

NEXTRANS Project No. 089OY04

RESEARCH, EDUCATION, AND OUTREACH  
DERIVED FROM CAMPUS TRANSIT LABORATORY

By

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Report Submission Date: April 28, 2014

## **ACKNOWLEDGMENTS AND DISCLAIMER**

The investigators gratefully acknowledge the support of The Ohio State University's Transportation and Traffic Management (TTM) department, formerly Transportation and Parking Services (T&P), Sarah Blouch, T&P's former director, and Elizabeth Kelley-Snoke, TTM's director. In addition, the technical assistance of Chris Kovitya, formerly at T&P, Yuxiong Ji, formerly postdoctoral researcher at OSU's Department of Civil, Environmental and Geodetic Engineering (CEGE), and Chas Ellerbrock, Senior Systems Manager at CEGE, are greatly appreciated.

Funding for this research was provided by the NEXTRANS Center, Purdue University under Grant No. DTRT07-G-005 of the U.S. Department of Transportation, Research and Innovative Technology Administration (RITA), University Transportation Centers Program, and by The Ohio State University's College of Engineering Transportation Research Endowment Program, Transportation and Parking Services (currently Department of Transportation and Traffic Management), Graduate School, Department of Civil, Environmental, and Geodetic Engineering, and Department of Statistics. The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the Department of Transportation, University Transportation Centers Program, in the interest of information exchange. The U.S. Government assumes no liability for the contents or use thereof.

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## **1 Introduction**

### **1.1 Background**

Increased use of public transportation is an effective means of decreasing roadway congestion and its associated externalities. To increase the use of public transportation under economic and resource constraints, it is important to improve the understanding of public transportation supply characteristics and demand behavior and make use of this understanding to improve planning and operations functions. Analyzing and interpreting *in situ* public transportation conditions that are readily accessible and observable can greatly improve this understanding.

Project investigators previously worked with The Ohio State University (OSU) Campus Area Bus Service (CABS) and a private technology provider to equip the CABS network with state-of-the-art sensing, communications, and passenger information systems that are presently used to provide real-time bus arrival information to CABS users and ridership and location information to CABS operators and planners. In addition to being used for service planning and operations, automatic vehicle location (AVL) and automatic passenger count (APC) data are downloaded nightly and archived by project investigators. The investigators couple these high-resolution and extensive data with manually collected data and data obtained from web-based surveys for research, education, and outreach.

The physical and data infrastructure and the strong partnership between service providers and project investigators, which developed over many years, have led to the establishment of the OSU Campus Transit Lab (CTL), a unique living lab that supports multiple internally and externally funded activities. This project is devoted to continued general data collection and targeted outreach, research, and educational activities designed to take advantage of existing CTL infrastructure and to sustain and to expand the infrastructure.

### **1.2 Data acquisition**

The CTL investigators continued regular manual and automatic data collection to form data bases for present and future research, outreach, and educational activities. Figure 1.2-1 shows the CABS system map for the academic year occurring during the timeframe of this project

Using the procedure presented in McCord et al. (2010), undergraduate and graduate students continued to board CABS buses to collect direct observations of passenger origin-destination (OD) flows on four CABS routes. Table 1.2-1 summarizes the numbers of bus trips and passengers sampled during this project to collect OD flow information.

The direct OD flow data, as well as less quantitative observations made by data collectors who were inserted into regular bus operations, are used to validate passenger OD estimation methodologies, to provide information to CABS managers for system planning and operations, and to generate topics for research and outreach studies. During the timeframe of this project, CTL investigators collected direct OD passenger flow observations and aggregated the observations into matrices summarizing OD

passenger flow probabilities by academic term (quarter), route, and time-of-day period (morning or afternoon). OD matrices based on route, term, and period can be found in Appendix A.

