Session Number XXXX

Using an Intelligent Transportation System Data Archive to Improve Student Learning at Portland State University

Steven Hansen, Dr. Robert L. Bertini
Portland State University

Abstract

The Portland, Oregon regional intelligent transportation systems (ITS) data archive (known as PORTAL) was inaugurated in July 2004 via a direct fiber optic connection between the Oregon Department of Transportation (ODOT) and Portland State University (PSU). The data archive receives 20-second data from the 436 inductive loop detectors comprising the Portland area's Advanced Traffic Management System (ATMS). PSU is designated as the region's official data archiving entity, consistent with the nationally specified ITS Architecture being developed.

This paper discusses the unique educational opportunities now available to PSU engineering students due to access to these data. Several transportation engineering topics are detailed. First is the understanding of various measures of congestion using real measured data. Second is the development of real transportation performance measures. Students are now able to move beyond the use of simplistic Level of Service (LOS) measures for assessing performance of the transportation system. The data archive can be used to estimate average traffic speed, duration of congestion, fuel consumption, vehicular delay, travel time, and travel time variance, to name a few. The extent of data available to the student and researcher now allows for flexibility and creativity that was not always available in a standard classroom environment.

Introduction

Portland, Oregon is known for its unique multimodal transportation system, and therefore students are drawn to study here, with the advantage of a laboratory right outside the classroom. Current students of Civil and Environmental Engineering and Urban and Regional Planning programs at Portland State University may someday hope to plan, design, manage and/or build the transportation infrastructure necessary to provide adequate mobility in our cities. It is critical that we educate and train a new generation of transportation engineers and planners who are ready to meet the challenges of the 21st century transportation system. In any systems engineering environment, it is well understood that a system cannot be properly managed unless its actual performance can be measured. Therefore, it is essential that these future transportation professionals gain the knowledge necessary to properly analyze the performance of a transportation system. The same premise applies to working professionals who may return to the classroom as a part of their lifelong learning enterprise. Even today, simplistic Level of Service (LOS) measures are often used as a default means of assessing performance of transportation systems. While these metrics are familiar to planners, engineers, policy makers and even citizens, many of them were developed more than 50 years ago, do not necessarily reflect local conditions and are not extensively validated. The use of these simple qualitative (A-F) measures began in response to the lack of data available to create “actual” quantitative metrics.

It has been said that “if you cannot tell how your system performed yesterday, you cannot hope to manage your system today.”[1] With this in mind, properly archiving transportation operations data can allow for the systematic analysis of system performance. Data archiving for intelligent transportation systems (ITS) refers to the systematic retention and re-use of operational ITS data. Though the original and primary purpose of generating these data is often for real-time management of transportation system operations, archiving these otherwise-discarded data offers a rich source of information to various entities and agencies with a heightening need to evaluate system performance and characteristics on a continuing basis.[2] Once retained, the vast amount of ITS-generated data can be used in transportation planning, administration and research by key stakeholders including metropolitan planning organizations (MPOs), state transportation planners, traffic management operators, transit operators and transportation students and researchers.[3]

In cooperation with the Oregon Department of Transportation (ODOT) and other regional transportation agency partners, the Portland Regional Transportation Archive Listing (PORTAL, located at http://portal.its.pdx.edu) was recently inaugurated via a direct fiber optic connection between ODOT and Portland State University (PSU). In July 2004, the data archive “went live,” receiving data at a 20-second level of aggregation (the most raw form available) from the 436 inductive freeway loop detectors comprising the Portland region’s Advanced Traffic Management System (ATMS). All features of PORTAL are available via the Internet to transportation engineering and planning students at PSU. This allows for a unique educational opportunity whereby students can move beyond the LOS measures and get first hand experience analyzing actual transportation data collected throughout the region in which they live. In addition, it facilitates an opportunity for students to interact with transportation agency staff, and learn about how an agency is operated. This close interaction will serve students well as they move into the job search phase of their university experience. Communication skills developed through this means will also serve them well in their careers.

This paper is organized as follows. First is a discussion of the educational context, followed by a discussion of congestion. Although transportation professionals agree that congestion needs to be effectively managed, there are many different definitions of congestion that are used in practice. Following is a discussion of PORTAL, and how students are able to use this ITS data archive to assess the Portland transportation system based on a variety of performance measures. PORTAL has only been established for six months, so assessment of student learning is ongoing. Therefore, the paper concludes with a preliminary discussion of how student learning has improved as a result of PORTAL, and next steps for incorporating PORTAL and its assessment in the transportation engineering and planning curriculum at PSU.

Educational Context

According to Bloom's Taxonomy, the learning process involves six levels—beginning with simple recognition and recall of basic facts, and rising through more complex levels to the highest level, known as evaluation. Bloom's six levels include: knowledge, understanding, application, analysis, synthesis and evaluation. With this in mind, most U.S. undergraduate transportation courses include principles of vehicle motion, geometric design, traffic flow, capacity, control, traffic engineering and urban transportation planning. The instructor and textbook are usually the sources of authority, communicating knowledge down to the students. Research shows that students must engage in real-world uses of knowledge in order to transfer classroom concepts to practical problem solving in everyday situations.[10] Students need to explore, question, experiment, and formulate their own solutions. In prior courses, students are conditioned to solve problems with one "right answer," and resist open-ended problems that are more typical of future work environments. In transportation, students are often presented pre-established formulas or models without having the opportunity to develop their own models through data collection and analysis.

