Validating Predicted Rural Corridor Travel Times from an Automated License Plate Recognition System: Oregon's Frontier Project

Robert L. Bertini, Matthew Lasky, and Christopher M. Monsere

Abstract— **This paper summarizes the results of a field validation of a corridor travel time prediction system that uses automated license plate recognition–the Frontier Travel Time project. As part of the Frontier project, the Oregon Department of Transportation deployed a video image processing system with license plate recognition and privacy-protecting data encryption, a central server, and proprietary algorithms to predict corridor travel times on a 25 mile section of rural highway in northwest Oregon. The system predicted travel times were compared to data independently collected by probe vehicles equipped with Global Positioning System devices. The comparison shows that the predicted travel times were not statistically different than the travel times observed by the probe vehicles. Despite attempts to validate the system under congested conditions, all comparisons were made under essentially free flow travel. Further validation of the system in a congested corridor with alternate routes is recommended.**

I. Introduction

TRAVELER information systems, designed to predict travel times and delays have primarily been implemented in large metropolitan areas. High volumes of commuter and time-sensitive freight traffic, availability of alternate routes, departure times and modes, and in many cases instrumented freeways, make developing these systems cost-effective and useful for the traveling public. The California-Oregon Advanced Transportation System (COATS) has been a joint effort between California and Oregon Departments of Transportation to demonstrate that advanced transportation technologies can successfully be transferred to rural environments.

The U.S. rural transportation network, consisting mainly of two-lane highways makes up more than 80 percent of the nation's highway mileage. Approximately 40 percent of vehicle-miles traveled (VMT) occurs on these rural facilities, and more than 60 percent of fatal crashes occur on rural roads. Rather than assuming that urban ITS technologies can be directly transferred to rural applications, the COATS program has sought to deploy, on a small scale, appropriate Intelligent Transportation System (ITS) technologies in rural areas, evaluate their performance and document the resulting benefits [1]. Eight states (California, Idaho, Montana, Wyoming, Texas, Washington, Utah, and Oregon) have formed the Frontier pooled-fund study which has implemented and tested ITS technologies in rural locations.

As part of the Frontier Travel Time (FTT) project, the subject of this field validation, the Oregon Department of Transportation (ODOT) deployed a video image processing system with license plate recognition and privacy-protecting data encryption, a central server, and proprietary algorithms to predict corridor travel time and delay on a 25 mile section of rural Oregon Route 18 (OR-18). To validate the predicted travel times, probe vehicles were deployed over the same span of roadway on two separate days. In this paper, a description of the study corridor is presented followed a brief description of the Frontier Travel Time project. Next we describe the Frontier system data as well as the data collected by the independent probe vehicle deployments. Finally the paper summarizes the results of the analysis comparing the travel time measurements from the two sources, and offers some conclusions and recommendations.

II. Study Corridor

Oregon Route 18 (OR-18) connects the population in the mid-Willamette valley to U.S. Highway 101 (US-101) and the beaches of the Pacific coast. The study corridor is shown in Fig. 1. To the east of the study segment, OR-18 continues to the southeastern Portland metropolitan area, and is joined by OR-22 which comes from the state capital in Salem. OR-18 is a rural highway characterized by heavy weekend and recreational traffic with destinations at the coast (including the Chinook Winds Casino Resort in Lincoln City) and the Spirit Mountain Casino located in Grande Ronde. The average daily traffic (ADT) between the eastern end of the study corridor and Grand Ronde is approximately 20,000 veh/day and between Grand Ronde and the western end near the coast, the ADT is 10,000 veh/day [2]. OR-18 has no parallel detour routes and is a major truck route to the Oregon coast [3]. The highway has primarily a 2-lane cross section, traverses rolling terrain of the Coast Range

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R.L. Bertini is with the Department of Civil & Environmental Engineering, Portland State University, P.O. Box 751, Portland, OR 97207-0751 USA (phone: 503-725-4249; fax: 503-725-5950; e-mail: bertini@pdx.edu).

M. Lasky is with the School of Urban Studies & Planning, Portland State University, P.O. Box 751, Portland, OR 97207-0751 USA (e-mail: mlasky@pdx.edu).

C. M. Monsere is with the Department of Civil & Environmental Engineering, Portland State University, P.O. Box 751, Portland, OR 97207-0751 USA (e-mail: monsere@pdx.edu).

