Transportation Learning Network

A partnership with MDT, NDDOT, SDDOT, WYDOT and the Mountain-Plains Consortium Universities

Improving Traveler Information on Rural Corridors in Wyoming Through the Use of Intelligent Transportation Systems

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IMPROVING TRAVELER INFORMATION ON RURAL CORRIDORS IN WYOMING THROUGH THE USE OF INTELLIGENT TRANSPORTATION SYSTEMS

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Mountain-Plains Consortium Webinar: October 3, 2016

University of Wyoming | Gonzaga | Laramie

Outline

- MPC Research Project
  - Introduction
  - Literature Review
  - Location Description
  - Data Sources
  - Methodology and Results
  - Proposed Implementation Plan
  - Conclusions
- Updates on Wyoming I-80 Corridor
- Recent Research on Travel Time and Travel Time Reliability

INTRODUCTION

Surveying Wyoming Travelers

- Wyoming travelers have expressed a need for an improved condition reporting system
  - 2008 Survey of Wyoming Travelers
    - Focus group of regular and random travelers asked which reported conditions affected their decisions
    - "Road Closed" and "No Unnecessary Travel" most reliable
    - Other conditions not taken as seriously
    - Current reporting methodology does not update as quickly desired

Intelligent Transportation System (ITS) Technology

- Research Question: Can we utilize ITS technology to create a more frequently updated condition reporting system that better conveys range of possible conditions?

LITERATURE REVIEW

Calculating Travel Times with Speed Sensors

- Masters Thesis by Paul Ringenberg, 2011
- Speed sensors reliable method to measure travel times
- Ideal speed sensor density 10 miles per sensor
- Speed sensor density requirements makes rural travel times difficult due to sensor investment

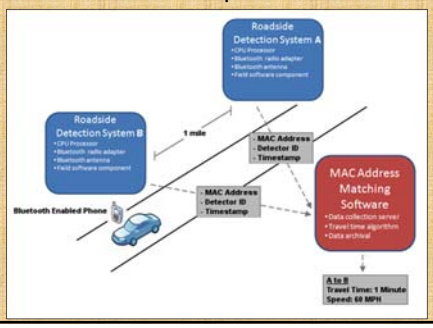
Other Travel Time Calculation Methods

- Pilot Car Method
- Floating Car Method
  - Popular way for measuring travel times in urban areas
    - Toll Transponders
    - License Plate Matching
    - Media Access Control (MAC) Address Matching



MAC Address Matching

- MAC Address is a unique 12 character code



Evaluating Bluetooth Sensor Effectiveness

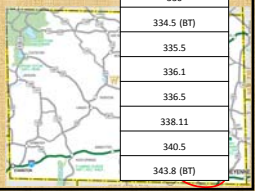
- Bluetooth sensor research in urban areas
  - Previous research focused on shorter corridors
  - Compared travel times from Bluetooth sensors and pilot car method using T-Test
  - Found that no significant difference between travel time calculated using Bluetooth sensors and "ground truth"
  - Requires devices to be in "discoverable mode", which is more common in older devices

CORRIDOR DESCRIPTIONS

I-80 between Cheyenne and Laramie

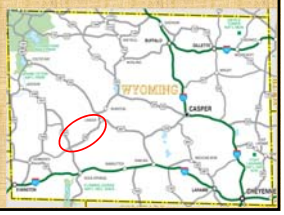
- MP 317 in Laramie and MP 358 in Cheyenne
- Four Lane Interstate (climbing lane adds fifth lane between mileposts 318 and 324)
- ITS Technology in corridor:
  - 14 Speed Sensors
  - 3 RWIS
  - 9 Web Cams
  - 13 DMS
  - 20 VSL

Speed Sensor Mileposts
317.2 (BT)
321.5
324
324.8
325.8
326.9
330
334.5 (BT)
335.5
336.1
336.5
338.11
340.5
343.8 (BT)



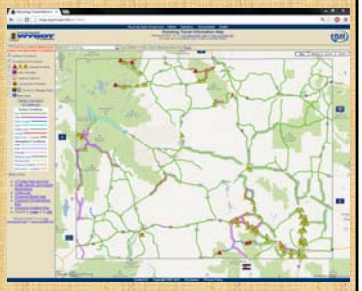
WY-28 between Farson and Lander

- MP 0.75 in Farson and MP 81 in Lander
- Two Lane Rural Highway, three climbing lane locations
  - Eastbound at MP 32.35
  - Westbound at MP 49.15 and MP 58
- ITS Technology in corridor
  - 9 Speed Sensors
  - 3 RWIS
  - 4 Web Cams
  - 9 DMS
  - 10 VSL