As students listen to lectures about concepts, theories and applications they miss the chance to use scientific inquiry.[12] Further, typical problem sets do help develop problem solving and design skills, but are usually simplistic. Students often think of learning as remembering facts, procedures, terms and definitions in order to answer exam questions. This can be further hampered if students have a narrow view of engineering (for example their interest may only be in structural design) and this may be frustrating for students and teachers alike. Placing the learning process in the hands of the instructor can limit students' development of cognitive skills, such as goal-setting, strategic planning, monitoring, evaluating and revising, critical skills for effective learning.[11,12]

The design for PORTAL has been conceived with the knowledge that students retain 10% of what they read, 26% of what they hear, 30% of what they see, 50% of what they see and hear, 70% of what they say, and 90% of what they say as they do something.[13] Classroom and laboratory experiences can often favor intuitive learners (principles and theories) by using verbal presentation styles (words). The design of PORTAL and its integration into the engineering curriculum recognizes that most students are sensory learners (facts, data, and experimentation) and prefer to receive information visually (pictures, diagrams and symbols). Also, since some students process information into knowledge via active experimentation and others use reflective observation, PORTAL's web interface accommodates both styles, allowing students brief pauses for thought, discussion or problem solving. Finally, because some students learn sequentially while others are global learners, we have aimed to provide the "big picture" or goal of each component of PORTAL before presenting the details. [13]

Understanding Congestion

In the transportation engineering and planning curriculum, the Federal Highway Administration (FHWA) definition of traffic congestion is often given to students as: "the level at which transportation system performance is no longer acceptable due to traffic interference." Because there is a relative sense to the word "congestion," the FHWA continues their definition by stating that "the level of system performance may vary by type of transportation facility, geographic location (metropolitan area or sub-area, rural area), and/or time of day," in addition to other variations by event or season.[4] The definition of congestion is imprecise and is made more difficult since people have different perceptions and expectations of how the system should perform based on whether they are in rural or urban areas, in peak/off peak, and as a result of the history of an area.

In reality, congestion can vary since demand (day of week, time of day, season, recreational, special events, evacuations, special events) and capacity (incidents, work zones, weather) are changing. Most researchers agree that recurrent congestion (due to demand exceeding capacity (40%) and poor signal timing (5%)) makes up about half of the total delay experienced by motorists, while nonrecurrent congestion (due to work zones (10%), incidents (30%) and weather (15%)) makes up the other half. It has been shown that four components interact in a congested system:[4]

- Duration: amount of time congestion affects the travel system.
- Extent: number of people or vehicles affected by congestion, and geographic distribution of congestion.
- Intensity: severity of congestion.
- Reliability: variation of the other three elements.

Because of the issue of user expectation, one proposal is to define "unacceptable congestion" as the travel time in excess of an agreed-upon norm, which might vary by type of transportation facility, travel mode, geographic location, and time of day.[4] "A key aspect of a congestion management strategy is identifying the level of 'acceptable' congestion and developing plans and programs to achieve that target."[5]

The FHWA has initiated a Mobility Monitoring Program based on measured travel time in which they are trying to answer a mobility question: "how easy is it to move around?" and a reliability question: "how much does the ease of movement vary?" The primary measures include:[6,7,8]

- *Travel time index*: ratio of travel conditions in the peak period to free-flow conditions, indicating how much longer a trip will take during a peak time (a travel time index of 1.3 indicates that the trip will take 30 percent longer). The calculation of this index assumes a capacity of 13,000 daily VMT/lane-mile on freeways and 5,000 daily VMT/lane-mile on principal arterials and compares measured VMT to these assumed capacity values.
- *Average duration of congested travel per day* (hours): "How long does the peak period last?" Trips are considered across the roadway network at five-minute intervals throughout the day. At any time interval, a trip is considered congested if its duration exceeds 130% of the free-flow duration. When more than 20% of all trips in a network are congested in any five-minute time interval, the entire network is considered congested for that interval. The total number of hours in which the network is designated as congested is reported in this measure.
- *Buffer index*: this measure expresses the amount of extra time needed to be on-time 95 percent of the time (late one day per month). Travelers could multiply their average trip time by the buffer index, and then add that buffer time to their trip to ensure they will be

on-time for 95 percent of all trips. An advantage of expressing the reliability (or lack thereof) in this way is that a percent value is distance and time neutral.

A recent synthesis examined more than 70 possible performance measures for monitoring highway segments and systems[9]. From users' perspectives, key measures for reporting the quantity of travel included: person-miles traveled, truck-miles traveled, VMT, persons moved, trucks moved and vehicles moved. In terms of the quality of travel, key measures included: average speed weighted by person-miles traveled, average door-to-door travel time, travel time predictability, travel time reliability (percent of trips that arrive in acceptable time), average delay (total, recurring and incident-based) and LOS. In the past, students had to rely on textbook examples of aggregate measures and rules of thumb in attempting to understand elements of traffic flow and transportation system characteristics. It was rare that students were asked to collect their own data, particularly from freeways, due to site access restrictions. It was even less common that for students to have the chance to think about, discuss and possibly develop their own measures of transportation system performance using basic traffic flow parameters.