Mountains, and has passing lane sections throughout the

Fig. 1. Map of study area.

study corridor. Anecdotally, OR-18 is known to be congested during holiday weekend periods, particularly during the summer. There are no traffic signals in the study corridor and there is a directional interchange located at the junction of OR-18 with US-101.

III. Frontier Travel Time System

The Frontier Travel Time system consists of six license plate recognition cameras mounted on poles above the roadway placed at two locations on OR-18 and one location on US-101 just north of Lincoln City as shown in Fig. 1. Each installation consists of two cameras, one for each direction. The distance between cameras 2 and 3 (Segment 1) is 3.15 miles and the distance between cameras 1 and 2 (Segment 2) is 22.25 miles. The total corridor length is 25.4 miles.

The Frontier Travel Time system logic is shown in Fig. 2. The license plate reading cameras used for this research are made by Telematica Systems Limited (TSL); TSL is an associate company of the Trafficmaster group and describes the system as Passive Target Flow Measurement (PTFM) [4]. The system uses infra-red technology to read license plates for travel time measurement. Similar to the London Congestion Charging system, the cameras along the corridor are calibrated to recognize the license plates of passing vehicles. The license plate numbers are privacy-protected number with encryption and time-stamped tags are sent via telephone communications network to the central server [5]. The server matches the time-stamped tags collected at different checkpoints to identify vehicles that have passed between two or more locations. Using the matched vehicles passage times and the distances between observations, the system estimates the travel time between segments based on an algorithm that also incorporates the number of vehicles passing the license plate readers and presumably other quality control factors. The camera system is proprietary and therefore this research did not have access to nor test the algorithms used to predict the travel times.

When fully deployed, the Frontier Travel Time system would eventually provide travel information to motorists via portable variable message signs (VMS) along the corridor, ODOT's statewide traveler information system TripCheck (www.tripcheck.com), and the statewide traveler information 511 system. Motorists could then presumably choose alternative routes and make travel decisions based on the travel time estimates.

IV. Data

Two days were selected for validation of the Frontier Travel Time System: Sunday, July 13, 2003 and Friday, July 2, 2004. The validation days were chosen because of the anticipated high volumes of traffic accessing the Oregon coast on summer and holiday weekends. The research team desired to study the Frontier Travel Time system with variable corridor travel times. However, on both days it turned out that there was minimal congestion in the study corridor (delays were noticed to the west of the study corridor on both days). Due to technical problems with the Frontier system on the second travel day, only the westbound cameras were operational. Therefore all data presented for July 2, 2004 only includes the westbound direction.

The number of probes required to obtain the minimum sample-size to obtain reliable, unbiased estimates was determined [6]. On July 13, 2003, six probe vehicles were used and on July 2, 2004 seven vehicles were used. Each test car drove from Lincoln City to Valley Junction and Valley Junction to Lincoln City, twice on both days. Probe vehicles left the initial starting point at approximately 10 minute headways. On Day 2, only westbound data was collected because only the westbound cameras were in

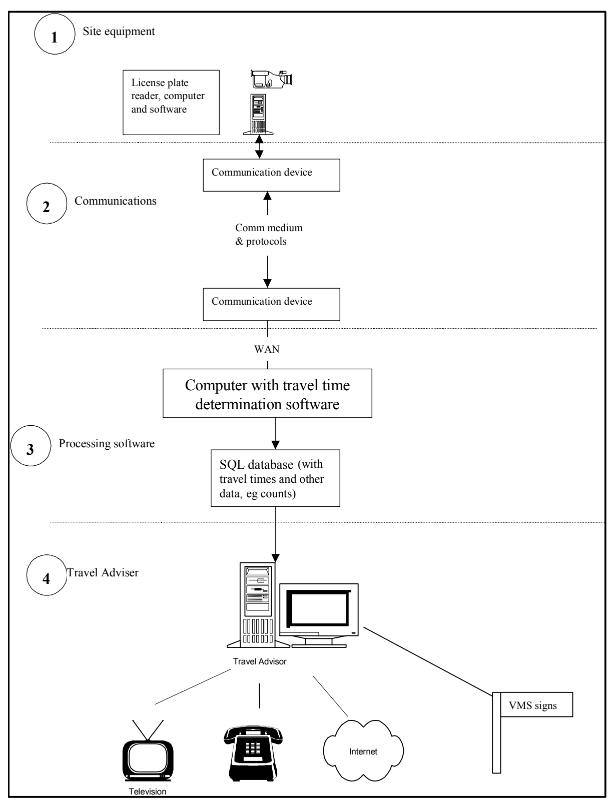


Fig. 2. Travel time information system.

operation. While gathering data, the probe vehicles followed standard probe vehicle instructions [7] by traveling at normal travel speeds.