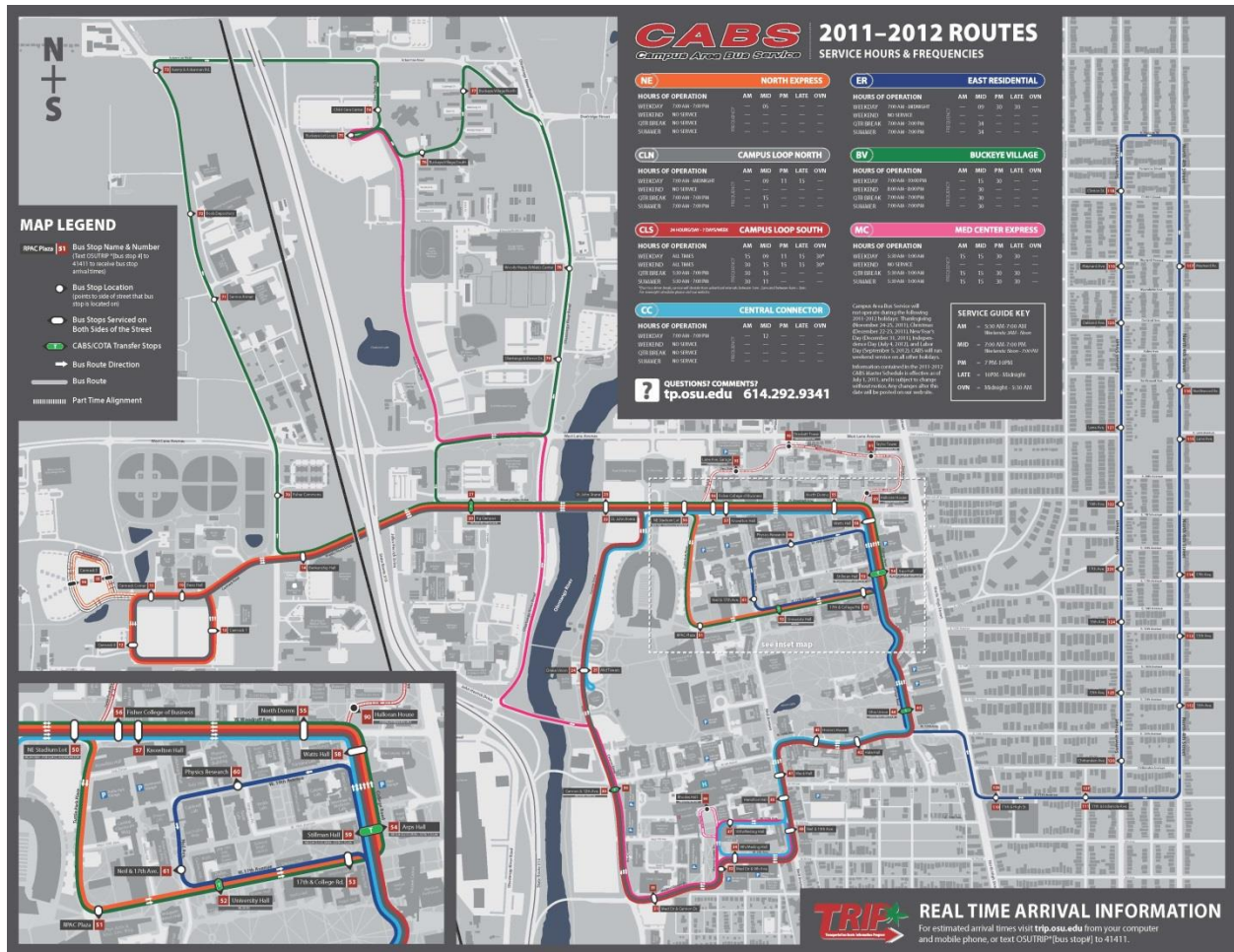


Figure 1.2-1: Ohio State University Campus Area Bus Service (CABS) route map operated in academic year 2011-2012

Table 1.2-1: Summary of numbers of bus trips and passengers sampled to collect OD flow information by academic term and route; CLS: Campus Loop South, CLN: Campus Loop North, NE: North Express, ER: East Residential, CC: Central Connector