PORTAL

As a result of the need to implement the FHWA performance monitoring program described above, the ODOT Region 1 transportation management operations center (TMOC) gathers data from 436 inductive loop detectors which comprise the Portland region's ATMS. These detectors have been implemented as part of the comprehensive ramp metering system, so dual mainline loops (also known as speed traps) are located just upstream of on-ramp locations, and the on-ramps themselves are also instrumented with count detectors. Recently, additional detection has been installed at several locations on a major freeway that includes a very long segment without ramps. These data (count, lane occupancy and time mean speed) are used in the day to day management of the transportation system to identify congested areas and incidents and to dispatch incident response or emergency vehicles to the appropriate locations.

At 20 second intervals, each loop detector records vehicle count, the average speed of these vehicles, and occupancy, or percentage of the sample period when a vehicle was over the detector. ODOT currently archives 15-min aggregate data for operations control purposes. Prior to PORTAL, the raw 20-second data were retained for only a short time before being discarded. Data are now transferred from the ODOT TMOC to the PSU relational database via a fiber optics link. The 20 second data is archived with no loss of resolution. PSU students and transportation professionals can now access these data using an easy to navigate web interface.

PORTAL itself is being developed by graduate and undergraduate students who are employed as research assistants in the PSU Intelligent Transportation Systems (ITS) Laboratory (http://www.its.pdx.edu). Thanks to the generosity of the National Science Foundation (through CAREER Grant No. 0236567), funds are available to embark upon a comprehensive research and education program involving the archiving of transportation system data and the generation and use of system performance measures. As currently deployed, each night at 3 a.m., the system aggregates the raw 20 second data to 5 minute and 1 hour tables. In addition to total volume, average occupancy and average speed, the 5 minute and 1 hour tables also include calculated values of vehicle miles traveled (VMT), vehicle hours traveled (VHT), delay, and travel time. A set of data fidelity algorithms is run in order to gauge the validity of each data point.

Figure 1 shows the new PORTAL user interface that is currently used by transportation engineering and planning students as part of their education at PSU. The map shows an example of how ODOT currently uses loop detector data in real time. The freeways are color coded to indicate the current traffic speed on each road segment, as indicated by the legend. This map, maintained by ODOT, is updated every 20 seconds when the loop detectors record average speed for the time period. This map is also available on ODOT's website www.tripcheck.com along with detailed information on road conditions, as part of Oregon's statewide traveler information system.