Pre-Trip Information Sources

- http://www.wyoroad.info/
- 511/511 Notify
- Traditional Radio



During Trip Information Sources

- Dynamic Message Signs (DMS)
  - Two or Three Line
  - Side or Overhead Mounted

DATA SOURCES

Speed Sensors

- Speed Sensors
  - Wavetronix SmartSensor HD
  - Data:
    - Direction of Travel
    - Length
    - Lane Number
    - Headway
    - Lane Occupancy

Speed Sensors on I-80

- Data collected between Oct. 2009 and Oct. 2010
- 15 min average intervals
- 1,420,276 records

SampleTime	Int Id	Det Id	Lane #	Dir	Count	Avg Occ	Avg Spd	#of Samples	#of Good Samples	#of non-zero speeds
12/1/09 12:00	36	1	2	w	66	3.56	69.69	30	30	30
12/1/09 12:00	37	2	1	w	26	0.82	76.53	30	30	30
12/1/09 12:00	38	3	1	e	12	0.35	86.32	30	30	30
12/1/09 12:00	39	4	2	e	61	2.82	77.48	30	30	30
12/1/09 12:15	36	1	2	w	58	3.04	70.77	30	30	30
12/1/09 12:15	37	2	1	w	16	0.43	75.42	30	30	30
12/1/09 12:15	38	3	1	e	21	0.4	86.96	30	30	30
12/1/09 12:15	39	4	2	e	65	3.03	75.47	30	30	30

Speed Sensor Data on WY-28

- ITS installed on the corridor in October 2012
- Started data collection November 8, 2012
- Speeds downloaded at 1 minute average intervals
  - Converted to 15 minute average intervals
- Downloaded data between Nov. 8, 2012 and Jan. 27, 2013
- Recorded individual data between Mar. 9 and Mar. 25

BlueCompass Specifications

- Internal antenna
  - 100 meter radius range
- 4 GB of storage
- Web-based interface
  - IP address 192.168.30.20
- Comma Separated Values

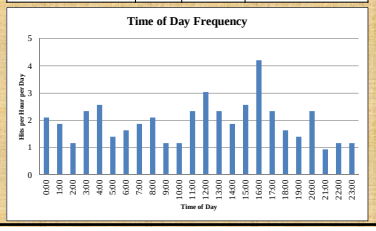
BlueCompass Data Output

Sample ID	Time-Stamp	MAC Address	Encrypted MAC Address	RF Strength	Sensor ID
1	Mon Sep 17 09:08:01 2012	7c:d1:c3:6e:13:32	5c63bad3c773e976711e49c65606092e	-81	162058
2	Mon Sep 17 09:08:03 2012	00:00:85:ee:60:a3	de5d42b367a5dc7d472713f497db6bcf	-85	162058
3	Mon Sep 17 09:12:52 2012	8c:58:77:cd:30:06	64cd3f0a523df4fcb2a6eacce41ad0ed	-87	162058
4	Mon Sep 17 09:18:12 2012	00:00:85:ee:60:a3	de5d42b367a5dc7d472713f497db6bcf	-83	162058
5	Mon Sep 17 17:03:00 2012	7c:d1:c3:6e:13:32	5c63bad3c773e976711e49c65606092e	-43	162058
6	Mon Sep 17 20:28:21 2012	00:16:a4:01:25:f5	7f81628a2bcfa2d6b7d08b518c2f0743	-89	162058
7	Mon Sep 17 20:33:28 2012	f8:0c:f3:de:b2:90	3e12c20782ab1fd9fa55367fb4315501	-83	162058
8	Mon Sep 17 21:55:08 2012	2c:27:d7:a3:a6:00	49988abdbb654f006494b9f760537509	-79	162058
9	Mon Sep 17 22:49:13 2012	f0:1c:13:cd:36:27	e917b3672aa31fe2c33001db817b16c0	-83	162058
10	Mon Sep 17 23:08:12 2012	2c:27:d7:a3:a6:00	49988abdbb654f006494b9f760537509	-79	162058
11	Mon Sep 17 23:43:19 2012	f8:0c:f3:df:30:3a	7f6483e40b65248e993489364b5a1ee5	-79	162058
12	Tue Sep 18 01:06:02 2012	00:16:a4:01:6f:41	bf92b98faf7a326441457a9054f4c2af	-87	162058
13	Tue Sep 18 08:40:42 2012	00:11:20:93:b6:68	e546b3184acb7b412e19317ea426a397	-87	162058
14	Tue Sep 18 09:39:20 2012	00:16:a4:20:54:45	edc11640bd05076e99e0927e4ca040aa	-85	162058
15	Tue Sep 18 10:04:36 2012	00:16:a4:fe:42:af	49694a5f5fdc09565f056b9568bd162f	-89	162058