<b>Autumn 2011 Academic Term</b>						
<i>Route</i>	<i>Passengers</i>			<i>Trips</i>		
	<i>AM</i>	<i>PM</i>	<i>Sum</i>	<i>AM</i>	<i>PM</i>	<i>Sum</i>
CLS	738	583	<b>1321</b>	16	12	<b>28</b>
CLN	436	388	<b>824</b>	8	10	<b>18</b>
NE	68	206	<b>274</b>	2	4	<b>6</b>
CC	366	394	<b>760</b>	14	12	<b>26</b>
<b>Sum</b>	<b>1608</b>	<b>1571</b>	<b>3179</b>	<b>40</b>	<b>38</b>	<b>78</b>
<b>Winter 2012 Academic Term</b>						
<i>Route</i>	<i>Passengers</i>			<i>Trips</i>		
	<i>AM</i>	<i>PM</i>	<i>Sum</i>	<i>AM</i>	<i>PM</i>	<i>Sum</i>
CLS	354	346	<b>700</b>	6	6	<b>12</b>
CLN	361	610	<b>971</b>	6	12	<b>18</b>
NE	182	162	<b>344</b>	4	4	<b>8</b>
CC	447	489	<b>936</b>	12	14	<b>26</b>
<b>Sum</b>	<b>1344</b>	<b>1607</b>	<b>2951</b>	<b>28</b>	<b>36</b>	<b>64</b>
<b>Spring 2012 Academic Term</b>						
<i>Route</i>	<i>Passengers</i>			<i>Trips</i>		
	<i>AM</i>	<i>PM</i>	<i>Sum</i>	<i>AM</i>	<i>PM</i>	<i>Sum</i>
CLS	247	473	<b>720</b>	4	10	<b>14</b>
CLN	312	514	<b>826</b>	6	12	<b>18</b>
NE	224	522	<b>746</b>	6	14	<b>20</b>
CC	0	98	<b>98</b>	0	4	<b>4</b>
<b>Sum</b>	<b>783</b>	<b>1607</b>	<b>2390</b>	<b>16</b>	<b>40</b>	<b>56</b>
<b>Cumulative: Autumn 2011 Academic Term - Spring 2012 Academic Term</b>						
<i>Route</i>	<i>Passengers</i>			<i>Trips</i>		
	<i>AM</i>	<i>PM</i>	<i>Sum</i>	<i>AM</i>	<i>PM</i>	<i>Sum</i>
CLS	1339	1402	<b>2741</b>	26	28	<b>54</b>
CLN	1109	1512	<b>2621</b>	20	34	<b>54</b>
NE	474	890	<b>1364</b>	12	22	<b>34</b>
CC	813	981	<b>1794</b>	26	30	<b>56</b>
<b>Sum</b>	<b>3735</b>	<b>4785</b>	<b>8520</b>	<b>84</b>	<b>114</b>	<b>198</b>

CTL investigators also continued to obtain and archive the APC and AVL data automatically downloaded from the buses on a nightly basis. A summary of the numbers of bus trips and passengers for which APC information was obtained is shown in Table 1.2-2. High resolution AVL data were also collected for these six CABS routes on a total of approximately 71,000 bus trips.

**Table 1.2-2: Summary of numbers of bus trips and passengers sampled to collect OD information by academic term and route; CLS: Campus Loop South, CLN: Campus Loop North, NE: North Express, ER: East Residential, CC: Central Connector, BV: Buckeye Village**

<i>Term</i>	<b>Autumn 2011</b>		<b>Winter 2012</b>		<b>Spring 2012</b>	
<i>Route</i>	<b>Trips</b>	<b>Passengers</b>	<b>Trips</b>	<b>Passengers</b>	<b>Trips</b>	<b>Passengers</b>
<b>CLS</b>	4659	189053	3829	171019	4327	164052
<b>CLN</b>	4615	196485	3803	182973	3168	140497
<b>NE</b>	7388	222795	6234	226794	7316	232834
<b>ER</b>	4063	131046	4044	152726	4332	148218
<b>CC</b>	2798	62144	2687	88858	3109	73932
<b>BV</b>	--	--	2338	49742	2342	36309

Estimated OD flow matrices for various routes, terms, and time-of-day periods are produced from these data as needed. The APC and AVL data are used for a variety of outreach investigations that arise on a one-time basis. In addition, the data are processed on a regular basis to support ongoing research and development investigations and course-based educational activities. Investigations and activities conducted for this project are discussed in the following sections.