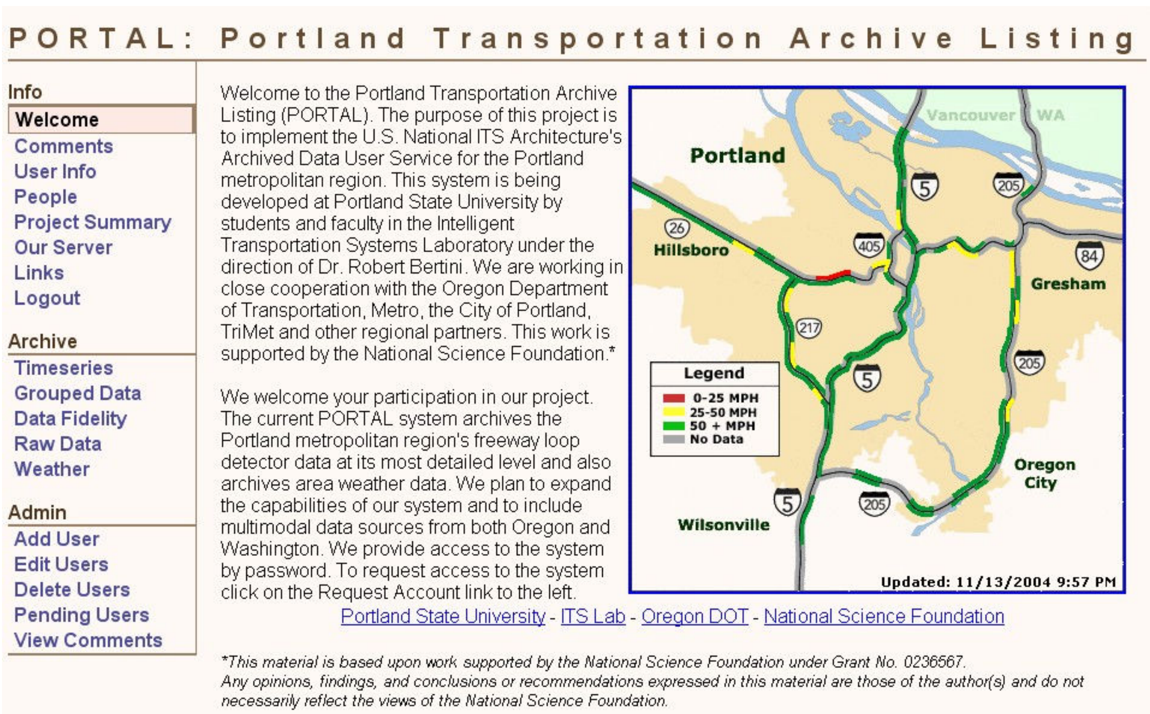


FIGURE 1 PORTAL Homepage

The time series tab allows students to perform queries on the 5 minute aggregated data to extract volume, speed, occupancy, vehicle miles traveled, vehicle hours traveled, travel time, and delay. Students can specify a specific loop detector station as well as a full highway segment, or the entire network. Additionally, the student user can choose the time period of interest and specific travel lanes being examined. Figure 2 shows a plot of volume for one station along Interstate 5 North for October 28, 2004. In coursework, students are told about the peaking phenomenon that exists in transportation, with typical directional morning and evening peak periods. This figure illustrates that at this particular location (at Going St.), the freeway demand increases from low levels at 6:30 a.m., but does not diminish much during the midday period. It also appears that the flow drops somewhat during the afternoon peak period. The use of this diagram, with its flexible pull-down menus, gives students the chance to explore patterns, perform trial and error on-line experiments, and then discuss their results with classmates and with their instructor. Students who are inclined to "learn by doing" seem to react well to this kind of exercise.

Previously, the transportation curriculum was more traditional and did not allow for students to become engaged in this way.

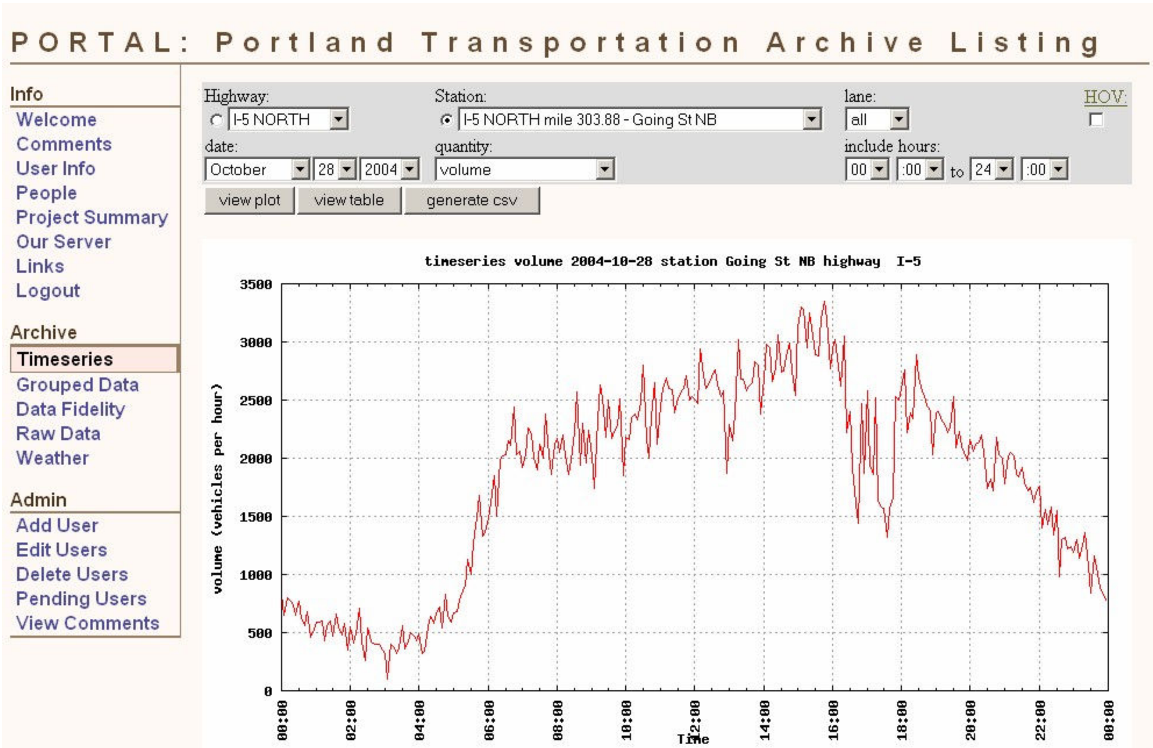


FIGURE 2 Sample Volume Plot for I-5 North Going Street Loop Detector Station, October 28, 2004

Similarly, Figure 3 shows a speed contour plot for the entire 22-mile segment of Interstate 5 North on October 28, 2004. This clearly shows a day's speed patterns along this key transportation corridor through Portland. In the morning peak, a temporal/spatial region of low speed can be clearly seen emanating from approximately milepost 296 (this is just south of downtown Portland). Similarly, in the afternoon peak, a congested region spilling back more than 10 miles from the Interstate Bridge (crossing the Columbia River into Washington) can be seen. The previous transportation engineering curriculum included presentation of traffic flow principles that described the propagation of queues on freeways from a theoretical perspective. Now, PORTAL allows students to "see" the queue propagation right before their eyes, bringing home the theory in a vibrant way that they are more likely to retain. Again, this timeseries tab allows students to explore different locations, days and time periods, allowing them to examine patterns and confirm assumptions about traffic patterns. We find that since many students are familiar with traffic patterns on area freeways, they are very interested in exploring whether their common sense understanding can be borne out by the data.

