change decisions.
- **Providing route-specific weather and highway information provides travelers a complete view of the route.** Further, *"…the weather report should include current (Nowcast) and forecasted specific parameters of weather that are expected to affect the route*

requested. National Weather Service watches and warnings that cover the route must be included as well."

- **Providing access to customer service center operators raises significant issues related to cost and service implications.** While public transportation information should be part of the 511 system, easy access to customer service centers may need to be carefully considered. *"Duplication of telephone lines and their associated cost, consistent activity from the 511 system to these centers, and questions of a routine nature repeatedly being asked of operators that could easily be provided through the 511 automated system are just some of the issues a state or city would have to deal with."*
- **The guidelines should include interregional information as part of the basic information required along highways.** *"The importance of this multi-region integration goes to the heart of a Nationwide 511 Traveler Information System".* Because of the importance of traveler access while traveling, integration of regional information can be determining factor as to whether or not a traveler receives the information requested.
  For example: *"Interstate 71 from Louisville KY to Cincinnati OH. This interstate segment runs along the Kentucky – Indiana border and Kentucky – Ohio border on the Kentucky side. Since radio waves don't recognize state lines, travelers between these two cities searching for route-specific information about Interstate 71 could easily find themselves connecting to a mobile tower in Indiana. Next they are told that no such Interstate number exists or they are connected to an Ohio mobile tower, only to discover the only information available along Interstate 71 is for Cincinnati to Columbus."*
- **Implementing a system that allows callers to report incidents raises quality control issues.** A system of quality control should be put in place to verify the accuracy yet ensure the timeliness of the information. *"It must be done very carefully to ensure a method is established to eliminate untrustworthy reports and expedite real reports."*
- **Some personalized services should be provided by the private sector.** Providing travelers with information and allowing them to make decisions *"...relieves the state of the responsibility and possibly liability of providing driving directions, delays in itinerary or trip planning, hotel or restaurant reservations, or other items that when things go wrong."*
- Accuracy, timeliness, and reliability are essential to maintaining users trust in the system because *"...once a system loses their trust, they no longer use the system."*

3.3.4.2 Summary

Three noteworthy implementation challenges and their outcomes were described. Two implementation challenges were anticipated and the third was unexpected. First, concern about the willingness of wireless companies to support the GYRTWIS 511 service was identified as a potential implementation stumbling block. Although not an isolated case, MDT's concern was similar to 511 deployments in other parts of the country such as in Arizona, Northern Kentucky. The wireless companies did agree to participate and support Montana's 511-telephone service and the last major wireless company signed an agreement with MDT in late May 2003.

Another challenge, which was previously discussed in the Institutional Lessons Learned section, was the legislative changes whereby the Montana Department of Administration became responsible for the purchase of computer and telephony equipment. This legislative requirement delayed the procurement of the telephone equipment, which, in retrospect, was beneficial to MDT, who decided to lease, not buy, the telephony equipment from Meridian, thereby avoiding operations and maintenance costs. Depending on demand, additional phone lines may be leased if needed.

The one unexpected challenge directly related to the development of the system. Because the 511 system was developed outside Montana using a different version of the interactive voice response (IVR) telephone system, the 511 system did not initially function as expected due to technical difficulties and delayed the deployment. However, the GYRTWIS 511-telephone service was successfully deployed on January 15, 2003. As a result of this challenge, Meridian has put in place a duplicate of the real-time system to test system changes prior to deployment. The test system enables MDT to call a test number and hear how the system is working prior to implementation.

The 511 Guidelines were perceived to be fairly general, yet useful in providing a high-level understanding of the 511 system. The guidelines were found to be helpful in explaining to higher levels of management the 511 design decisions. The content guidelines were described as helpful for identifying the type of National Parks information that could be included in 511. However, since GYRTWIS was developed using Meridian's #SAFE system, the Guidelines were not viewed as very helpful in terms of aiding actual development.

The ITS Architecture Standards were viewed as useful for planning purposes. The ITS Architecture Standards provided a framework for the regional architecture as well as the development of the overall GYRTWIS architecture. One limitation was noted regarding the ITS Architecture Standards. The ITS Architecture Standards for ATIS were not viewed as very helpful in providing guidance on message sets for signs. However, participation in the 511 Deployment Coalition meetings and events provided MDT a means to learn from other 511 activities and discuss issues with other 511 implementers.