### **1.3 Report overview**

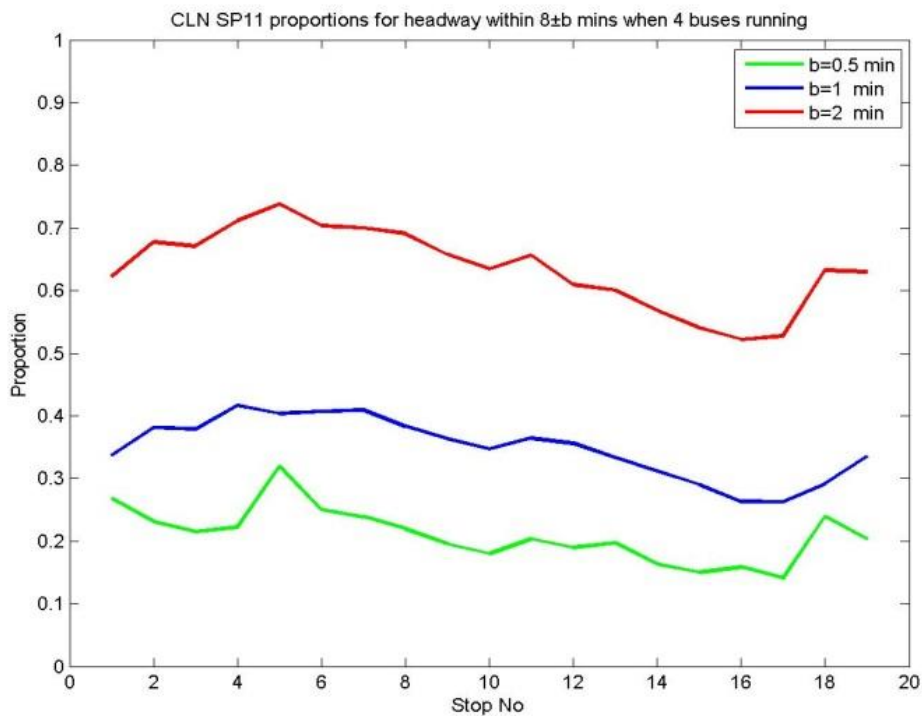
This report documents the research, outreach, and educational activities conducted within the context of the OSU CTL based on recently and previously manually and automatically collected data. Section 2 details various outreach activities between the CTL investigators and CABS managers. This section also lists technical presentations and papers produced as a result of CTL activities. Section 3 summarizes the various research activities conducted in the CTL within the scope of this project. The data collected and processed by CTL investigators are used to support and develop modules, assignments, and exam questions for use in undergraduate and graduate courses. These educational activities are described in Section 4. Finally, the outreach, research, and educational activities and findings are summarized in Section 5.



## 2 Outreach and dissemination

### 2.1 Bus headway monitoring and inter-route headway performance

Maintaining regular bus headways is an important factor in providing reliable bus service. CTL investigators produced summaries of CABS headway distributions by bus route, stop, and time-of-day in order to monitor the operation and performance of the CABS bus service. These summaries quantified the deviation of actual bus headways from the design values for different numbers of buses running on the route. Figure 2.1-1 shows the proportion of headways within a certain threshold of the scheduled headway for the Campus Loop North route during the Spring 2011 academic term with four buses running. The extent of the actual deviations from the designed headways across multiple routes and periods was previously unknown to the CABS service manager. At the time, CABS included schedule adherence as one of the metrics for which their drivers were evaluated. Based on the bus headway monitoring conducted by CTL investigators, CABS revisited its policy for using schedule adherence as an evaluation metric and began considering the importance of maintaining regular headways to service reliability.



**Figure 2.1-1: Proportions of actual headways within thresholds (+/- b minutes) of scheduled headways by stop for Campus Loop North (CLN) route in Spring 2011 academic term**

There are multiple segments in the CABS system where routes overlap and serve the same stops. CTL investigators developed algorithms and corresponding codes to produce distributions of headways

between consecutive buses on the same or different routes. Distributions were produced, and preliminary analysis was conducted.

## **2.2 Additional scheduling of CC route**

In the Autumn 2010 academic term, a new circulator route, Central Connector (CC), was introduced on campus. CTL investigators developed a schedule for the new route based on a linear programming formulation and conveyed these results to CABS (Mishalani et al, 2011). Following the introduction of CC, CTL investigators continued to monitor the conditions of the inter-route headways between CC and other routes serving shared route segments. Previously, CABS decided to forsake perfectly regular headways determined by CTL investigators in favor of less regular headways because of the resulting increased cycle-times imposed by the perfectly regular headways. Consequently, CTL investigators produced preliminary schedules incorporating the new CC route with even and uneven headways.

## **2.3 Web-based survey of transit perceptions and attitudes**

Previously, a two-wave survey of the OSU community was conducted to assess possible changes in transit perceptions and attitudes resulting from the implementation of an advanced passenger information system on the CABS system (Mishalani et al, 2011). Several aspects deemed pertinent and otherwise unavailable to CABS for planning and operations had been communicated in writing and in person to CABS managements and staff (McCord et al, 2014).

During the timeframe of this project, additional pertinent and otherwise unavailable aspects were communicated to CABS management and staff. These aspects focused on the effects of the introduction of the real-time passenger information system, as indicated by differences in Wave 1 and Wave 2 responses. These differences were first identified in the research activities, the results of which are presented in Section 3.1, and then communicated to CABS.

## **2.4 Papers and presentations at conferences**

During the timeframe of this project, additional dissemination of important activities and results was accomplished through papers and presentations at technical conferences. The following papers were published:

- Ji, Y., Mishalani, R. G., McCord, M. R., & Goel, P. K. (2011). Identifying homogeneous periods for bus route origin-destination passenger flow patterns based on automatic passenger count data. *Transportation Research Record*, No. 2216, pp. 42-50.