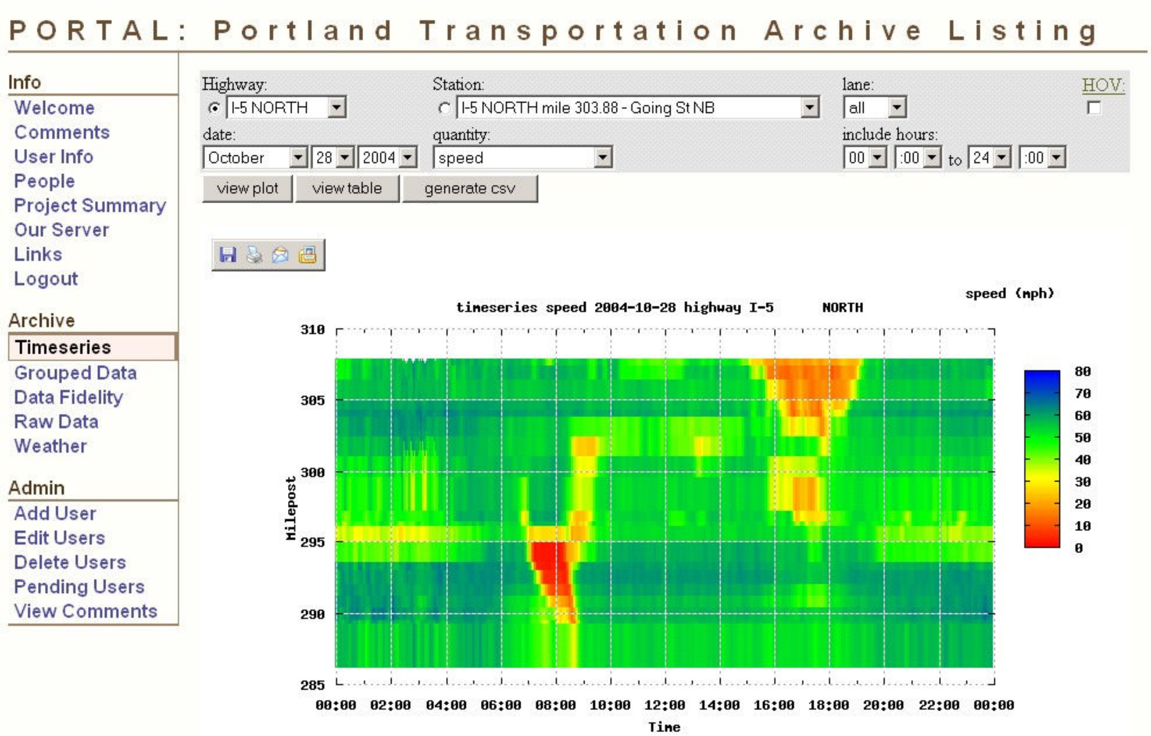


FIGURE 3 Sample Speed Contour Plot for I-5 North, October 28, 2004

Knowing that the true value of a data archive can be realized by using data from more than simply one day, the grouped data section has been designed to allow transportation students to summarize data from multiple days and examine patterns using simple statistics. The data can be grouped by hour of day, day of week, or week of year. Students can also determine the statistics they wish to see, including, mean, minimum value, maximum value, and standard deviation. From these reports, students can generate their own 85th percentile speeds, and can examine the relationship between default lane capacity values with actual measured maximum flows. To illustrate this, Figure 4 shows a plot of the mean hourly weekday speeds on a section of Oregon Highway 217 North for the month of November 2004. The error bars represent plus/minus one standard deviation of the speed. In addition to plotting the data, users also have the choice of displaying a table or downloading a comma separated value (CSV) data file. The value of this capability is that it gives students the chance to download the data and import it into their software tool of choice (e.g., Access, Excel or Matlab) and perform further manipulations. In the past, the production of a contour plot such as the one shown in Figure 3 would require numerous manual or automated manipulations of raw loop detector data, sometimes requiring many hours of student labor. Now, these plots can be produced almost instantly, while still allowing the student to examine the raw data for greater understanding.