The 511 Content and Consistency Guidelines were reviewed and a variety of suggestions and comments yielded the following key points:

- The national guidelines should not be limited to just one solution.
- There should be a more definitive split between urban and rural areas.
- Allowing users to provide feedback can help planners/developers to identify problems, obtain input on suggested improvements to content, menu design, etc., and can be a valuable public relations tool.
- Flexibility in the selection of road segments, routes, or corridors is a desirable feature.
- Providing route-specific weather and highway information provides travelers a complete view of the route.
- Providing access to customer service center operators raises significant issues related to cost and service implications.
- The guidelines should include interregional information as part of the basic information required along highways.

- Implementing a system that allows callers to report incidents raises quality control issues.
- Some personalized services should be provided by the private sector.
- Accuracy, timeliness, and reliability are essential to maintaining users trust in the system.

3.3.4.3 Conclusions

The GYRTWIS development effort encountered both anticipated and unexpected implementation challenges. Two anticipated challenges, the participation of wireless companies and changes to Montana's procurement processes, were resolved by late May 2003. The changes to Montana's procurement processes came to a beneficial resolution for MDT, as it decided to lease, not buy, the telephony equipment from Meridian and thereby avoiding operations and maintenance costs.

The unexpected challenge resulted in Meridian utilizing a duplicate of Montana's real-time system to test system changes prior to deployment. The test system enables MDT to call a test number and hear how the system is working prior to implementation.

The 511 Guidelines and ITS Architecture Standards were useful for planning purposes. In addition, the 511 Guidelines were useful for providing a high-level understanding of the 511 information service, explaining to higher levels of management the 511 design decisions, and in identifying information that should be included in 511. However, since GYRTWIS was developed using Meridian's #SAFE system, the Guidelines were not viewed as very helpful in terms of aiding actual development.

The ITS Architecture Standards were useful for providing a framework for the regional architecture as well as the development of GYRTWIS overall architecture. However, it was not viewed as very helpful in providing guidance on message sets for signs. Participation in the 511 Deployment Coalition meetings and events was found to provide MDT a means to learn from other 511 activities and discuss issues with other 511 implementers.

4.0 Lessons Learned

The Phase III Evaluation of the GYRTWIS project consisted of investigations of system usage, customer satisfaction, and case studies of the GYRTWIS business model, institutional lessons learned, 511 implementation challenges, and the role of 511 guidelines and ITS Architecture Standards. The following lessons learned were derived from the GYRTWIS 511 deployment:

- **Road condition and weather forecast information is more important to rural travelers in cold weather regions than other types of information.** Travelers surveyed in 1997 and 2003 consistently rated road condition and weather forecast information as more important than other types of travel information. These results suggest that travelers on Montana's rural roads and highways are more concerned with the safety of road conditions and weather forecast information than another other types of information (e.g., city road conditions, accident information, public transit).
- **Low-cost methods of promoting the 511 service can be effective.** In Montana, raising public awareness of 511 was promoted using Transportation Awareness Program staff at public events and other low cost methods such as press releases, TV new interviews, newspaper articles, highway signs, announcements on pre-511 telephone numbers, and "word-of-mouth" about road and weather information services. Based on the analyses of numbers of calls it appears the promotion methods were reasonably effective in raising public awareness.
- **Allocate adequate staff time for planning, development, and oversight of the 511 deployment effort.** In retrospect, this was one of the most overlooked issues for MDT staff. As a result of multiple duties and overwork, it was difficult to monitor progress, address issues, maintain coordination between team members, and keep open lines of communication.
- **Incorporate adequate budget for travel costs to project meetings, conferences, and other related activities.** This was especially important for the GYRTWIS team because not only were they geographically dispersed, but they also found conferences and in-person meets to be very useful in discussing and addressing issues.
- **Clearly define roles, responsibilities, plans, and processes.** Detailed partnership agreements, SOW documents, and systems engineering plans are very important to define roles, responsibilities, and provide detailed descriptions of functional specifications, deliverable dates, and system test requirements.
- **Document calls, meetings, and discussions when they involve making important decisions.** As the GYRTWIS development effort progressed, details on design decisions (such as what was decided and by whom) became difficult to recall until the team began keeping records of important calls and discussions. The records were distributed and kept so they could be later referenced, if needed.
- **Planning documents are important for providing guidance and information to upper-level management and any staff that might be threatened by the new technology.** Having a Montana DOT Strategic Business Plan and a regional ITS architecture provided a framework for others to understand how GYRTWIS fit into the current MDT environment.