Four (Day 1) or five (Day 2) probe vehicles were equipped with Palm OS handheld computer units equipped with Global Positioning System (GPS) receivers and the ITS-GPS software developed at Portland State University. On both days, two additional vehicles were equipped with laptop computers using CoPilot navigation software and GPS receivers. The GPS data collection devices were programmed to record date, time, time elapsed between readings, latitude, longitude, distance in miles traveled since last reading, and vehicle miles per hour at three-second intervals. These time-stamped probe vehicle locations were used to construct trajectories (on a time-distance plane) for each vehicle run during the field experiments.

Subsequent to the field experiments, the data were retrieved from the Palm devices and the laptop computers and assembled in a spreadsheet for data cleaning and statistical analysis. The distance between each point was calculated using the spherical geometry method [8]. Upon review of the data, it was found that for some sections of the study corridor, the GPS devices lost a satellite and did not record location information. The device would attempt to gather data every three seconds until a satellite fix was re-established. As a result, total distances calculated for the trip did not match the measured road distance for a few trips. Since the location information recorded by the GPS units is the distance between points as a straight line, the distances were interpolated accordingly throughout the data sets. For example, the total distance between the cameras was 25.4 miles but a probe vehicle only recorded 24.4 miles due to the GPS unit readings. The error was distributed among each of the data points for the trip using the following equation:

Interpolated Distance = Distance between readings*(25.4/Total distance measured by GPS unit)

As an integral part of the evaluation, ODOT provided the research team with output from the Frontier system for the study days. The system compiles a set of variables including date, time, site ID, link ID (delineated as one to four depending on which of the four link trips the camera is recording), number of matched tags the cameras record from camera to camera, average travel time between sites, number of tags the cameras identify from the link within the two minute time period, and number of flags. The data used in this analysis were exported from the system in comma-separated format files making it easily configurable for spreadsheet software.

V. Analysis

As noted, the first date used for validation was July 13, 2003. Fig. 3 shows the raw reported travel times for westbound traffic for the 24-hours of the test day as

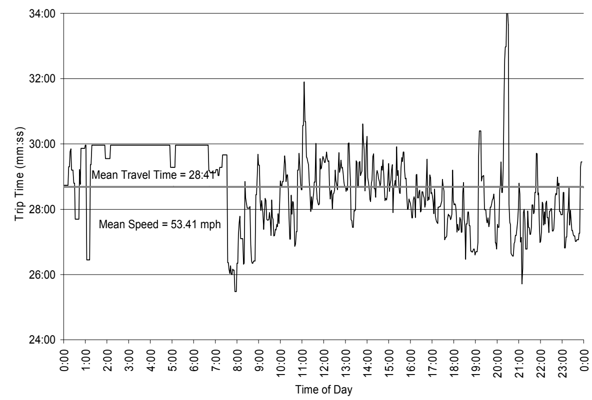


Fig. 3. Frontier travel times, raw data: westbound, Valley Junction to Lincoln City.

predicted by the Frontier system. The figure also shows the mean predicted travel time of about 29 minutes for east and westbound. The average predicted speed for all matched vehicles was approximately 51 mph. The travel time reported by the system was matched the time that each probe vehicle entered a measurement link. The system travel time was then compared to the actual probe vehicle's link trip time for similar departure times. The system times closest to the departure times were chosen for the comparison analysis.

In order to make this comparison, the probe vehicle data and the system predicted travel time data were plotted using a time-space diagram for each study day and direction. A sample of these plots is shown in Fig. 4, where the *x*-axis is time and the *y*-axis is the distance along the highway. The predicted travel time between each camera is shown for departure time of each vehicle as a dashed line. In this case, the trajectory will always be straight line between camera locations, since no intermediate travel information is known. The slope of the line indicates the average travel speed for the corridor. For the study days, the Frontier system's average predicted travel times were 29 minutes for east and westbound on the first day and second day. The average predicted speed for all trips was approximately 51 mph. The probe vehicle trajectories were plotted knowing the vehicles' locations and time stamp every three seconds. Since the conditions were generally freely-flowing, the trajectories of the probe vehicles look almost identical to the