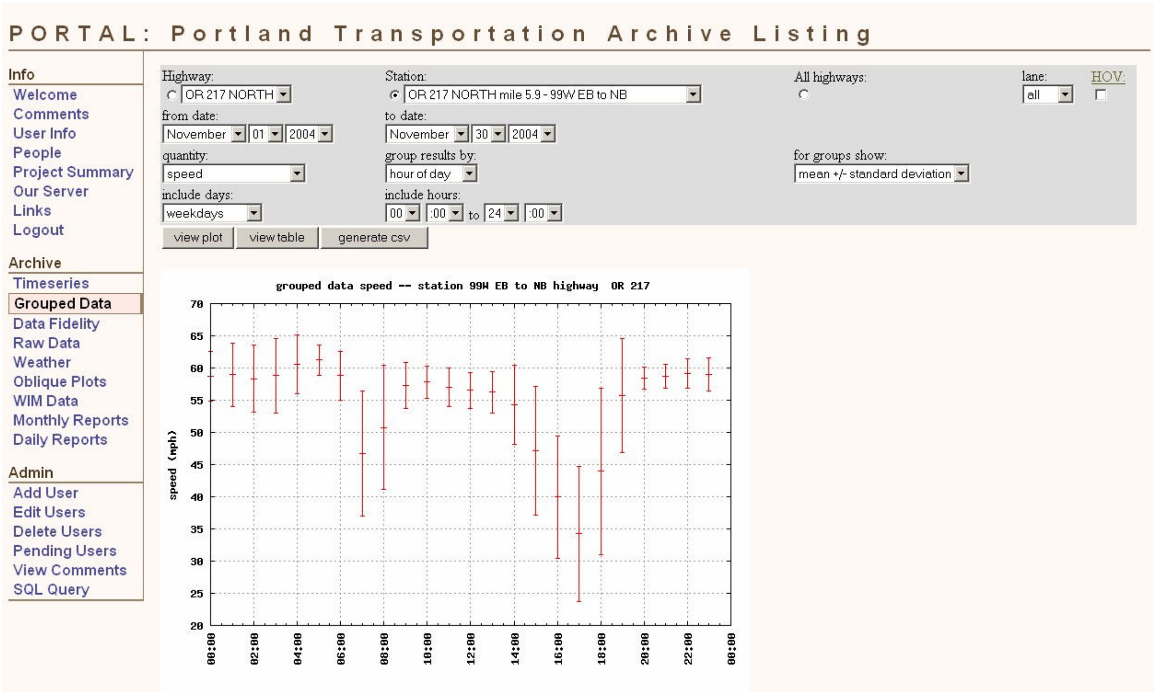
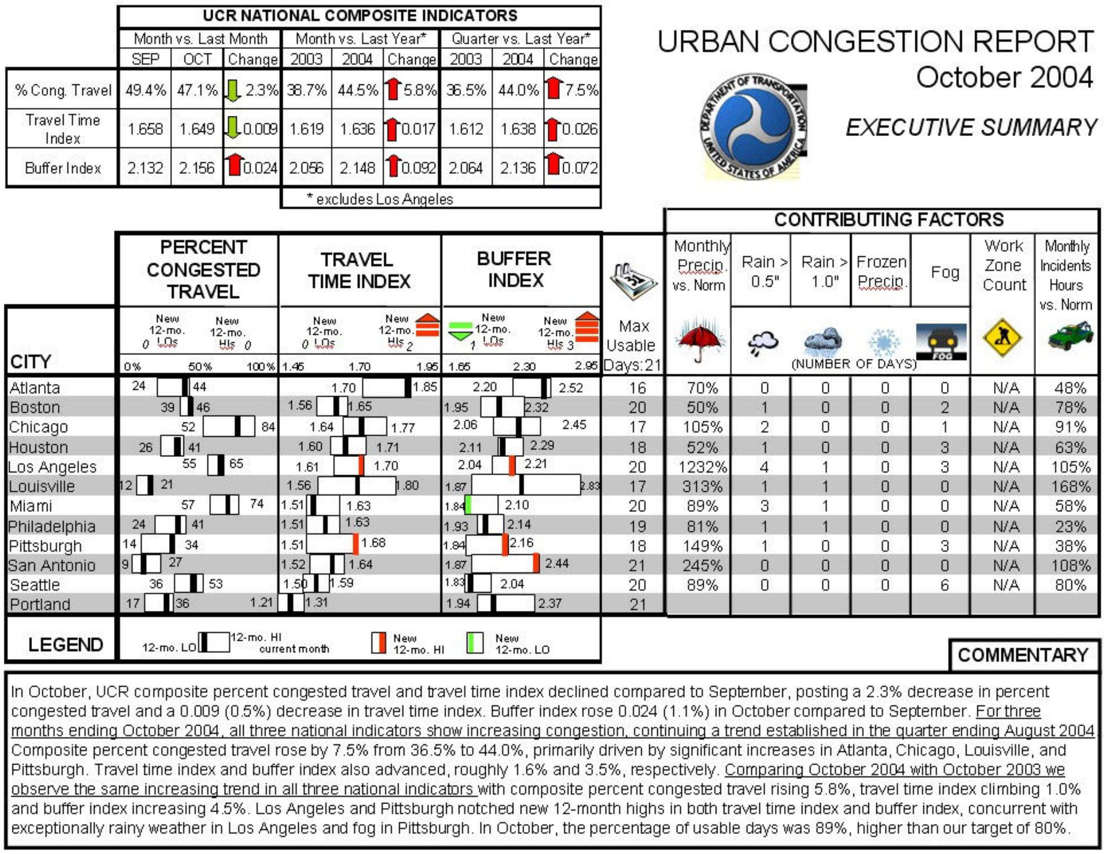


FIGURE 4 Sample Average and Standard Deviation of Speed on OR 217 North, mile 5.9, weekdays, November 2004.

The time series and grouped data sections of PORTAL are very valuable in helping students visualize what is happening on the freeway, either at one point or over a segment. However, these sections alone do not give information about the abovementioned measures of congestion – travel time index, average duration of congested travel per day, and buffer index. Students can create daily and monthly reports to extract this information about specific freeway segments, or the entire freeway system. Below is an example is the report for I-5 North for the month of December 2004:

MONTHLY FIGURES
Average Travel Time: 35.70 Minutes
Average Travel Speed (Highway length/ Average Travel Time): 43.64 MPH
Average Vehicle Speed (Sum(volume*speed)/total volume): 61.46 MPH
Highway Length: 25.97 Miles
15th-Percentile-Travel-Time (free-flow): 31.70 Minutes
15th-Percentile-Travel-Speed (free-flow): 49.15 MPH
95th-Percentile-Travel-Time: 40.76 Minutes
95th-Percentile-Travel-Speed: 38.23 MPH
Percentage of Time Congested 4.70%
Buffer Index: 1.14

As shown in Figure 5, the monthly report data for the Portland metropolitan area has been added to the FHWA Urban Congestion Report for October 2004. Currently, for other cities, the FHWA must extract large raw data files and perform their own calculations. Using the architecture established for PORTAL, the FHWA could simply click one button and receive the monthly performance reporting data that they need to track national congestion trends.