BlueCompass Data Quality

- Penetration Rate and Time of Day Frequency

Number of MAC Address Hits and Penetration Rate			
Total # of MAC Address Hits for 10 days	Hits per Day	Hits per Hour	Average Penetration Rate
766	76.6	3.2	0.6%



Road Weather Information Sensor Data

- Data Downloaded from one RWIS station at Vedauwoo
  - Between October 2009 and December 2009
- Some weather variables inconsistent, left out of statistical analysis

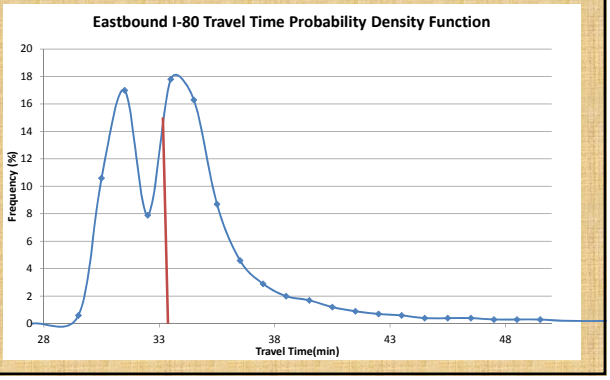
Index	SfTemp	AirTemp	RH	Dewpoint	AvgWindSpeed	GustWindSpeed	WindDirection	Precip	DayNight
0	57.2	46.7	71.7	38.0	5.0	7.3	5	0	0
0	57.2	46.7	71.7	38.0	5.0	7.3	5	0	0
0	48.6	44.0	79.0	38.0	3.0	6.0	4	0	0
0	48.6	44.0	79.0	38.0	3.0	6.0	4	0	0
0	50.9	45.3	76.3	38.0	2.0	3.7	3	0	0
0	50.9	45.3	76.3	38.0	2.0	3.7	3	0	0
0	57.2	48.0	66.3	37.7	6.7	10.3	3	0	0

METHODOLOGY AND RESULTS

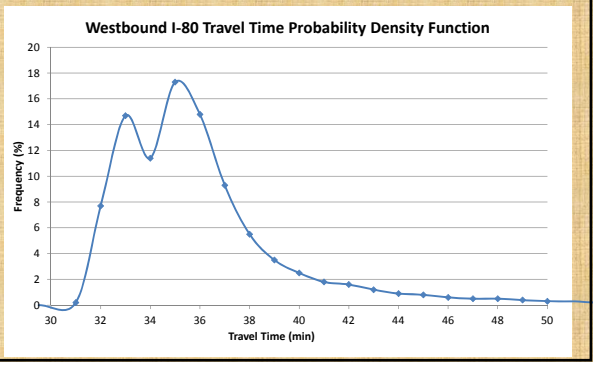
I-80 Speed Sensor Travel Time Analysis

- Oct 2009 to Oct 2010
- Choose one sensor as the starting sensor
- Calculate average travel time to the next sensor by using average speed from the beginning sensor
  - Using 10 miles/density rule to pick sensors within milepost in question
- At the speed limit (75 mph), expected travel time is around 34 minutes

I-80 Travel Time Analysis



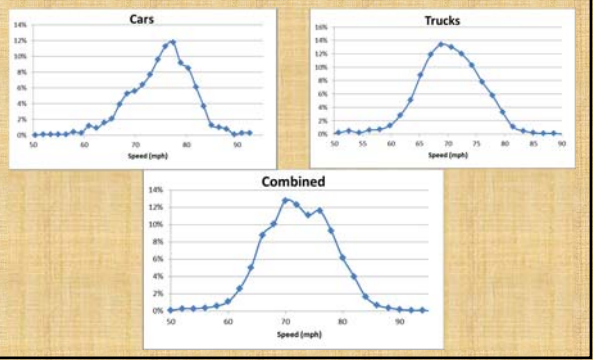
I-80 Westbound Travel Time Analysis



Bi-modal Distribution

- Bi-modal distribution most likely caused by difference in speed decisions between:
  - Night and Day Driving (Using Nautical Twilight as a reference)
  - Passenger Vehicle and Commercial Vehicle

