Greater Yellowstone Rural ITS Project

Work Order I-13 Phase I Evaluation and Final Report

Prepared for

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and

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In Cooperation with

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and

U.S. DEPARTMENT OF INTERIOR, YELLOWSTONE NATIONAL PARK

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Implementation Statement

This study is sponsored by the Montana Department of Transportation in cooperation with the U.S. Department of Transportation, Federal Highway Administration, the Wyoming Department of Transportation, the Idaho Transportation Department, and the Yellowstone National Park. The major objective of this document is to summarize Phase I of the Greater Yellowstone Rural Intelligent Transportation Systems (GYRITS) Project.

Disclaimer

The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the Montana Department of Transportation the U.S. Department of Transportation, Federal Highway Administration, the Wyoming Department of Transportation, the Idaho Transportation Department, or the Yellowstone National Park.

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Table of Contents

List of Figures

List of Tables

Introduction/Background

This report summarizes the efforts of Phase I of the Greater Yellowstone Rural ITS Project (GYRITS Project). The evaluation of the AVI system will be finalized in *Work Order II-2D Automated Vehicle Identification (AVI) at Yellowstone National Park Entrance Stations*. However, this report summarizes the initial installations at the North and Northeast Entrances and the evaluation data and analysis conducted to date. The purpose of this work order is to summarize previous efforts and Work Orders in Phase I, provide evaluation results and discuss project continuance.

Report Organization

- The *Introduction* provides some background information on the entire project and this document, in particular.
- The *Summary of Phase I Efforts* gives an overview of the tasks and products of the Phase I project.
- *Evaluation of AVI System* describes the evaluation efforts to date including a system description, data collection and analysis.
- *The Summary and Project Continuance* contain a brief summary of this report and discuss the future of the GYRITS Project.

Description of the GYRITS Corridor

The Greater Yellowstone Rural ITS Project (GYRITS Project) was initiated to move rural ITS forward by demonstrating and evaluating ITS in a rural environment. GYRITS began in January 1997 with a Congressional Earmark to fund (1) the development of a Regional ITS Strategic Deployment Plan, (2) the implementation of "early winner" projects, and (3) the development of supporting documentation. In February 2000 a strategic plan was completed that included stakeholder input, GYRITS organizational structure, regional architecture, legacy systems, and candidate projects. The AVI system is one of the candidate projects selected for implementation.

The Greater Yellowstone Rural Intelligent Transportation System Priority Corridor is a 200-mile long, 100-mile wide, heavily utilized rural transportation corridor between Bozeman, Montana and Idaho Falls, Idaho (Figure 1). This corridor includes:

- Three states: Montana, Idaho and Wyoming;
- Two national parks: Yellowstone (YNP) and Grand Teton (GTNP); and
- A variety of transportation facilities ranging from Interstate freeway to low-volume, two-lane rural highways.

Primary transportation facilities include:

- Interstate 90/15 from Bozeman, Montana to Idaho Falls, Idaho through Butte, Montana;
- U.S. Highway 191/20 from Bozeman, Montana to Idaho Falls, Idaho; and
- U.S. Highway 89/26 from Livingston, Montana through Jackson, Wyoming to Idaho Falls, Idaho.

Additionally, highways added to the corridor at the March 1998 Steering Committee meeting include:

- Highway 212 from Red Lodge, Montana, through Cooke City, Montana and into Yellowstone National Park;
- Highway 14 from Cody, Wyoming, through the east entrance of Yellowstone National Park and into the Park interior; and Highway 31 from Swan Valley Idaho, over Teton Pass to Jackson, Wyoming.

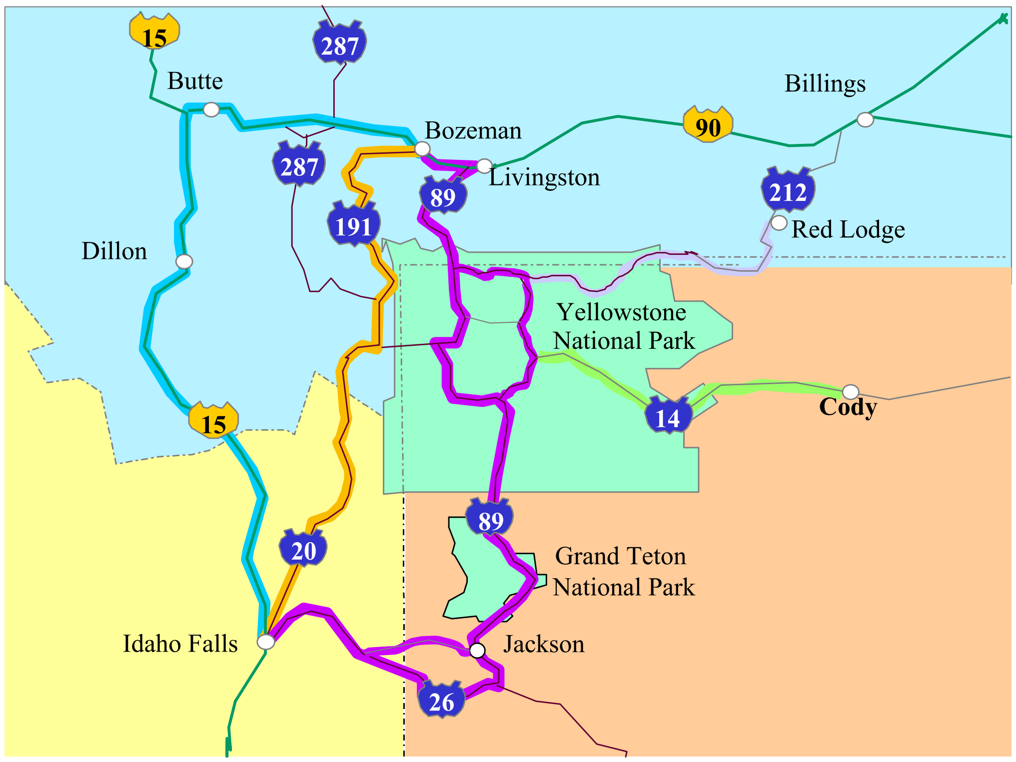

Figure 1: Study Area

These routes represent vital transportation links for the economy and well-being of the three-state area of Montana, Wyoming and Idaho. They also serve the recreational and resource needs of a growing number of individuals seeking to utilize the Greater Yellowstone ecosystem and Grand Teton National Park. The national importance of the corridor is further emphasized by its function as the connector for the trucking industry between the upper Midwest markets along Interstate 90 and the Intermountain and Southwest markets accessible by Interstate 15.

Summary of Phase I Efforts

The major results of Phase I included the development of a GYRITS Strategic Plan, the deployment of the AVI System, and the instigation of several ITS projects in the GYRITS Corridor. Although the Strategic Plan and this report summarize Phase I results, more detail can be found in the Technical Memoranda described below.