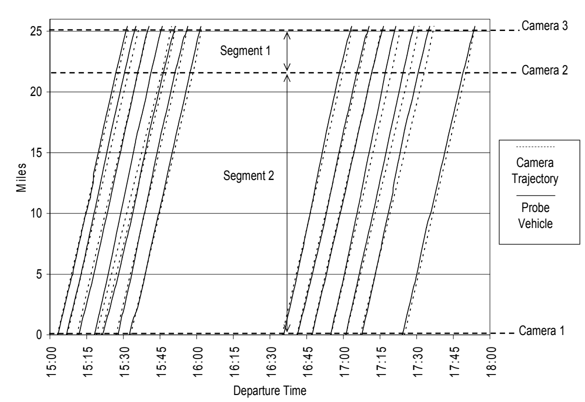
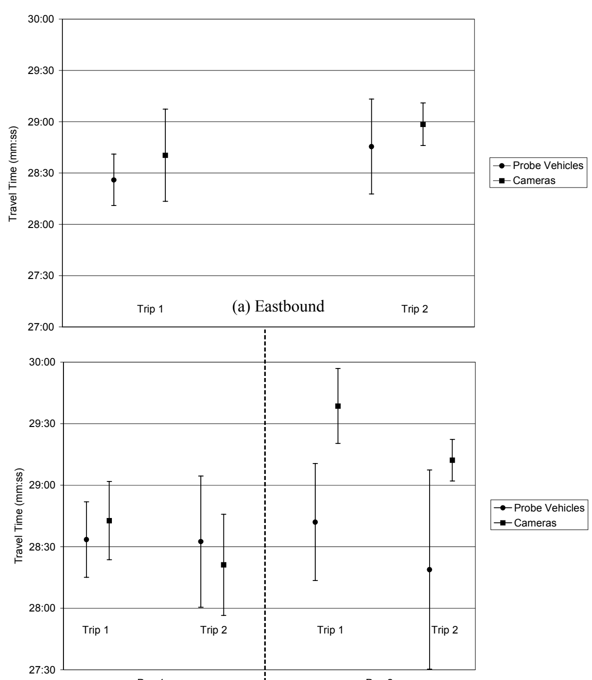


Fig. 4. Trajectory: day 2, westbound.

Frontier system's predicted trajectories. If delay had been present, the probe vehicle trajectories would have varied over time. This figure, and others for each direction that are not shown, demonstrate the close similarity between most system predicted travel times and actual probe vehicle travel times for the days analyzed.

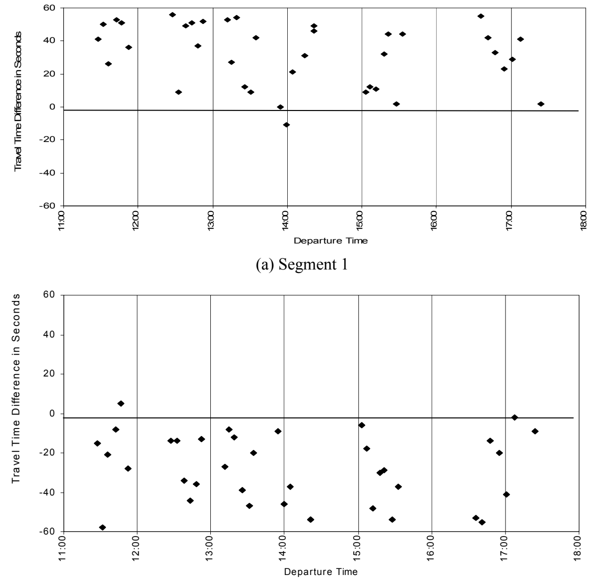
Further statistical analysis was conducted to test the similarities between the mean trip time for each group of probe vehicle trips with the mean of the system predicted travel time using all times between the first and last probe vehicle departure. The summary statistics for westbound trips are shown in Table 1 and eastbound in Table 2. Since the Frontier system's output occurs about every 3 seconds, the *n* value for the system is larger than for the probe vehicles. The means were then plotted with each 95% confidence interval as shown in Fig. 5. The various trips are defined by the groupings of probe vehicle departures. For example, in Fig. 4 all probe vehicles departing from 15:00 to 15:30 are considered a trip. The results show that in all cases except for Day 2, Trip 1, the means are not significantly statistically different because there is some overlap between the probe vehicle and Frontier system travel time confidence intervals. Although there are some differences in the system's ability to predict shorter trips as mentioned below, the system is effective predicting the total 25.4 mile corridor trip.