- Mishalani, R. G., Ji, Y., & McCord, M. R. (2011). Empirical evaluation of the effect of onboard survey sample size on transit bus route passenger OD flow matrix estimation using APC data. *Transportation Research Record*, No.2246, pp.64-73.

The following technical presentations were also given:

- Ji, Y., Mishalani, R. G., & McCord, M. R. (2012, January). *Empirical evaluation of alternative transit route-level passenger origin-destination flow estimation methods*. Transportation Research Board Annual Meeting, Washington, DC.
- McCord, M. R., Mishalani, R. G., & Ji, Y. (2011, August). *Estimating bus transit passenger OD flows for a homogeneous time-of-day period using APC data*. INFORMS Midwestern Conference, Columbus, OH.
- McCord, M. R., Mishalani, R. G., & Hu, X. (2012, January). *Bus stop grouping for aggregation of route-level passenger origin-destination flow matrices*. Transportation Research Board Annual Meeting, Washington, DC.
- McCord, M.R. and Mishalani, R.G. (2012, April). Presentation to Xerox Research at The Ohio State University, Columbus, OH:
  - “Campus Transit Lab (CTL): Select Research Activities”
  - “Overview of Campus Transit Lab (CTL) at The Ohio State University”
- McCord, M.R., Mishalani, R.G. (2012, April). Presentation to Allan Johnson (alumnus and donor) at The Ohio State University, Columbus, OH:
  - “Campus Transit Lab (CTL): Research, Education, and Outreach Activities”
  - “Overview of Campus Transit Lab (CTL) at The Ohio State University”
- Mishalani, R. G., McCord, M. R., & Ji, Y. (2011, October). *Empirical investigations of bus passenger origin-destination estimation using APC data*. Ohio Transportation Engineering Conference, Columbus, OH.
- Mishalani, R.G., McCord, M.R., Goel, P.K. (2013, April). Presentation in conjunction with EU COST Action site visit at The Ohio State University, Columbus, OH:
  - “Campus Transit Lab (CTL): Research, Education, and Outreach Activities”
  - “Overview of Campus Transit Lab (CTL) at The Ohio State University”

### **3 Research activities**

#### **3.1 Web-based survey of transit perceptions and attitudes**

Previously, a two-wave web-based survey was conducted to assess transit perceptions and attitudes of the OSU community before and after the introduction of a real-time information system called TRIP (Mishalani et al, 2011). Cross-tabulations of the responses obtained in the two waves were constructed to allow comparisons of perceptions of the value, safety, and environmental contribution of CABS before and after the introduction of TRIP. The results from the cross-tabulation analyses indicated a

positive association between the introduction of TRIP and increased users' perception of the value of CABS. The introduction of TRIP was also positively associated with increased traveler perceptions of safety, both when walking to and waiting at stops. The positive association between the introduction of TRIP and increased perception of safety was greater for females than males. In addition, the introduction of TRIP was positively associated with increased perceptions, of both users and nonusers, of CABS's contribution to a green campus. Furthermore, the introduction of TRIP was positively associated with increased perceptions, of both users and nonusers, of CABS's contribution to a reduction in traffic congestion on campus. The results motivated further statistical modeling as part of future research.

### 3.2 Weather-related effects on intra-campus bus passenger flows

Based upon observations made during manual data collection and on anecdotal experience, there appeared to be an increase in the proportion of CABS passengers who took short bus trips within the main campus area during cold or rainy weather. Historic temperature and precipitation data were gathered from an independent source and paired with CTL OD flow data to investigate the hypothesized weather effect quantitatively. Multiple plots were produced and analyzed to assess if there appeared to be an effect on the volume and proportion of intra-campus passenger trips. A plot of temperature and percentage of intra-campus trips by day is shown in Figure 3.2-1. The results of this preliminary study indicated that weather-related variables have a strong effect on the relative attractiveness of taking the bus for short, intra-campus passenger trips, which motivated statistical modeling and inclusion of additional variables in further research.