- ***GYRITS Task 2 Report: Regional Stakeholder Partnership Business Plan Working Paper***, March 1998, provides a guiding organizational structure for the project and identifies potential stakeholders.
- ***GYRITS Task 3 Report: ITS Related Inventory: Regional Needs Assessment***, March 1998, summarizes the legacy ITS systems and regional challenges. This data was collected from a number of sources including extensive stakeholder outreach, crash data analysis, interviews, and census data.
- ***GYRITS Task 4 Report: Rural Traveler Needs Survey***, September 1997, provides a summary (Volume I) and detailed data (Volume II) for the 481 motorists surveyed. These surveys queried motorists regarding transportation challenges, the use of traveler information, and of ITS applications.
- ***GYRITS Task 4 Report: Professional and Stakeholder Opinion Assessment of Rural Traveler Needs and ITS Applications,*** September 1997, summarizes responses from 94 transportation professionals to the motorist survey mentioned above. In general the purpose was to assess the differences in responses between general travelers and professionals in the field of transportation.
- ***GYRITS Task 5 Report: ITS Vision Working Paper,*** January 1998, provides a vision developed by the GYRITS Steering Committee. This report includes goals, objectives and a graphical vision.
- ***GYRITS Tasks 6, 7, and 8 Report: Regional Architecture Development,*** July 1998, provides a Regional ITS Architecture for the GYRITS Corridor. The National ITS Architecture was "ruralized" by adding new market packages that did not previously exist. Many of these "ruralizations" have since been incorporated into the National ITS Architecture.
- Several project ranking and construction documents have also been developed from Tasks 9 and 10 including ***Preliminary Project Identification and Evaluation*** (Appendix to Strategic Plan), and ***AVI Functional Requirements*** (included in Yellowstone National Park Bid Package). These were not formally submitted to MDT and FHWA as their primary purpose was to facilitate the deployment of ITS projects in the GYRITS Corridor.
- ***GYRITS Task 11 Report: Define Regional Architecture,*** June 1999, further refined the architecture including a regional architecture database developed on a Microsoft Access Platform. This report also details the data flows, potential expansions, and possible applicable standards that apply to the early deployment projects identified in Task 9.

- ***GYRITS Task 12 Report: Strategic Plan,*** February 2000, describes how the plan was developed, the organizational structure and vision of the GYRITS Project, the regional architecture, financial considerations, existing legacy projects, and prioritized candidate ITS projects.

Copies of these reports can be requested from WTI. Although they contain a great detail regarding the GYRITS Project, they are only summarized here in the interest of brevity. The largest obstacles to ITS are generally institutional and jurisdictional issues. Although not a physical deliverable, possibly the greatest accomplishment of Phase I was the education, interaction, and involvement of a wide array of transportation agencies and individuals.

Evaluation of AVI System

This section provides an overview of evaluation efforts to date. The final evaluation results will be documented in *Work Order II-2D Automated Vehicle Identification (AVI) at Yellowstone National Park Entrance Stations.*

Entrance Station Operating Procedures

In order to effectively describe the AVI deployments in Yellowstone, one must first understand the existing entrance gates prior to AVI installation. Three (north, northeast, and tentatively west) of the five YNP entrances were included in the AVI System work. The south and east entrances were not included. The topics covered include a description of the entrance station procedures prior to the AVI deployments and a detailed description of each entrance station.

Each entrance station is unique in regards to physical configuration. However, the purpose and operating procedures remain the same across all gates. The purpose of all entrance stations is to sell passes, check pass holders before re-entry, and provide up-to-date park information. Visitors entering the park receive a newspaper containing information regarding safety, facility availability, and park regulations. It is imperative from a safety and liability standpoint that all YNP patrons receive the safety information contained in the newspaper.

The opening and closing dates for each entrance facility differ based upon location. The schedule of operations for the North, Northeast, and West Entrance stations is shown below in Table 1.

Table 1: Schedule of Operations

Entrance Station	Opening Date	Closing Date
North	*Open Year Round*	
Northeast	*Open Year Round*	
West (Summer Schedule)	Aprox. April 19	Aprox. Nov 4

Additionally, each entrance station is staffed from approximately 6 AM to 12 AM daily during the summer with hours adjusted accordingly by season.

YNP provides patrons with multiple options for pass purchase upon entering the park. Additionally, special entry permits are provided for employees and other forms of residential, commercial, and business traffic. A description of all passes and their respective prices is provided below in Table 2.

Table 2: Existing Passes and Fee Structure

Pass Type	Cost	Description	Duration
Private Non-Commercial	$20.00	Receipt	7 day
Individual Motorcycle/ Snowmobile	$15.00	Receipt	7 day
Single Entity (foot, bike, etc.)	$10.00	Receipt	7 day
Annual Area Permit for YNP and Grand Teton NP	$40.00	Card	1 year from purchase date
Golden Eagle Pass (all parks)	$50.00	Card	1 year from purchase date
Golden Age Passport (all parks, U.S. citizens over 62)	$10.00	Card	Lifetime
Golden Access (all parks, disabled individuals)	Free	Card	Lifetime
Permanent Employees	N/A	Sticker	Variable
Seasonal Employees	N/A	Sticker	Variable
Residents	N/A	Sticker	Variable
Contractors	N/A	Red or White card	Variable
Park Vendors	N/A	Black text on blue card	Variable
Commercial Vendors	N/A	Sheet	Variable

North Entrance Station (Gardiner)

Traffic entering the park through the North Entrance approaches on the southbound lane of U.S. Highway 89/26 out of Livingston, Montana. Additionally, a separate vendor road merges into the northbound lane approximately 100 ft North of the entrance gate. Once within 75 ft. of the gate, the southbound lane splits into two lanes, with the right lane signed for employees and the left for visitors. Traffic exits the park using a single lane. The entrance station itself is a modern log building positioned such that both entrance lanes pass the window on one side and the exit lane on the other.

The procedures followed for gate operations are relatively simple; yet, high traffic volumes during peak months require the use of alternate procedures for mitigating congestion. Therefore, two sets of procedures are followed according to the level of traffic volume.

When the queue is short (traffic in the left lane does not extend past the junction between the vendor road and U.S. 89/26), the left entrance lane (hereon referred to as Lane 1) is allocated for all visitors. Traffic in Lane 1 proceeds to the service window and either purchases a pass or shows a prepaid pass/receipt for verification. Park employees, vendors, commercial traffic, contractors, government vehicles, and Cooke City residents with an entrance sticker or valid pass proceed to the right lane (hereon referred to as Lane 2). Once at the gate the driver must wait for the gate attendant's approval, usually denoted by a wave of the hand before entering the park.

In the event that traffic in the left lane extends past the junction between U.S. 89/26 and the vendor road for a prolonged period, a ranger goes out to the congested junction and directs traffic such that visitors with a prepaid pass may also use Lane 2. The objective of this strategy is to better utilize the capacity of the outer lane and reduce the overall queue length. In this case the traffic volume of the outer lane increases, but the queue length does not grow substantially. From multiple days of observation, it was determined that without this ranger intervention, the queue length may extend one-third of the distance to Roosevelt Arch.