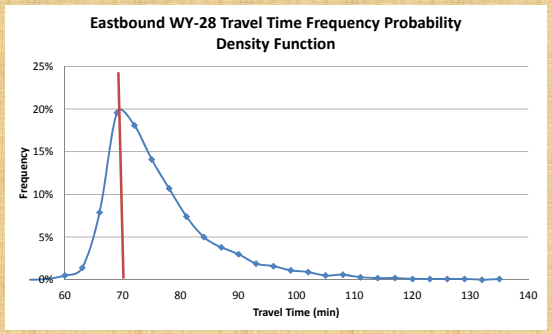
Passenger Vehicle versus Commercial Vehicle



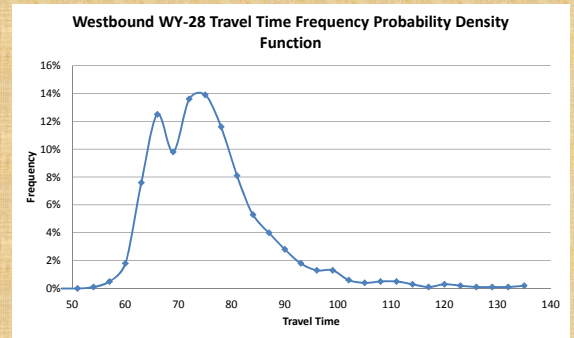
WY-28 Travel Time Analysis

- Nov. 8 to Jan. 27, and Mar. 9 to Mar. 25
- Same methodology as I-80 travel time analysis
- At the speed limit (65 mph), the expected travel time between Farson and Lander is 69 min.

WY-28 Eastbound Travel Time Analysis



WY-28 Westbound Travel Time Analysis



WY-28 Travel Time Analysis

- Average Travel Time much longer than expected
- Need more ideal condition data

Eastbound		Westbound	
Average Travel Time (min)=	75.44	Average Travel Time (min)=	75.07
90th Percentile Travel Time (min)=	88.06	90th Percentile Travel Time (min)=	88.33
Std. Dev.=	11.40	Std. Dev.=	14.07

Bluetooth Sensor Travel Time Analysis

- General travel time statistics between three Bluetooth sensors

Segment between MP 317 and MP 334.8

	Average	Standard Deviation	Maximum	Minimum
Travel Time (min)	18.1	4.8	57.9	13.0
Average Speed (mph)	60.1	9.5	80.6	18.1

Segment between MP 334.8 and MP 343.5

	Average	Standard Deviation	Maximum	Minimum
Travel Time (min)	8.6	1.8	31.3	6.5
Average Speed (mph)	65.8	6.6	86.3	17.9

Total Segment between MP 317 and MP 343.8

	Average	Standard Deviation	Maximum	Minimum
Travel Time (min)	26.8	5.1	66.8	20.7
Average Speed (mph)	62.9	5.3	77.1	35.9

Bluetooth Sensor Travel Time Analysis

- T-Test Results

Westbound	*Bluetooth*	*Speed Sensor*
Mean	39.98	34.91
Variance	95.31	0.92
Observations	64	64
Pearson Correlation	0.249458858	
Hypothesized Mean Difference	0	
df	63	
t Stat	4.238179873	
P(T<=t) one-tail	3.74853E-05	
t Critical one-tail	1.669402222	

Eastbound	*Bluetooth*	*Speed Sensor*
Mean	43.48	34.33
Variance	28.67	1.36
Observations	71	71
Pearson Correlation	0.22629953	
Hypothesized Mean Difference	0	
df	70	
t Stat	14.77911653	
P(T<=t) one-tail	1.63187E-23	
t Critical one-tail	1.666914479	

Travel Time Index

- Two peaks found in travel time histogram for each direction
  - 70 minutes (36 mph)
  - 100 minutes (25 mph)
- Six Indices created

Index #	Color	Travel Time Range (min)
0	Green	<= 40
1	Blue	40.01 - 55
2	Purple	55.01 - 70
3	Yellow	70.01 - 85
4	Orange	85.01 - 100
5	Red	> 100

Travel Time Index

- Flow chart for reporting the travel time index created
- Index applied to Oct 2009 to Oct 2010 data