- **Identify and utilize experts to help solve complicated issues.** When confronted with the task of meeting and negotiating agreements between MDT and the region's telephone companies, MDT was able to identify and enlist the help of a telecommunications expert within the State of Montana Department of Administration to work with the telephone companies and negotiate an agreement for the 511 service.
- **Leasing, not buying, equipment and services can be an attractive alternative to avoid operations and maintenance costs.** MDT decided to lease the equipment to avoid operating and maintaining the telephone system, and if necessary, MDT has the ability to lease additional phone lines when needed.
- **Test the new 511 system and any upgrades on any system platform identical to the one being used in the field.** System testing on an identical system platform will reduce the risk of technical problems when attempting to deploy in the field.
- **The 511 Guidelines and ITS Architecture Standards are useful for guidance, but also seek other sources of information for guidance.** The GYRTWIS team found meetings and conferences provided opportunities to learn from others and discuss issues.

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APPENDIX

Pre- and Post-Montana Travel Information Surveys

(Provided under Separate Cover)

Final

APPENDIX
for
Final Evaluation Report for the Greater Yellowstone Regional Traveler and Weather Information System (GYRTWIS)

Contract Number: DTFH61-96-C-00098

Task 9826

Prepared for:
U.S. Department of Transportation
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FHWA

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SAIC
An Employee-Owned Company

Montana Travel Information Survey

1. **HOW OFTEN do you travel on U.S. or Interstate highways in Montana? (Fill in only one blank)**

_____ times per day
_____ times per week
_____ times per month
_____ times per year

2. **When traveling in Montana, WHAT RESOURCES do you NORMALLY use to determine road conditions or to hear a weather forecast report? (Check all that apply)**

- ❑ Television
- ❑ Radio (FM/AM)
- ❑ Telephone
- ❑ Cell Phone
- ❑ *ROAD (*7623)
- ❑ 800-226-ROAD (7623)
- ❑ Local Montana Department of Transportation Phone Numbers (*see question 3 c through n*)
- ❑ www.mdt.state.mt.us/travinfo
- ❑ Internet
- ❑ Highway Advisory Radio
- ❑ Observations of Existing Conditions
- ❑ Notices at Truck Stops, Convenience Stores, Rest Areas
- ❑ Communication with Other Drivers
- ❑ Other (*please specify)* ___________________________.

3. **HOW OFTEN do you use the following services to determine road and/or weather conditions? (Check only one response for each item)**

Service	Location	Always		Sometimes		Never	Didn't know about it
a) *ROAD (**7623*)	Montana	☐	☐	☐	☐	☐	☐
b) 800-226-ROAD (7623)	Montana	☐	☐	☐	☐	☐	☐
c) 657-0209	Billings	☐	☐	☐	☐	☐	☐
d) 586-1313	Bozeman	☐	☐	☐	☐	☐	☐
e) 494-9646	Butte	☐	☐	☐	☐	☐	☐
f) 377-2314	Glendive	☐	☐	☐	☐	☐	☐
g) 453-1605	Great Falls	☐	☐	☐	☐	☐	☐
h) 265-1416	Havre	☐	☐	☐	☐	☐	☐
i) 444-9424	Helena	☐	☐	☐	☐	☐	☐
j) 751-2037	Kalispell	☐	☐	☐	☐	☐	☐
k) 538-1358	Lewistown	☐	☐	☐	☐	☐	☐
l) 233-3638	Miles City	☐	☐	☐	☐	☐	☐
m) 728-8553	Missoula	☐	☐	☐	☐	☐	☐
n) 653-1692	Wolf Point	☐	☐	☐	☐	☐	☐

If you have *NOT* used the services in Question 3 in the past 12 months, please skip to *Question 12* on the back.

OTHERWISE

Answer Questions 4-11 *based on the service most frequently used*, as indicated in Question 3.

4. **Do you TYPICALLY use this service to access road conditions or hear a weather forecast report…**

- ❑ Before you start a trip?
- ❑ While on the road?
- ❑ Both

5. **When trying to access this service, HOW AVAILABLE is it? (Check only one)**

Very Available		Neutral		Very Unavailable	Don't Recall
☐	☐	☐	☐	☐	☐

6. **HOW EASY to understand are the road condition reports and weather forecasts provided by this service? (Check only one)**

Very Easy		Neutral		Very Difficult	Don't Recall
☐	☐	☐	☐	☐	☐

Please continue on other side ►

7. HOW ACCURATE are this service's road condition reports and weather forecasts? (Check only one)

Very Accurate		Neutral		Very Inaccurate	Don't Recall
☐	☐	☐	☐	☐	☐

8. HOW LIKELY is this service's road condition reports and weather forecasts to affect your travel plans? *(Check only one)*