Northeast Entrance Station (Cooke City)

Traffic entering the park through the Northeast Entrance approaches on the westbound lane of U.S. Highway 212 out of Red Lodge, Montana. Both the westbound (entrance side) and eastbound (exit side) lanes divide into two lanes approximately 100 ft. in advance of the entrance gate. The Northeast Entrance is a National Historic Landmark log structure with a low overhang that encloses the inner lane on both the entrance and exit sides. Due to the nature of this structure, the inside lane cannot accommodate larger vehicles such as recreational vehicles or large trucks. As such, large vehicles are directed to the outside lane. A picture of the Northeast gate showing the lane configuration and historic structure is provided below in Figure 2.

Figure 2: Northeast Entrance and lane configuration

The physical setup of the gate is such that lane allocation similar to the North Entrance is not possible. Vehicles approach the gate and divide into the appropriate lane according to size. If the vehicle has a valid pass the gate attendant waves the vehicle through with little delay. If the vehicle does not have a park-furnished sticker or prepaid pass, the driver must stop and buy a pass before proceeding. Drivers of large vehicles in the outer lane who need to purchase a pass must park and approach the window on foot. Figure 3 shows the lane signing for low and high clearance vehicles.

Figure 3: Lane signing for clearances

West Entrance Station

Although the initial AVI deployment is only located at the North and Northeast Entrances, there are tentative plans to expand to the West Entrance. As such this report contains some information on the West Entrance as well.

Traffic entering the park through the West Entrance approaches in the eastbound lane of U.S. Highway 20 out of West Yellowstone, Montana. The West Entrance is equipped with four entrance lanes due to the high traffic volume. There are three permanent gate booths available to service entering traffic. At least one of the three permanent lanes is open all day, with others opening as volumes increase. The right-most lane, *(facing east)*, is reserved as an express lane, and is opened by a ranger when the volumes are highest. A picture of the west gate lane configuration is provided below in Figure 4.

Figure 4: Side View of West Entrance Lane Configuration

System Description

The AVI system installed in Yellowstone National Park is a modification of the automatic toll collection systems seen in many urban areas. This section will provide a detailed description of the setup and configuration of the AVI installations at the North and Northeast Entrance gates.

The systems include vehicle tags, entrance equipment, and a main server. Each of which are described in detail below. The systems were designed and implemented by Kanawha Scales and Systems Inc. of Charleston, WV.

Vehicle Tags

The vehicle tags are the Amtech AT5102 models as shown in Figure 5. They are attached to the rearview mirror using Velcro adhesive strips to allow for removal and verification at gates without operational AVI. For cars and pickup trucks, tags are installed on the center of the windshield behind the rearview mirror. For busses and large trucks, tags are attached to the lower middle portion of the windshield. 2000 tags were provided with the initial system. Approximate dates and numbers of tag distribution are shown in Table 3.

Table 3: Distribution of Tags

Date	# Of Tags	User Type
July 2002	120	Permanent Employees

Figure 5: Vehicle Tag

Entrance Equipment

This section briefly describes the physical equipment and hardware used by the AVI system. Only the right lane at the North Entrance is AVI equipped. The AVI components at the North Entrance include two vehicle detector loops, an AVI antenna, a red/green traffic signal, battery backup system, a Pentium computer, and a push button to manually control the signal. The Northeast Entrance has two lanes equipped for AVI and has in addition two vehicle detector loops, an AVI antenna, and a red/green traffic signal. The general lane configuration of the AVI system at the North and Northeast Entrance stations is shown below in Figure 6.

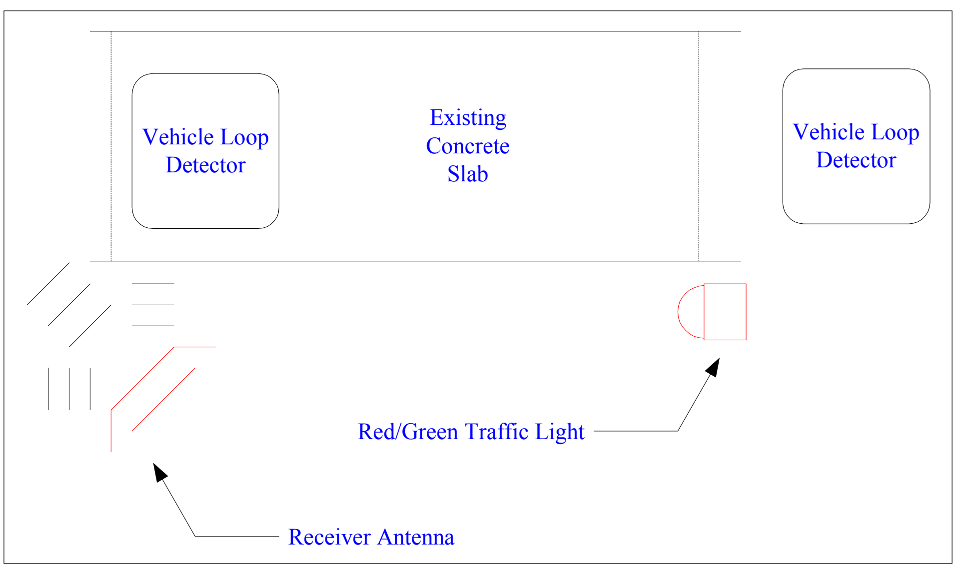

Figure 6: AVI Lane Configuration

The general equipment layout for both the North and Northeast Entrance gates is provided in Figure 7 below.