Travel Time Index

Westbound				
Index #	Total Time Used	Average Duration	Maximum Duration	% of Time
0	6018:45:00	23:03:37	200:45:00	68.709%
1	877:15:00	3:27:13	40:30:00	10.015%
2	148:00:00	1:49:38	6:45:00	1.690%
3	102:15:00	1:53:37	15:15:00	1.167%
4	40:15:00	1:32:53	5:45:00	0.459%
5	19:15:00	1:55:30	4:45:00	0.220%
N/A Data	1554:00:00			
Total Time	8759:45:00			

Travel Time Index

Eastbound				
Index #	Total Time Used	Average Duration	Maximum Duration	% of Time
0	6327:45:00	29:59:22	281:45:00	72.237%
1	612:15:00	3:00:58	16:30:00	6.989%
2	144:45:00	1:55:48	10:45:00	1.652%
3	79:30:00	1:56:20	11:30:00	0.908%
4	14:45:00	0:59:00	2:15:00	0.168%
5	10:30:00	3:30:00	7:00:00	0.120%
N/A Data	1570:15:00			
Total Time	8759:45:00			

Modeling Travel Time Index and Weather Variables

- Determine the relationship between weather variables travel time index
- Ordinal Logistic Regression
  - Cumulative probability for each category

$$\pi_{ij} = \frac{\exp(\alpha_j + \beta x_i)}{1 + \exp(\alpha_j + \beta x_i)}$$

Modeling Travel Time Index and Weather Variables

- Pearson Correlation Table

Pearson Correlation Coefficients, N = 500

	SfTemp	AirTemp	RH	Dewpoint	Avg Wind Speed	Gust Wind Speed	Precip	DayNight
Index	-0.62957 <.0001	-0.72281 <.0001	0.75132 <.0001	0.08279 0.0643	0.25565 <.0001	0.283 <.0001	0.76588 <.0001	-0.03049 0.4964
SfTemp		0.89176 <.0001	-0.67147 <.0001	0.26338 <.0001	-0.24175 <.0001	-0.25584 <.0001	-0.74053 <.0001	-0.28559 <.0001
AirTemp			-0.77064 <.0001	0.2583 <.0001	-0.21006 <.0001	-0.22253 <.0001	-0.84743 <.0001	-0.06149 0.1698
RH				0.40721 <.0001	0.43782 <.0001	0.4571 <.0001	0.94037 <.0001	0.04343 0.3324
Dewpoint					0.36284 <.0001	0.37135 <.0001	0.18244 <.0001	-0.02606 0.561
Avg Wind Speed						0.98531 <.0001	0.37694 <.0001	-0.02611 0.5602
Gust Wind Speed							0.39296 <.0001	-0.00654 0.884
Precip								0.05237 0.2424

Modeling Travel Time Index and Weather Variables

- Final Model Choice
  - Estimate Interpretation
  - Intercept Interpretation

Analysis of Maximum Likelihood Estimates					
Parameter		DF	Estimate	Wald Chi-Square	Pr > ChiSq
Intercept	5	1	-8.0341	71.2618	<.0001
Intercept	4	1	-6.7473	62.1598	<.0001
Intercept	3	1	-4.6518	31.5933	<.0001
Intercept	2	1	-1.1675	1.8383	0.1751
Intercept	1	1	1.6758	4.5738	0.0325
AirTemp		1	-0.1202	55.9316	<.0001
RH		1	0.0666	68.9191	<.0001
DayNight	1	1	-0.2831	9.0466	0.0026

PROPOSED IMPLEMENTATION METHOD

Dynamic Message Signs

- Follow the FHWA guidelines
  - Short and as concise as possible
  - For speeds greater than 35 mph
    - 2 lines per phase
    - 2 phases

Wyoming Travel Information Map

UPDATE ON I-80 CORRIDOR

Update on I-80 Corridor

- Focus switched to use of Connected Vehicle Technology to improve safety and operation of the corridor
- Selected in Sept. 2015 by US DOT as one of 3 CV Pilot Deployment Sites
  - Phase 1 recently wrapped up and Phase 2 (deployment) began Sept. 2016
  - http://www.its.dot.gov/pilots/pdf/CVP_WyomingComprehensiveDeploymentPlanWebinar.pdf

SHRP 2 TRAVEL TIME RELIABILITY

SHRP 2 Reliability

- Reliability one of 4 major areas of the SHRP 2 Research Program so a tremendous amount of work has been released in recent years on this topic
  - http://www.trb.org/StrategicHighwayResearchProgram2SHRP2

Questions?

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