Closer examination of the differences between the Frontier system predicted travel times and probe travel times reveals that errors for the shorter and longer segments are different. The plot in Fig. 6 (a) shows travel time difference



(b) Westbound

Fig. 5. Means and confidence intervals for probe vehicle and predicted travel times.



(b) Segment 2

Fig. 6. Difference between probe vehicles' trip times and cameras' predicted trip times.

(predicted – probe vehicles) that the Frontier system generally predicted longer travel times than observed by the probe vehicles for the segment 1 (3.15 miles). The Frontier system predictions were a maximum of 56 seconds greater than the probe vehicle times and were consistent longer for all probe comparisons. However, for the longer segment 2 (22.25 miles), the system predicted a shorter time than all but one of the probe vehicle trips (Fig. 6 (b)). For segment 2, the maximum difference of the system predicted times and the probe was 58 seconds.

VI. Results

Based on a comparison of the mean travel times for the days examined, the Frontier Travel Time system on OR-18 and on US-101 between Lincoln City and Valley Junction predicts trip times effectively for the total 25.4 mile trip based on only one of the six comparisons being significantly statistically different. As for the short segments 1 and 2, the cameras were also effective from a practical perspective.

VII. Conclusion

The results of the field validation indicate that the Frontier Travel Time system is sufficiently accurate in predicting corridor travel times. Since all probe vehicle tests were performed while generally free flow traffic conditions prevailed, the results of this field test have limited application. In general, it is shown here that the Frontier system can reliably predict travel times within a minute, which is robust considering the length of the corridor. With this in mind, it is suggested that the system's predicted trip times be displayed on several VMS at key junction points upstream of the point where drivers enter the corridor. This

TABLE I
SUMMARY STATISTICS WESTBOUND

	Day 1				Day 2			
	Trip 1		Trip 2		Trip 1		Trip 2	
	Probe	Camera	Probe	Camera	Probe	Camera	Probe	Camera
n	7	16	7	26	6	14	6	13
Mean	28:42	29:39	28:19	29:12	28:34	28:43	28:32	28:21
Standard Deviation	00:38	00:37	01:06	00:26	00:23	00:36	00:40	00:45
Confidence Interval	00:28	00:18	00:49	00:10	00:18	00:19	00:32	00:25

TABLE 2
SUMMARY STATISTICS EASTBOUND

	Trip 1		Trip 2	
	Probe	Camera	Probe	Camera
n	6	13	6	12
Mean	28:26	28:40	28:45	28:59
Standard Deviation	00:19	00:50	00:35	00:22
Confidence Interval	00:15	00:27	00:28	00:12

would be particularly useful in the case of incidents, which are known to occur along the corridor (but did not occur on either of the study days). Given additional travel information would allow drivers to change their route, destination, or travel mode.

Additional field tests comparing probe vehicle trips to the Frontier system predicted trip time could only improve this research. Based on these results it is likely that the system will perform well during freely flowing conditions. One issue with all travel time reporting systems is the latency of the data. In all travel time systems that measure actual vehicles' travel times over a highway segment can only report that travel time at the end of the trip across the segment. In urban areas where segments are short, this is usually not a major concern. However, along a rural corridor with long segments such as this, a travel time that would be reported to a driver entering the corridor could be 30 minutes old or older. This would be exacerbated at the beginning and end of congested periods. Therefore it is conceivable that some motorists could receive information predicting freely flowing conditions along the corridor as they begin their trip, but would actually experience substantial delay due to an incident or congestion. The opposite would also be true, whereby motorists would be given information predicting very long travel times but would actually experience freely flowing conditions due to queue dissipation. These experience (particularly the first condition) would likely cause users to doubt the reliability of the travel time prediction system. As such, this should be the subject of further research.

Also, linking the results from this study with other research that looks at the amount of delay time drivers are willing to accept before choosing alternative routes would also benefit this research. Finally, we recommend that ODOT test the actual travel time reporting system and conduct a user survey to determine how drivers use the travel time information. It is possible that such a system could be extended to other key corridors around the state, so some consideration of criteria for implementing such a travel time measurement system should also be the subject of further work.

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