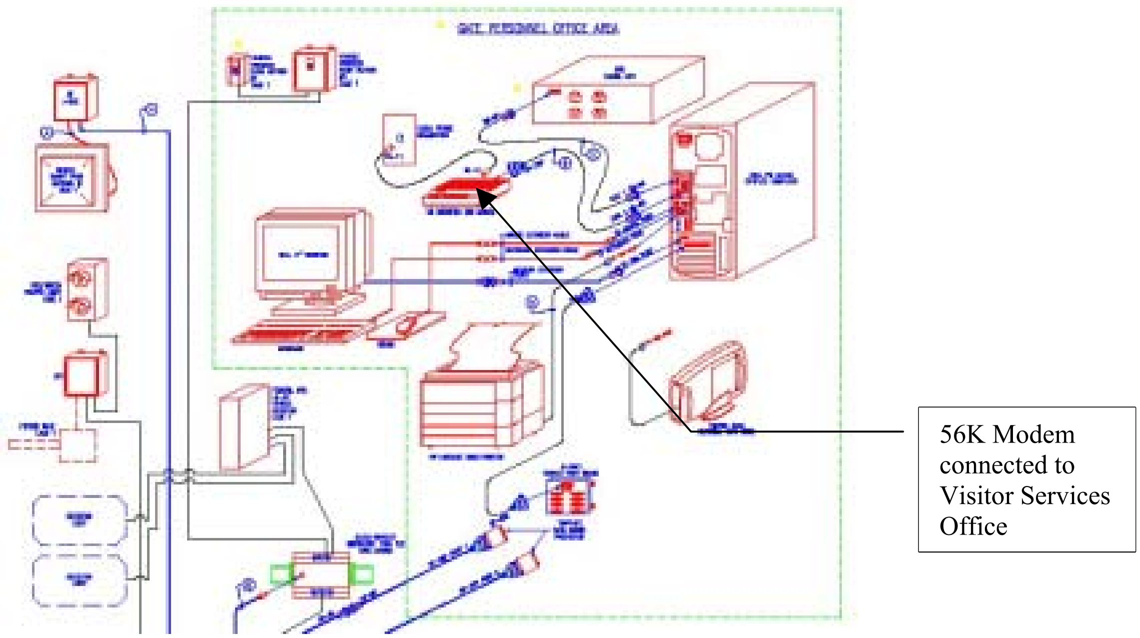

Figure 7: General equipment layout

The AVI antenna and detector loops will determine if a vehicle is (1) a vehicle with a valid tag, (2) a vehicle with no tag or an invalid tag, and (3) a vehicle that drives through the system without permission. The process for each of the three vehicle types is described below:

Valid Tag

1. The vehicle passes the AVI antenna with a valid tag.
2. The computer processes the tag information.
3. The computer verifies and logs a valid tag.
4. When the vehicle crosses the first loop, the signal will turn to green.
5. When the vehicle crosses the second loop, the signal will turn back to red.

No/Invalid Tag

1. The vehicle crosses the AVI antenna and first loop.
2. The signal will remain red.
3. A sound will alert the attendant that someone requires attention in the AVI lane.
4. After the attendant has attended to the vehicle, he/she will use the push button control to change the signal to green.
5. The computer logs a “no tag” vehicle entering.
6. When the vehicle crosses the second loop, the signal will turn back to red.

Violator

1. The vehicle crosses the AVI antenna and first loop.
2. The signal will remain red.
3. A sound will alert the attendant that someone requires attention in the AVI lane.
4. The vehicle does not stop at the red light.
5. When the vehicle crosses the second loop, a different sound will alert the attendant of the violation.
6. The computer will signal the Reliable Security camera system to record the violating vehicle.
7. The computer logs a violator.

If there are malfunctions, the attendant can reset the system by pressing and holding the manual signal control button for 10 seconds. The attendant can also use the computer to change from "active" mode described above to "inactive solid green" or "inactive flashing green." In inactive mode the system ignores traffic and the signal is either continuously green or flashing green (indicating proceed slowly).

In order to meld with the historic and natural setting of the YNP entrances, the antenna and signal, Figure 8, are brown. Also, the system was configured for the addition of a gate arm should YNP determine the need for one as part of the AVI system.

Figure 8: Antenna and Traffic Signal at North Entrance

At the North Entrance the right entrance lane, previously designated "employees only" is now "employee and AVI user only." Because of the unique layout at the Northeast Entrance, both entrance lanes are equipped with AVI. Therefore, an AVI user can either use the left (regular) or right (oversized vehicles) lane.

Main Server, Communications and Software

As shown previously in Figure 7, each entrance station computer is connected via modem to the main server located at YNP Headquarters at Mammoth. The main server coordinates with the entrance station computers to update changes to the user database, and store data logged by the AVI computer. The software allows YNP personnel to enter, edit, or delete user accounts. The main server is designed for easy expansion of all five entrances.

Deployment Costs

Kanawha Scales was paid $289,920 to provide the equipment, installation and training for the AVI system. Other related costs include:

- YNP staff time to oversee contract and installation
- YNP staff time to receive training on the system
- Use of existing modem equipment
- Use of existing surveillance system

Challenges and Issues

Some of the challenges encountered are listed below. Most have plans for resolution in progress.

- Because of the historic nature of the buildings, there were limitations to the design of the AVI system. The antennae and signal heads were brown and made to look inconspicuous. There may be challenges in that users will not see the signal head clearly.

- Initially the notification sounds were loud and annoying to the entrance attendants. The sounds are currently being changed to softer sounds.

- AVI equipment takes up some of the limited storage space at the Northeast Entrance.

- As with any system of this type, there were initial bugs and the system is not currently working perfectly.

Data Collection Methodology

This section of the report will detail the methodology employed in gathering preliminary data. Data collected includes traffic volumes, interviews with entrance station staff, and delay times. Results of this data are detailed in the Analysis and Results Section.

The gates studied as part of this evaluation were North, Northeast, and West. The West Entrance gate was included in this study because of the possibility for future system expansion.

Historical Visitation Data (Traffic Volumes)

Visitation patterns and growth trend data were required in order to establish appropriate data collection time frames. For the purpose of this study it was determined that collection time frames must coincide with peak volume periods. Therefore, historical visitation data was required as a benchmark. The following sections describe the sources of the historical data, how the values were manipulated, and the conclusions drawn from this portion of the study.

The Visitor Services Office (VSO) of Yellowstone National Parks keeps statistics on the number and type of visitors entering the park. These statistics are recorded at the entrance gates using the gate's cash registers. When collecting that data, visitors are classified into six categories. The six classifications are shown in Table 4 below.

Table 4: Visitor Classifications Established by VSO

Category Number	Category Label	Category Name	Types of Vehicles/Visitors
1	AUTO/CYCLE	Auto/Cycle	All private vehicles not listed below
2	BIKE/SKI	Bike/Ski	Bicycles and Skiers
3	BUS	Bus	Busses
4	RV	Recreational Vehicles	Recreational Vehicles
5	NON-REC	Non-Recreational	Cooke City residents, park suppliers
6	NR-TRAFFIC	Non-Reportable	YNP employees, YNP contractors

Daily and monthly totals were collected from 1997-1999 for the North, Northeast, and West Entrance gates. In order to further simplify the evaluation, the categories established by VSO were grouped into three adjusted classifications. The adjusted classification scheme is shown below in Figure 9.

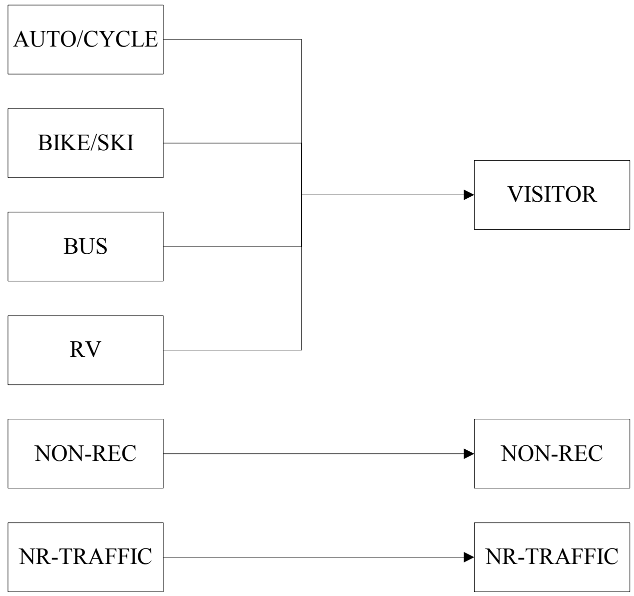

Figure 9: Adjusted classifications

The annual totals for 1997-1999 are provided below in Table 5 for the North, Northeast and West Entrance gates, respectively.