URBAN CONGESTION REPORT

October 2004

EXECUTIVE SUMMARY

UCR NATIONAL COMPOSITE INDICATORS	Month vs. Last Month			Month vs. Last Year*			Quarter vs. Last Year*		
	SEP	OCT	Change	2003	2004	Change	2003	2004	Change
% Cong. Travel	49.4%	47.1%	2.3%	38.7%	44.5%	5.8%	36.5%	44.0%	7.5%
Travel Time Index	1.658	1.649	0.009	1.619	1.636	0.017	1.612	1.638	0.026
Buffer Index	2.132	2.156	0.024	2.056	2.148	0.092	2.064	2.136	0.072

* excludes Los Angeles

PERCENT CONGESTED TRAVEL: New 12-mo. LOs 0; New 12-mo. HIs 0; scale 0% – 50% – 100%

TRAVEL TIME INDEX: New 12-mo. LOs 0; New 12-mo. HIs 2; scale 1.45 – 1.70 – 1.95

BUFFER INDEX: New 12-mo. LOs 1; New 12-mo. HIs 3; scale 1.65 – 2.30 – 2.95

CONTRIBUTING FACTORS (Rain, Frozen Precip., Fog: NUMBER OF DAYS)

CITY	Percent Congested Travel 12-mo. LO	Percent Congested Travel 12-mo. HI	Travel Time Index 12-mo. LO	Travel Time Index 12-mo. HI	Buffer Index 12-mo. LO	Buffer Index 12-mo. HI	Max Usable Days:21	Monthly Precip. vs. Norm	Rain > 0.5"	Rain > 1.0"	Frozen Precip.	Fog	Work Zone Count	Monthly Incidents Hours vs. Norm
Atlanta	24	44	1.70	1.85	2.20	2.52	16	70%	0	0	0	0	N/A	48%
Boston	39	46	1.56	1.65	1.95	2.32	20	50%	1	0	0	2	N/A	78%
Chicago	52	84	1.64	1.77	2.06	2.45	17	105%	2	0	0	1	N/A	91%
Houston	26	41	1.60	1.71	2.11	2.29	18	52%	1	0	0	3	N/A	63%
Los Angeles	55	65	1.61	1.70	2.04	2.21	20	1232%	4	1	0	3	N/A	105%
Louisville	12	21	1.56	1.80	1.87	2.83	17	313%	1	1	0	0	N/A	168%
Miami	57	74	1.51	1.63	1.84	2.10	20	89%	3	1	0	0	N/A	58%
Philadelphia	24	41	1.51	1.63	1.93	2.14	19	81%	1	1	0	0	N/A	23%
Pittsburgh	14	34	1.51	1.68	1.84	2.16	18	149%	1	0	0	3	N/A	38%
San Antonio	9	27	1.52	1.64	1.87	2.44	21	245%	0	0	0	0	N/A	108%
Seattle	36	53	1.50	1.59	1.83	2.04	20	89%	0	0	0	6	N/A	80%
Portland	17	36	1.21	1.31	1.94	2.37	21							

LEGEND: 12-mo. LO, 12-mo. HI, current month; New 12-mo. HI; New 12-mo. LO

COMMENTARY

In October, UCR composite percent congested travel and travel time index declined compared to September, posting a 2.3% decrease in percent congested travel and a 0.009 (0.5%) decrease in travel time index. Buffer index rose 0.024 (1.1%) in October compared to September. For three months ending October 2004, all three national indicators show increasing congestion, continuing a trend established in the quarter ending August 2004. Composite percent congested travel rose by 7.5% from 36.5% to 44.0%, primarily driven by significant increases in Atlanta, Chicago, Louisville, and Pittsburgh. Travel time index and buffer index also advanced, roughly 1.6% and 3.5%, respectively. Comparing October 2004 with October 2003 we observe the same increasing trend in all three national indicators with composite percent congested travel rising 5.8%, travel time index climbing 1.0% and buffer index increasing 4.5%. Los Angeles and Pittsburgh notched new 12-month highs in both travel time index and buffer index, concurrent with exceptionally rainy weather in Los Angeles and fog in Pittsburgh. In October, the percentage of usable days was 89%, higher than our target of 80%.

FIGURE 5 FHWA Urban Congestion Report, October 2004 with Portland Data

Conclusions and Next Steps

Problem-based learning develops both problem solving strategies and disciplinary knowledge by placing students in active roles as researchers and problem solvers confronted with ill-structured problems mirroring real-world situations.[14] PORTAL allows projects and assignments to be structured so students work cooperatively and collaboratively in small heterogeneous, flexible groups promoting team skills, peer teaching and interpersonal communication.[15,16]

These enhancements will increase students' exposure to a variety of teaching styles, improve integration with the systems engineering courses, incorporate information technology and develop examples and projects using real transportation data. To complement collaborative work, some PORTAL-centered project will allow students to work independently at their own pace and in their own space (classroom, computer lab, library or at home). More and more, university students have different backgrounds, experiences, abilities, cultural origins, learning styles, family responsibilities and personalities. Individual projects provide flexible schedules, incentives for self-direction, promote independent thinking and provide self-motivated learning that may continue throughout life.[11]