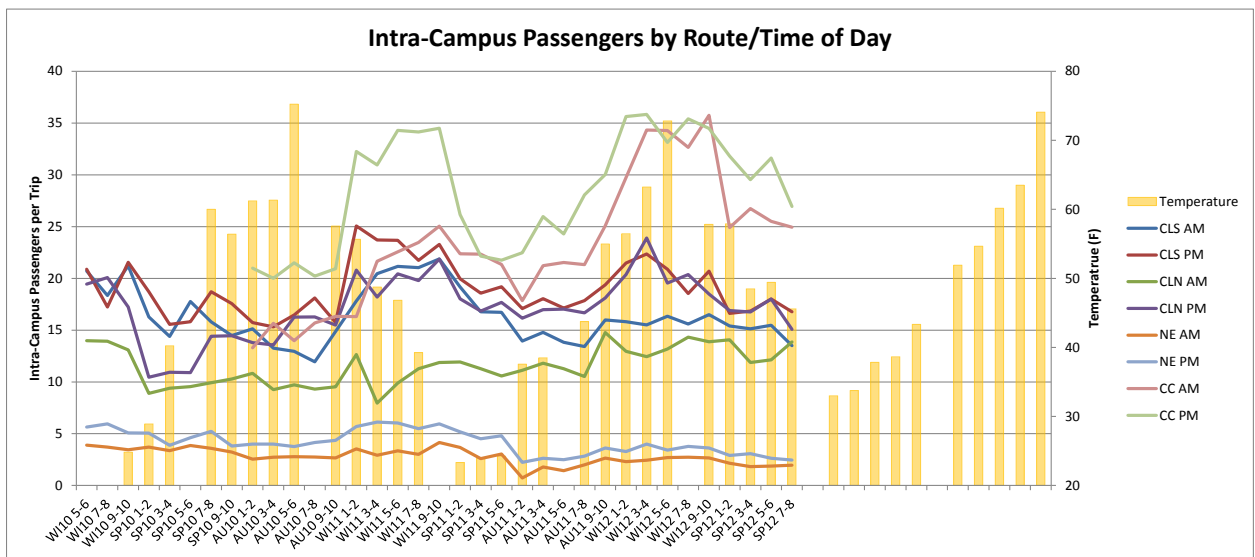


Figure 3.2-1: Average number of intra-campus passengers per bus trip and average temperature as a function of week in the term for various CABS routes

### 3.3 Route choice model

There are a number of route segments on the OSU campus where multiple CABS bus routes operate. A binary logit model was estimated to model choice between competing routes as a function of travel time and direction of route (through the “academic core” of campus or through south campus). Both travel time and the dummy variable related to travel through the academic core of campus were found to be significant with respect to route choice. The statistically significant preference for passing through the academic core of the campus is hypothesized to be associated with landmarks or familiarity of geographic areas.

### 3.4 Evaluation of IPF-IB and HEM estimation methods

For another project, CTL investigators developed two methods – a Heuristic Expectation Maximization (HEM) method and an Iterative Proportional Fitting with Iterative Base (IPF-IB) method – for improved estimation of route-level OD flows. Preliminary results had indicated the promise of these methods when used with large quantities of APC data (McCord et al, 2014). Additional CTL data were used to strengthen these conclusions with more systematic analyses.

## 4 Educational activities

CTL investigators continued to take advantage of the underlying physical and institutional infrastructure of the transit living laboratory and the automatically and manually collected data on CABS to support the incorporation of transit-related educational activities in existing classes taught by project investigators.

Previously (Mishalani et al, 2011), a lecture was introduced in the Autumn Quarter 2010 offering of *Civil/Environmental Engineering 540: Civil and Environmental Engineering Systems* on the linear programming-based bus scheduling approach previously developed as part of an outreach effort for CABS decision makers. (*Civil/Environmental Engineering 540* was a course required of all Civil Engineering and Environmental Engineering undergraduate students.) The lecture was designed to illustrate a practical application of linear programming, which was a major methodological component of the course, and to present the application and empirical results in what was intended to be an understandable context for the students. In the Autumn Quarter 2011 offering (during the timeframe of this project), the course presentation was refined and expanded. A presentation was added on the empirical CTL AVL data used as input to a scaled-down version of the scheduling problem that retained the important elements of the larger problem used in the previous outreach efforts and on the linear programming output of this version of the problem. An exam problem related to this presentation was also included. The exam problem appears in Appendix B.

In the Winter 2012 offering of *Civil Engineering 570: Transportation Engineering and Analysis*, a large transportation course required of all Civil Engineering undergraduate students, a module containing material on the CTL setting, on OD passenger flow estimation from APC data, and on bus travel time and dwell time determination from AVL data was presented. An assignment using empirical CTL APC and AVL data was again distributed and included in an associated exam problem. The assignment and exam problem appear in Appendix B.

Previously, in Winter Quarter 2010, the CTL was introduced to students in *Civil Engineering 670: Urban Public Transportation* through an extended project that utilized field observations and forecasted bus trip arrival times (Mishalani et al, 2011). This project was refined in Winter Quarter 2011 to include an activity where students compared directly observed boarding and alighting counts and bus trip arrival times at bus stops to CTL APC and AVL data. During this project, students were also introduced to the CC route for the first time. (McCord et al, 2014). This project was once again used for this course in Winter Quarter 2012. The project parts I (data collection) and II (analysis) appear in Appendix B.