Table 5: Annual totals by entrance gate

Entrance Gate	**1997**	**1998**	**1999**
North	167,753	176,496	185,730
Northeast	78,652	54,886	66,551
West	323,124	394,945	354,382
Total	569,529	626,327	606,663

In accordance with our preliminary objectives, it was required that the data be further analyzed to determine the peak time frame for data collection. To accomplish this task, the data from 1999 was analyzed on a monthly basis for each entrance. Figures 10, 11 and 12 below summarize the aggregate data for the North, Northeast and West Entrances, respectively.

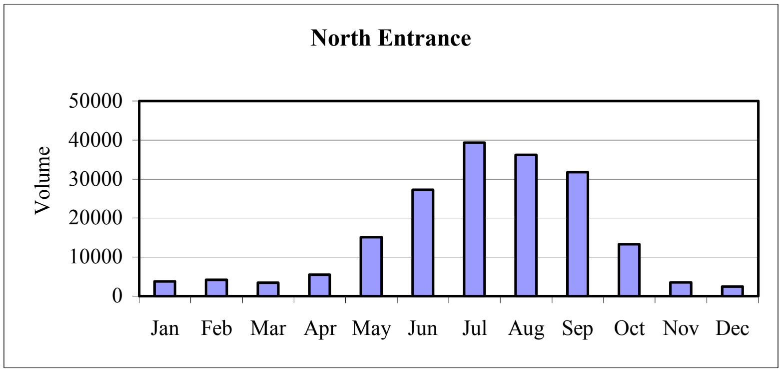

Figure 10: Graph of Monthly Volumes for North Entrance

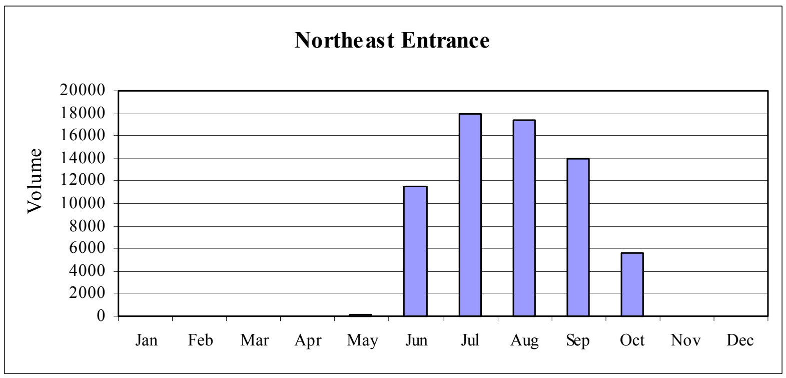

Figure 11: Graph of Monthly Volumes for Northeast Entrance

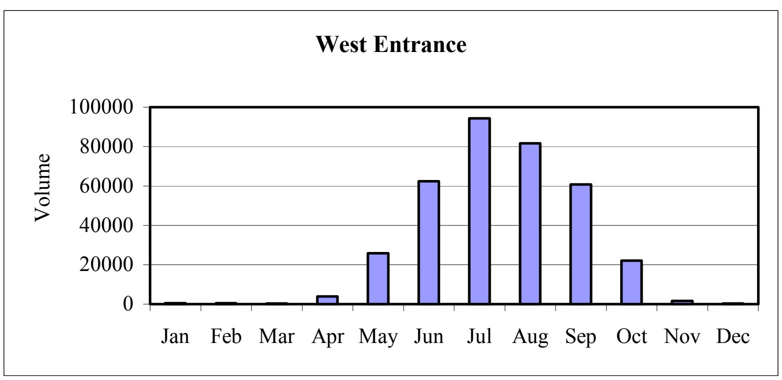

Figure 12: Graph of Monthly Volumes for West Entrance

From the graphs displayed above, one can see that all three of the entrance gates displayed similar visitation patterns throughout the summer of 1999, with peak periods occurring from early July to August. Provided with this information, the evaluation team could select data collection dates within the peak time frame assuming that visitation patterns do not fluctuate drastically from year to year.

Interviews with Entrance Station Staff

In order to prepare an evaluation technique, personnel were interviewed to obtain estimates of the maximum expected delay, typical time frames of the maximum queue and its respective length, and current methods employed to mitigate congestion. The ranger in charge of each gate provided the relevant information.

Ranger Rick McAtum provided pertinent information on the North Entrance gate. From this interview, the following pieces of information were gathered:

1. A queue typically forms beginning at 9 AM and is fairly constant through 1 PM.
2. Employees constitute a large portion of the traffic during this time frame
3. Approximately 5-10% of the gate's traffic uses the outside lane
4. The convergence of an upstream vendor road causes traffic congestion.

Ranger Bundy Phillips provided similar information concerning the Northeast Entrance gate.

1. A queue typically forms from 10 AM through 4 PM.
2. This queue forms late in the morning due to the long travel time on the Beartooth Highway.
3. The maximum probable queue at the northeast lane is approximately 15 vehicles long.

Ranger Julie Hannaford provided similar information concerning the West Entrance to the Park.

1. The longer queues usually are present from 7:30 AM through 1:30 PM. In an effort to combat this problem, the entrance gate was built four lanes wide.
2. A ranger operates the express lane when volumes are highest (approximately 9:00 AM-11:00 AM).
3. By utilizing this four-lane operation, the queue lengths are limited to approximately 20 vehicle maximums.

Please refer to the section heading: *Entrance Station Operating Procedures* for further information.

Delay Times

Using the information provided above, the evaluation team developed a strategy for collecting the following data for each vehicle at all three entrances.

- Arrival Time – time when a vehicle comes to within one vehicle length of the standing queue or the gate entrance
- Process Time – difference between the gate arrival and departure times.
- Pass Type – defined above in Table 4

Using custom-made data collection sheets, the evaluators recorded the time each vehicle entered and left the queue as defined above. The upstream data collectors recorded vehicle make, class, color and time entering queue. The downstream data collectors recorded vehicle make, class, color, entrance sticker type, and time leaving the queue. This technique was employed due to the speed and volume of traffic flowing through the gate. A schedule of the data collection times and dates is provided below in Table 6.