The previous transportation curriculum did not take advantage of the unique transportation laboratory in place outside the classroom. With several new faculty in place and through this new partnership between PSU and ODOT, students have been developing a unique resource that is now available to all Civil & Environmental Engineering and Urban Studies & Planning students. PORTAL currently has 67 registered users, many of whom are PSU students. Although PORTAL is still in its infancy, it is being used successfully in enhancing educational opportunities at PSU. One of the main benefits for students is that it helps students better visualize what is happening on the freeway system. We have begun an assessment program to track the numbers of students using PORTAL for coursework and for research purposes, and we hope to increase the level of interest in the transportation sub-discipline by making the PORTAL system visible to all students and by using it in general and specialized transportation engineering and planning coursework.

During the Fall 2004 term, one student used data extracted from PORTAL for his term paper in a graduate course, Intelligent Transportation Systems. Through this experience, he gained firsthand knowledge in the analysis of real traffic measurements. This included the confrontation of data collection errors (as with any empirical data source) and the need to carefully manipulate the data taking these errors into account. The student presented the results of his work to the entire class, thus transferring the knowledge gained and his experiences to the other students. In the future, we expect to see similar experiences among the undergraduate students. It is anticipated that continuing documentation and tracking of student experiences will assist in the development and expansion of the PORTAL data archiving system. Some of these plans include the hope to archive transit system and city traffic signal data from transportation agency partners in the Portland metropolitan region.

Bibliography

1. Variaya, P. (1997) How to measure transportation system performance. http://www.path.berleley.edu/~variaya/papers_ps.dir/TSperf.pdf
2. Turner, S. (2001) *Guidelines for Developing ITS Data Archiving Systems.* Report 2127-3. FHWA, U.S. Department of Transportation, Texas Department of Transportation, and Texas Transportation Institute.
3. ADUS Program. (2000) *ITS Data Archiving: Five-Year Program Description*. USDOT.
4. Lomax, T., S. Turner and G. Shunk. (1997). *Quantifying Congestion*, NCHRP Report 398, National Academy Press, Washington D.C.
5. Lomax, T., S. Turner, M. Hallenbeck, C. Boon and R. Margiotta. (2001). Traffic Congestion and Travel Reliability.
6. Turner, S., T. Lomax, R. Margiotta and V. Pearce. FHWA's Mobility Monitoring Program: Transforming Gigabytes of Archived Operations Data into Mobility and Reliability Performance Measures.
7. Lomax, T., S. Turner and R. Margiotta. (2001). *Monitoring Urban Roadways in 2000: Using Archived Operations Data for Reliability and Mobility Measurement*, Federal Highway Administration.
8. Jung, S., K. Wunderlich, J. Larkin, and A. Toppen. (2004). Rapid Nationwide Congestion Monitoring: The Urban Congestion Reporting Program. *Proceedings of the 2004 IEEE Intelligent Transportation Systems Conference*, Washington, D.C., 286-291.
9. NCHRP. (2003). Performance Measures of Operational Effectiveness for Highway Segments and Systems, Synthesis **311**, Transportation Research Board, Washington D.C.
10. Jonassen, D., Mayes, T. and McAleese, R. (1993) A manifesto for a constructivist approach to uses of technology in high education. *In:* J.V. Dempsey and G.C. Sales (eds) *Interactive Instruction and Feedback*, Springer-Verlag, Heidelberg.

11. National Science Foundation (1995). *Restructuring Engineering Education: A Focus on Change*. Report of NSF Workshop on Engineering Education, NSF Directorate for Education and Human Resources, Division of Undergraduate Education NSF 95-65.
12. Berryman S.E. (2002) *Designing effective learning environments: cognitive apprenticeship models*. Institute on Education and the Economy, Columbia University, New York, New York.
13. Felder, R.M. and Silverman, L.K. (2002) Updated: Learning and teaching styles in engineering education. *Engineering Education*, 78(7), 674-681 (originally published in 1988).
14. Finkle, S.L., and Torp, L.L. (1995) Introductory documents. Center for Problem-Based Learning, Illinois Math and Science Academy, www.imsa.edu/team/cpbl
15. Johnson D.V. and Johnson, R.T. (1993) Cooperative learning and feedback in technology-based instruction. In: J.V. Dempsey and G.C. Sales (eds) Interactive Instruction and Feedback, Springer-Verlag, Heidelberg.
16. Marzano, R.J., Brandt, R.S., Hughes, C.S., Jones, B.F., Presseisen, B.Z., Rankin, S.C. and Suhor, C. (1988) Dimension of Thinking: Framework for Curriculum and Instruction. ASCD, Alexandria.

Biographical Information

STEVEN HANSEN
B.S. Operations Research and Industrial Engineering, Cornell University, 1997
Candidate for Masters of Urban and Regional Planning, Portland State University, 2005

ROBERT L. BERTINI
Associate Professor of Civil & Environmental Engineering and Urban Studies & Planning, Portland State University
Ph.D., Civil Engineering, University of California at Berkeley, 1999
M.S., Civil Engineering, San Jose State University, 1991
B.S., Civil Engineering, California Polytechnic State University, 1988