Very Likely		Neutral		Very Unlikely
☐	☐	☐	☐	☐

9. Overall, HOW USEFUL is this service's road condition reports and weather forecasts? *(Check only one)*

Very Useful		Neutral		Very Useless
☐	☐	☐	☐	☐

10. Which of the road condition and weather forecast phone numbers do you prefer?

- ❑ Statewide Number [i.e. *ROAD (*7623) or 800-226-ROAD (7623)]
- ❑ Local Montana Department of Transportation Phone Numbers (*see question 3 c through n*)

11. Why do you prefer the phone number in Question 10? *(Check all that apply)*

- ❑ Contains statewide information
- ❑ Contains more localized information
- ❑ Shorter message
- ❑ More accurate information
- ❑ Easier to use
- ❑ Know the phone number
- ❑ Other________________________________

____

The following information is needed to ensure that your responses are properly represented in this survey. It will be used for the purposes of this survey ONLY. *(Check only one response per question)*

12. What is your current state of residence?

- ❑ Montana
- ❑ Other__________________________.

13. What is your gender?

- ❑ Male
- ❑ Female

14. What is your age?

- ❑ 15– 24 years
- ❑ 25 – 44
- ❑ 45 – 64
- ❑ 65 or older

15. What is the PRIMARY PURPOSE for the majority of your vehicle travel on highways in Montana?

- ❑ Work
- ❑ School
- ❑ Shopping
- ❑ Medical
- ❑ Recreation
- ❑ Visit family or friends
- ❑ Vacation
- ❑ Other____________________.

16. What is the AVERAGE number of miles traveled for the trip purpose in Question 15?

- ❑ 0 – 24
- ❑ 25-49
- ❑ 50 – 99
- ❑ 100 – 300
- ❑ 300+

17. Do you have a cellular phone in your household?

- ❑ Yes ____________________*Service Provider*
- ❑ No

18. What is your approximate annual household income?

- ❑ Under $20,000
- ❑ $20,000 - $39,999
- ❑ $40,000 - $79,999
- ❑ $80,000 or more

19. What TYPE of vehicle do you PRIMARILY drive on highways in Montana?

- ❑ Automobile
- ❑ Commercial (Truck, bus)
- ❑ Other_______________________

General comments/suggestions: ____

____

____

THANK YOU FOR YOUR PARTICIPATION!

When finished, please return the completed survey in the postage paid envelope along with the yellow card to be entered in the drawing for $50 by June 14, 2002.

Montana Travel Information Survey

The purpose of this survey is to identify travel information needs in Montana and to get your opinion on the accuracy and usefulness of the new Montana 511 Travel Information phone number.

This anonymous survey is sponsored by Montana Department of Transportation and the US Department of Transportation and is being administered by the Western Transportation Institute, Montana State University – Bozeman

1. HOW OFTEN do you travel on highways in Montana (U.S. routes, Interstates, or state routes)?

_____ times per week

2. When traveling in Montana, WHAT RESOURCES do you NORMALLY use to determine road conditions or to hear a weather forecast report? ***(Check all that apply)***

- ❑ Television
- ❑ Radio (AM/FM)
- ❑ Telephone
- ❑ 511 travel information phone number
- ❑ 800-226-ROAD (7623)
- ❑ Local Montana Department of Transportation road conditions phone numbers
- ❑ www.mdt.state.mt.us/travinfo
- ❑ Other Internet sites
- ❑ Highway advisory radio
- ❑ Observations of existing conditions
- ❑ Notices at truck stops, convenience stores, rest areas
- ❑ Communication with other drivers
- ❑ Other (*please specify*) ______________________

3. If you were to call a travel information phone number, how important are the following features? ***(Check only one response for each item)***

	Very Important		Neutral		Very Unimportant
a) Winter road conditions on highways	❑	❑	❑	❑	❑
b) Construction information on highways	❑	❑	❑	❑	❑
c) Weather forecast	❑	❑	❑	❑	❑
d) Accident information	❑	❑	❑	❑	❑
e) Public transit information	❑	❑	❑	❑	❑
f) Information about conditions on city roads	❑	❑	❑	❑	❑
g) Access to information in neighboring states	❑	❑	❑	❑	❑
h) Regional road condition and construction reports	❑	❑	❑	❑	❑
i) Hands-free voice activation	❑	❑	❑	❑	❑
j) Opportunity to record comments and give feedback	❑	❑	❑	❑	❑