Table 6: Data collection times and dates

Entrance	**North**		**Northeast**		**West**	
Dates	7/31/00	8/1/00	8/15/00	8/16/00	7/27/00	7/28/00
Time of Day	7:30 AM - 3:30 PM	7:30 AM - 2:30 PM	8:00 AM - 4:00 PM	8:00 AM - 2:00 PM	7:15 AM - 4:00 PM	7:15 AM - 2:00 PM

Each vehicle was recorded twice, upon entering and leaving the queue. Therefore, it was necessary to match the two data records in order to calculate each vehicle's delay time. Due to error in identifying and recording vehicle characteristics, a decision logic sequence was developed to match upstream and downstream records. If the vehicle's match was not clear, it was left out of further calculations.

Analysis and Results

Having compiled and sorted the raw data, the evaluation team focused efforts on understanding and analyzing the data. The following sections of this report will address the accuracy of the data, calculation and assessment of flow times, and development of an integrated queuing model for iterative analysis.

Assessment of Data Accuracy

After matching and evaluating the data, it was apparent that a large portion of the data was missing a required field or was inaccurate. The North Entrance was used to provide an estimate of the error in the data, where the error % is calculated as follows:

$$Error\% = \left(\frac{Invalid\ \mathrm{Re}cords}{Valid\ \mathrm{Re}cords}\right)x100$$

The overall estimate of the error was determined to be 20%. Please refer to Table 7 below for the calculations.

Table 7: Estimate of error in data

	July 31, 2000	**August 1, 2000**	**% Error**
Valid Records	1021	1034	2055
Invalid Records	240	179	419
% Error	24%	17%	**20%**

Calculation of Flow Times

Despite a relatively high percent error, it was determined that the preliminary data could be used to provide estimates of the flow time at each entrance. To determine estimates for each entrance, the arrival time was subtracted from the departure time and the overall average was calculated. The calculations described above were performed for all of the valid records from the North and Northeast Entrances.

The North Entrance had an average flow time of 2.59 minutes with a max and min of 14.48 minutes and 0.02 minutes respectively. Table 8 below displays a detailed assessment of the values for both July 31st and August 1st of 2000, and is followed by Figure 13 displaying the distribution of flow times in seconds.

Table 8: North Entrance Flow Times

Flow Time Summary for all Vehicles on July 31 and Aug 1, 2000						
	Avg Flow Time		**Max Flow Time**		**Min Flow Time**	
Date	*seconds*	*minutes*	*seconds*	*minutes*	*seconds*	*minutes*
31-Jul-00	147.38	2.46	869.00	14.48	1.00	0.02
1-Aug-00	164.75	2.75	755.00	12.58	1.00	0.02
Overall Avg Flow Time	155.46	***2.59***	869.00	14.48	1.00	0.02

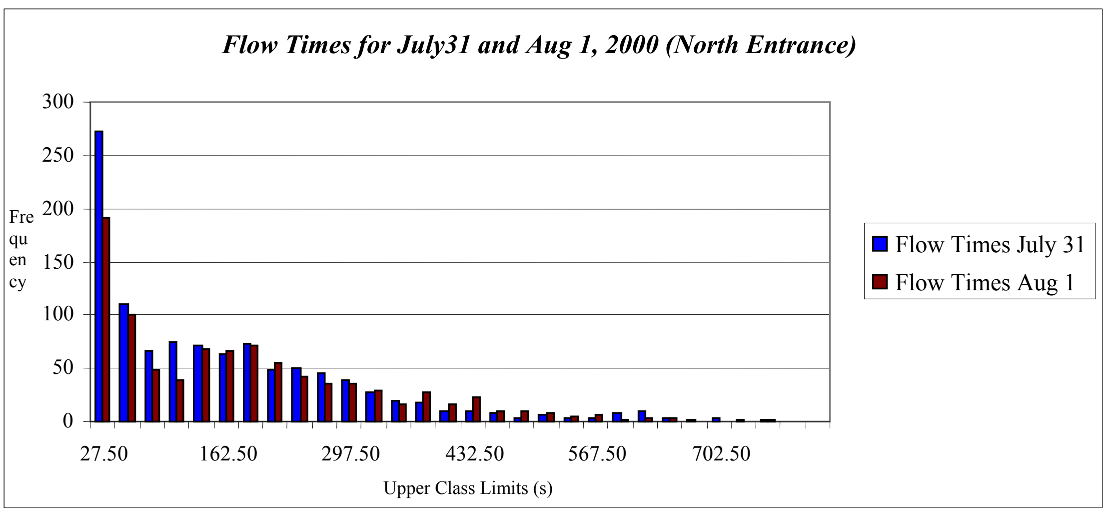

Figure 13: Histogram of flow times at North Entrance

The Northeast Entrance had an average flow time of 1.55 minutes with a max and min of 12.75 minutes and 0.02 minutes respectively. Table 9 displays a detailed assessment of the values for both August 15th and 16th of 2000, and is followed by Figure 14 displaying the distribution of flow times.

Table 9: Northeast Entrance flow times

Flow Time Summary for all Vehicles on Aug 15 and Aug 16, 2000 (Northeast)						
Date	**Avg Flow Time**		**Max Flow Time**		**Min Flow Time**	
	seconds	*minutes*	*seconds*	*minutes*	*seconds*	*minutes*
31-Jul-00	90.45	1.51	396.00	6.60	1.00	0.02
1-Aug-00	97.33	1.62	765.00	12.75	2.00	0.03
Overall Avg Flow Time	93.01	***1.55***	765.00	12.75	1.00	0.02

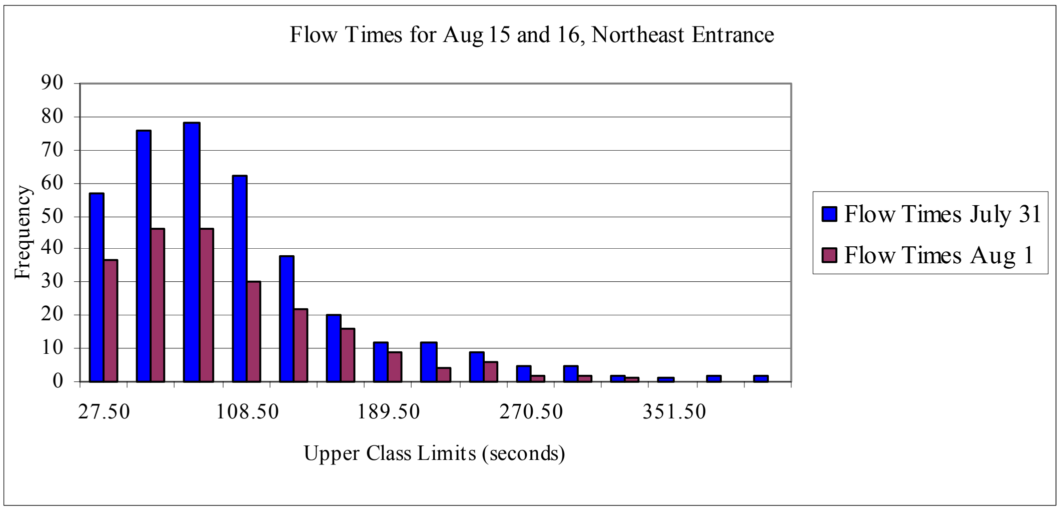

Figure 14: Histogram of flow times at Northeast Entrance

Queuing Model

As a part of the preliminary evaluation, it was determined that an accurate simulation model should be developed to aid in the analysis. The North Entrance was chosen as the preliminary evaluation site because of its traffic volume and focus within the AVI implementation. The goal of the model is to facilitate the following objectives:

- Provide a tool for analyzing "what if" scenarios.
- Assess gate operations over many iterations (days) under varying traffic conditions.
- Analyze pass assignment strategies with and without the AVI system.
- Identify further opportunities for improvement.