## **5 Summary**

This report documents the activities conducted within the Campus Transit Lab (CTL) at The Ohio State University for the purposes of research, education, and outreach. CTL investigators utilized automatically and manually collected data from CABS to support these goals. CTL investigators conducted outreach with CABS to assess the headways of buses on campus and evaluate the operation of a new circulator route based on different conditions. CTL investigators continued to analyze the results of a two-wave web-based survey to assess changes in transit attitudes and perceptions.

Data collected in the CTL were used to investigate the effect of familiar geographic areas on the choice of competing bus routes. Continued evaluation was conducted on two OD estimation methods developed to take advantage of the large quantities of boarding and alighting data collected with the regular use of APC technologies. The effect of weather related variable on bus ridership was also investigated.

CTL data and infrastructure continued to be used in undergraduate and graduate courses through class lectures, assignments, and exam questions.

## 6 References

McCord, M.R., Mishalani, R.G., Goel, P.K., Strohl, B. (2010). *Empirical comparative assessment of the IPF procedure for determining bus route passenger OD flows*. Transportation Research Record, Vol. 2145. pp. 59-65.

Mishalani, R.G., McCord, M.R., Goel, P. K. (2011). *Smart campus transit laboratory for research and education*. U.S. DOT Region V University Transportation Center, NEXTRANS Project No. 032OY02. Final Report, December 31, 2011.

McCord, M.R., Mishalani, R.G., Goel, P.K. (2014). *Smart campus transit laboratory for research and education*. U.S. DOT Region V University Transportation Center, NEXTRANS Project No. 067OY03. Final Report, April 28, 2014.





**Table A.3: CLN Autumn 2011 Academic Term, AM Period: 8 Trips, 436 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
1		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.01%	0.93%	1.16%	0.23%	0.46%	0.23%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.02%
2			0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.46%	0.69%	0.23%	0.23%	4.17%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.87%
3				0.00%	0.00%	1.16%	0.00%	15.28%	2.78%	5.56%	0.93%	0.46%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	26.16%
4					0.00%	1.39%	0.46%	13.66%	3.01%	3.01%	3.01%	0.46%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	25.00%
5						0.00%	0.00%	0.93%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.93%
6							0.00%	2.55%	3.01%	0.69%	0.93%	0.00%	0.23%	0.00%	0.00%	0.23%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.64%
7								0.00%	0.23%	0.23%	0.46%	0.46%	0.46%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.85%
8									0.00%	0.46%	0.93%	0.46%	0.46%	0.00%	0.23%	0.23%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.78%
9										0.00%	0.69%	0.46%	1.39%	0.00%	0.00%	0.46%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.01%
10												1.16%	1.62%	1.39%	0.00%	0.23%	0.00%	0.00%	0.93%	0.00%	0.23%	1.39%	0.23%	4.63%
11													0.46%	1.16%	0.93%	0.46%	0.69%	0.23%	0.00%	0.46%	0.23%	0.00%	0.00%	4.63%
12														0.00%	0.23%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.23%
13															0.00%	0.00%	0.00%	0.00%	0.00%	0.93%	0.00%	0.23%	1.39%	2.78%
14																0.00%	0.23%	0.69%	0.00%	1.85%	0.00%	0.00%	0.00%	2.78%
15																	0.00%	0.00%	0.23%	0.46%	0.00%	0.00%	0.23%	0.93%
16																		0.00%	0.00%	0.23%	0.46%	0.00%	0.00%	0.69%
17																			0.00%	0.23%	0.46%	0.00%	0.00%	0.69%
18																					0.46%	0.00%	0.00%	0.46%
19																						0.23%	0.46%	0.93%
20																							0.00%	0.00%
21																							0.00%	0.00%
22																								0.00%
23																								0.00%
	0.00%	0.00%	0.00%	0.00%	0.00%	2.55%	0.46%	37.50%	10.42%	11.81%	8.56%	5.09%	9.49%	1.16%	0.93%	2.08%	0.93%	0.23%	4.63%	1.39%	0.69%	1.62%	0.46%	100.00%