4. What other features would you like to see on a travel information phone system?

____

5. If it were necessary for you to identify your location to access travel information, which method would you prefer? ***(Check only one)***

- ❑ By highway number and mile marker
- ❑ By highway number and names of communities you are between (for example, I-90 between Bozeman and Butte)
- ❑ By region (for example, Southwest Montana, Northeast Montana, etc.)
- ❑ By community (for example, near Billings, near Helena, etc.)
- ❑ By origin and destination (for example, from Kalispell to Bozeman)
- ❑ Other ______________________

6. How have you been made aware of the 511 travel information phone number? ***(Check all that apply)***

- ❑ Radio
- ❑ Television
- ❑ Public service announcements/advertisements
- ❑ Newspaper articles
- ❑ Department of Transportation
- ❑ Family/Friends
- ❑ Internet
- ❑ Blue highway information signs
- ❑ Billboard
- ❑ Phone/cell phone provider
- ❑ Promotional flyers
- ❑ Transportation booths at fairs
- ❑ Other_____________
- ❑ I was not aware of 511 before this survey

7. In your opinion, have you received enough information about the 511 travel information phone number?

- ❑ Yes
- ❑ No

8. How often have you used 511 since January 2003? ***(Check only one)***

- ❑ Have not used 511
- ❑ 1-3 times
- ❑ 4 -6 times
- ❑ 7 - 10 times
- ❑ More than 10 times

Please continue on other side ►

If you HAVE NOT USED the 511 travel information phone number, please skip to Question 14.

9. When do you USUALLY access 511? *(Check only one)*

- ❑ Before I start a trip
- ❑ During a trip
- ❑ Both before and during a trip

10. If you were to compare the previous travel information phone numbers (800-226-ROAD, *ROAD, or local Montana Department of Transportation phone number) to 511, which do you prefer? (Check only one)

- ❑ 511
- ❑ Previous MDT system report
- ❑ No preference
- ❑ I have not used the previous system
- ❑ Comments:____

11. When you hear of poor travel conditions on 511, how likely are you to…
(Check only one response for each item)

	Very Likely		Neutral		Very Unlikely
a) stop at a nearby town?	❑	❑	❑	❑	❑
b) change travel times?	❑	❑	❑	❑	❑
c) take an alternate route?	❑	❑	❑	❑	❑
d) cancel the trip?	❑	❑	❑	❑	❑
e) continue on regardless?	❑	❑	❑	❑	❑
f) seek an alternate mode of travel?	❑	❑	❑	❑	❑

12. How satisfied are you with the following 511 capabilities? *(Check only one response for each item)*

	Very Satisfied		Neutral		Very Unsatisfied
a) The quality of the service	❑	❑	❑	❑	❑
b) The usefulness of the service	❑	❑	❑	❑	❑
c) The accuracy of the reported road conditions	❑	❑	❑	❑	❑
d) The accuracy of the weather forecast	❑	❑	❑	❑	❑
e) The ease of accessing the information you want	❑	❑	❑	❑	❑
f) The ease of understanding the information	❑	❑	❑	❑	❑
g) The availability of the system (system is working/no busy signals)	❑	❑	❑	❑	❑

13. Overall, how would you rate the Montana 511 travel information system?

Excellent		Average		Poor
❑	❑	❑	❑	❑

The following information is needed to ensure that your responses are properly represented in this survey.
It will be used for the purposes of this survey ONLY. ***(Check only one response per question)***

14. What is your home zip code?________________

15. What is your gender?

- ❑ **Male**
- ❑ **Female**

16. What is your age?

- ❑ **18 – 24 years**
- ❑ **25 – 44**
- ❑ **45 – 64**
- ❑ **65 or older**

17. Do you own a mobile phone?

- ❑ **Yes**
- ❑ **No**

18. What is the PRIMARY PURPOSE for the majority of your vehicle travel on highways in Montana?
(Check only one)

- ❑ Personal trips (excluding tourism)
- ❑ Business trips
- ❑ Tourism
- ❑ Long-distance commercial vehicle operator
- ❑ Local fleet operator (school bus, parcel delivery, etc.).
- ❑ Other ____________________

19. What is the highest level of education you have completed?

- ❑ Did not finish high school
- ❑ High school graduate or equivalent
- ❑ 2-year college (community/technical)
- ❑ 4-year college/university
- ❑ Post-graduate college/university

20. General comments/suggestions:

____

THANK YOU FOR YOUR PARTICIPATION!

When finished, please return the completed survey in the postage paid envelope along with the yellow card to be entered in the drawing for $50 by April 25, 2003.