Model development was divided into multiple parts to validate assumptions and aid in the design process. The following sections highlight and describe a phase of the modeling process in sufficient detail to facilitate a broad understanding.

Modeling Considerations and Assumptions

The physical setup and operational procedures of the North Entrance had to be understood in order to facilitate model development. To accomplish this task, a process flow chart was developed and is shown in Figure 15.

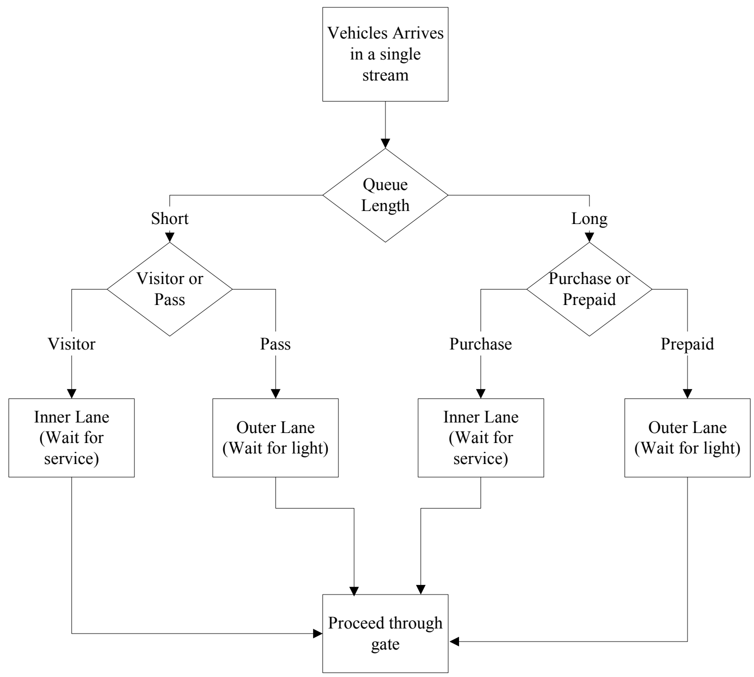

Figure 15: Flow Chart of North Entrance Procedures for Simulation

To facilitate the analysis of multiple scenarios, vehicles entering the gate were further divided into smaller classifications. This was done to facilitate the assignment of parameters to different classifications and enable the analysis of "what if" scenarios. For example, the model could enable the assignment of AVI passes to an individual classification. This classification scheme is based upon park-furnished entrance passes and visitor passes. The different classifications are listed below for reference and will be used throughout the remainder of this discussion.

- Permanent Employees – PEMP
- Seasonal Employees – SEMP
- Cooke City Residents – RES
- Contractors – CONT
- Vendors to the Park – VEND
- Commercial Vendors – VENDCOM
- Government Vehicles – GOV
- Park Visitors – VISITOR
    - Purchasing pass – NP
    - Have park pass – P

A model of a physical system can only approximate reality. To provide a good approximation, the following assumptions were made:

- Lanes 1 and 2 have independent attendants/servers.
- Queue interaction between Lane 1 and Lane 2 only occurs when the queue for Lane 1 is longer than 10.
- The arrivals of vehicles in different classifications follow a random probability distribution of best fit and are independent of one another.
- The service time of vehicles in different classifications follow a random probability distribution of best fit and are independent of one another.
- Service time is independent of queue length.

Distribution Fitting and Model Parameters

To carry out a simulation using random inputs, we have to fit the raw data to probability distributions of best fit. To accomplish this task, the arrival and service times for each classification were fit to their respective distributions. It was assumed that all arrival and service time distributions could be approximated by an exponential distribution for the model based upon the closeness of the mean and standard deviation for each classification.

A discrete probability distribution was used to address the issue of classification assignment to incomplete records (See Analysis and Results – Assessment of data accuracy for discussion of missing records). The discrete probabilities for the distribution were calculated by dividing the number of total occurrences for a classification by the total occurrences for the respective sample period.

Model Operation

Provided with the base modeling data, the code was then written using SIMAN V, the code construct for the graphical package ARENA. The general operation of the model is shown in Figure 16.

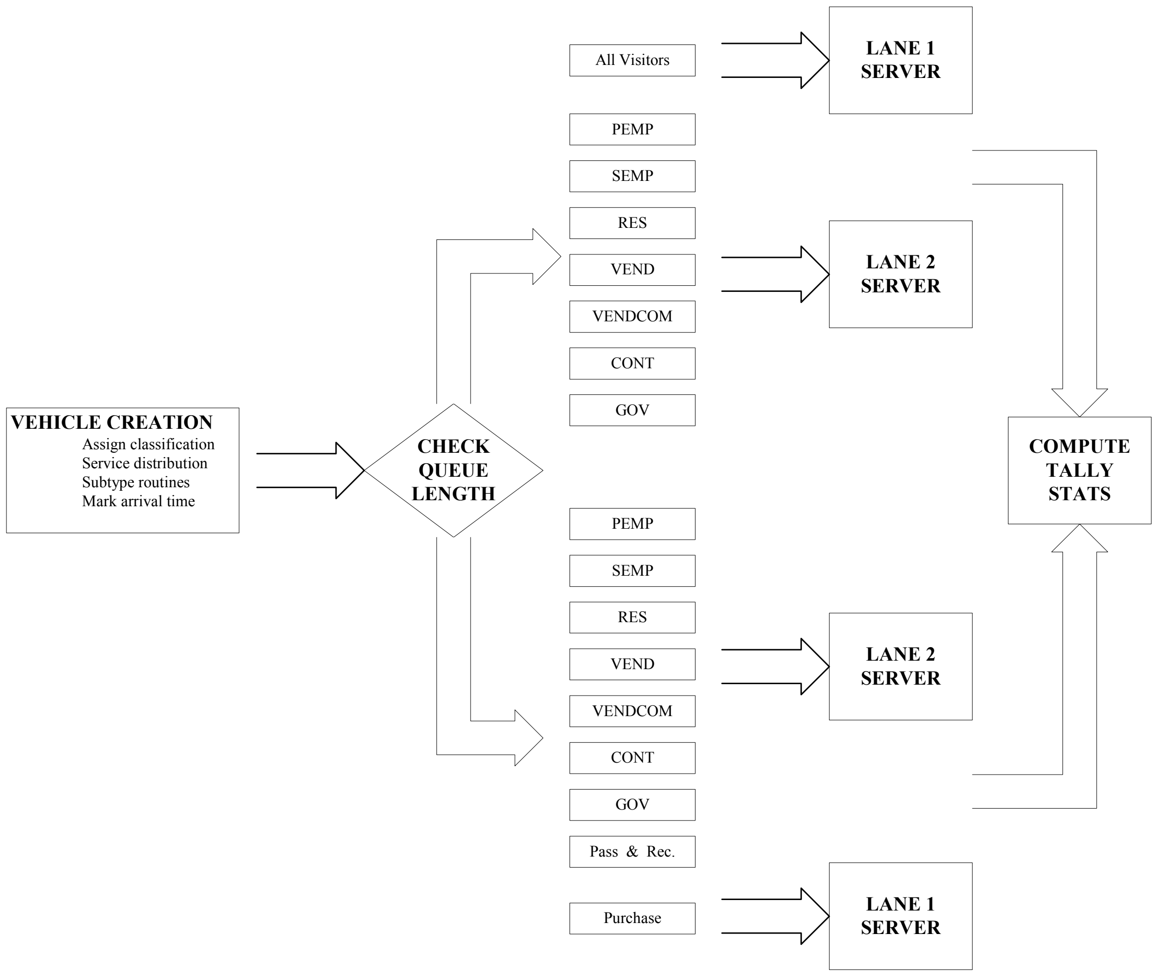

Figure 16: General Model Operation

Model Output

The model is designed to output the following: (Please note that 1 replication = 1 day)

- Average, minimum, and maximum flow time for each classification.
- Average, minimum, and maximum number of cars in each queue.
- Average, minimum, and maximum flow time for each classification over all replications
- Average, minimum, and maximum number of cars in each queue over all replications.

The model output run for one replication is provided in Tables 10 and 11.

Table 10: Flow Times for One Replication of the Model

Vehicle Type	Average Flow Time (s)	Max Flow Time (s)	Min Flow Time (s)
Employee	24	106	7
Visitor	167	391	16
Vendor	23	50	11
Commercial Vendor	25	75	12
Resident	26	70	11
Government	27	118	13
Contractor	30	107	13
All	129	391	7

Table 11: Queue Lengths for One Replication of the Model (in number of vehicles)

	Average	Min	Max
Main Queue (before split)	0.01	0	3
Right Queue (Lane 2)	0.05	0	5
Left Queue (Lane 1)	4.4	0	11

Model Validation

Qualitative comparisons between the model output and actual observations indicated that the model is reasonable. Queue lengths and flow times are similar to the ranges measured. The count and average flow time for each of the classifications over 30 replications of the model is shown below in Table 12 along with the manually collected data described previously.

Table 12: Comparison of Model and Real Data

	Daily Vehicle Count		Average Flow Times	
Vehicle Type	Model	Data	Model	Data
Employee	190	191	25	23
Visitor	911	938	192	190
Vendor	39	35	24	41
Commercial Vendor	33	21	25	56
Resident	29	31	27	35
Government	35	23	27	42
Contractor	10	3	40	39
All	1247	1242	149	155

Setbacks and Current Action Items

In order to complete the AVI evaluation, a number of actions must be completed to ensure the validity of the data and meet project objectives. To accomplish this task, the following steps will be taken.

1. Collect more accurate base line data at the North, Northeast and West Entrances with time stamp video to ensure accuracy.
2. Collect data from the Visitor Services Office (VSO) of YNP to establish traffic volumes for low, mid, and high load periods.
3. Build and refine models of all entrances with the new data to accomplish the objectives of the evaluation.
4. Conduct user surveys.

At this point, the AVI evaluation is preliminary. The above listed items are currently being completed and will be summarized in *Work Order II-2D Automated Vehicle Identification (AVI) at Yellowstone National Park Entrance Stations*.

Summary and Conclusions

The AVI system certainly has potential to reduce delay, ease entrance attendant workload, and improve the visitor's experience. For this to happen the challenges and issues need to be resolved and tag holders need to be expanded both in number and visitor type. As the AVI system is continually improved and developed, WTI will continue to monitor, evaluate and provide guidance.

Summary and Project Continuance

The GYRITS Phase I project has certainly had its delays, and challenges. However, this report marks the culmination of many of the initial goals of the GYRITS Project. Phase II will continue to deploy and evaluate the current ITS deployments described below.

- Work Order II-2A Interactive Touch Screen Kiosks are currently being deployed in up to 10 locations. One has been installed in the Bozeman Rest Area for several months. It is expected that the additional units will be installed in September 2002.

- Work Order II-2B Cellular Incident Hotline Signing was terminated as it was determined not to be in the best interest of the traveling public at this time.

- Work Order II-2C Dynamic Warning Variable Message Signs has resulted in three separate projects in each of the three participating states.

    - The Idaho Transportation Department purchased 8 portable variable message signs in fall 2000. They have been in permanent locations with snow and ice challenges in the winter and in various construction zones in the summer. WTI is currently preparing the final evaluation report, expected fall 2002.

    - The Wyoming Department of Transportation installed a permanent variable message sign with a vehicle classifier on Highway 14A east of Lovell, WY on the west slope of Bighorn Pass. This system has been in place since fall of 2001 and is currently being evaluated.

    - The Montana Department of Transportation purchased portable variable message signs currently being used in several areas in the state. They will be located on Interstate 90 on Homestake Pass in the winter for evaluation purposes. Evaluation is currently being conducted.

- Work Order II-2D AVI in Yellowstone Park is detailed in this report. Currently approximately 120 tags are being used by park employees. As bugs are worked out of the system, more tags will be issued. Further evaluation efforts will be reported through Work Order II-2D.

- Work Order II-2E GIS in Teton County was only recently initiated in July 2002. This effort will take an existing land use forecasting model and incorporate more dynamic transportation infrastructure component.

- Work Order II-3 Incident Management plan is currently being finalized. All interviews have been conducted. A final report is expected fall 2002. Follow-up workshops are a possibility and will be discussed at the next Steering Committee Meeting.

- Phase III the Greater Yellowstone Regional Traveler and Weather Information System (GYRTWIS) will be deploying 511 in Montana in the winter of 2002. The pavement prediction model is being refined and improved using Bozeman Pass and Lookout Pass. Additionally use of the model for bridge deck temperature forecasts are being studied.

The GYRITS Project has a fair amount of momentum currently. If this report is accepted, the 1996 earmark will be complete. Once the 1998 earmark is complete, there will be no major revenue source funding the project. However, there are additional projects being funded including the expansion of the AVI system to the West Entrance (CMAQ funding) and a federal lands project to employ ITS on U.S. 89 between Livingston and Yellowstone National Park. As long as there is interest by the steering committee and continued ITS projects in the GYRITS corridor, WTI will continue to coordinate the GYRITS efforts as appropriate.