**Table A.4: CLN Autumn 2011 Academic Term, PM Period: 10 Trips, 388 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
1		0.00%	0.00%	0.00%	0.00%	0.00%	0.77%	0.52%	0.00%	0.26%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.55%
2			0.00%	0.00%	0.00%	0.00%	0.00%	0.52%	1.03%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.55%
3				0.00%	0.00%	0.00%	0.00%	1.55%	0.26%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.90%
4					0.00%	0.26%	0.00%	1.80%	1.03%	0.77%	1.29%	0.52%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.67%
5						0.00%	0.00%	0.26%	0.00%	0.00%	0.52%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.77%
6							0.00%	3.35%	3.09%	3.09%	3.87%	0.52%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	13.92%
7								0.00%	0.26%	0.26%	1.03%	0.26%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.80%
8									0.26%	0.52%	4.64%	0.26%	1.29%	0.52%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.26%	7.73%
9										0.00%	2.58%	1.03%	0.52%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.12%
10											9.28%	3.61%	3.35%	0.52%	0.52%	1.29%	0.52%	0.00%	0.00%	0.00%	0.00%	0.26%	0.26%	19.59%
11												0.77%	2.58%	3.35%	0.52%	1.29%	1.55%	0.26%	0.00%	2.58%	0.00%	0.77%	1.29%	10.82%
12													0.00%	0.00%	0.00%	0.00%	0.52%	0.00%	0.00%	0.00%	0.00%	0.00%	0.52%	12.89%
13														0.00%	0.26%	0.77%	0.77%	0.52%	2.84%	0.26%	4.12%	3.09%	12.89%	
14															0.00%	0.77%	0.52%	0.00%	0.77%	0.00%	0.52%	0.77%	3.35%	
15																0.00%	0.00%	0.52%	0.00%	0.77%	0.00%	0.52%	1.03%	2.84%
16																	0.26%	0.77%	0.00%	0.52%	0.52%	0.77%	0.26%	3.09%
17																		0.00%	0.26%	0.26%	0.00%	1.03%	1.03%	2.58%
18																			0.00%	0.00%	0.00%	0.26%	0.26%	0.52%
19																				1.29%	0.00%	0.52%	0.00%	1.80%
20																					0.00%	0.00%	0.00%	0.00%
21																						0.00%	0.00%	0.00%
22																							0.00%	0.00%
23																								0.00%
	0.00%	0.00%	0.00%	0.00%	0.26%	0.26%	1.03%	7.99%	5.93%	6.19%	24.48%	6.96%	7.73%	1.55%	0.77%	2.06%	4.38%	2.84%	0.77%	9.02%	0.77%	8.76%	8.25%	100.00%

**Table A.5: NE Autumn 2011 Academic Term, AM Period: 2 Trips, 68 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
1		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.97%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.97%	
2			0.00%	0.00%	0.00%	0.00%	0.00%	2.99%	0.00%	0.00%	0.00%	0.00%	1.49%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.48%	
3				0.00%	0.00%	1.49%	0.00%	4.48%	17.91%	5.97%	2.99%	0.00%	1.49%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	34.33%	
4					0.00%	1.49%	0.00%	8.96%	19.40%	5.97%	1.49%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	37.31%	
5						0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
6							0.00%	1.49%	1.49%	1.49%	1.49%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.97%	
7								0.00%	2.99%	1.49%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.48%	
8									1.49%	1.49%	1.49%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.48%	
9										0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
10											0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
11												0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.99%	0.00%	2.99%	
12													0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
13														0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
14															0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
15																0.00%	0.00%	0.00%	0.00%	0.00%	
16																	0.00%	0.00%	0.00%	0.00%	
17																		0.00%	0.00%	0.00%	
18																				0.00%	
19																					0.00%
	0.00%	0.00%	0.00%	0.00%	0.00%	2.99%	0.00%	17.91%	49.25%	16.42%	7.46%	0.00%	2.99%	0.00%	0.00%	0.00%	0.00%	2.99%	0.00%	100.00%	

**Table A.6: NE Autumn 2011 Academic Term, PM Period: 4 Trips, 206 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
1		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.99%	
2			0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.99%	
3				0.00%	0.00%	0.00%	0.00%	1.97%	1.97%	0.49%	0.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.42%	
4					0.00%	0.49%	0.00%	0.49%	2.96%	1.97%	0.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.90%	
5						0.00%	0.00%	0.00%	0.00%	0.00%	0.49%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.49%	
6							1.48%	0.00%	0.99%	0.99%	2.96%	0.99%	0.49%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.88%	
7								0.00%	0.00%	0.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.99%	
8									0.49%	1.97%	0.99%	1.48%	0.49%	0.00%	0.00%	0.49%	0.00%	2.96%	1.97%	10.84%	
9										0.00%	0.49%	0.99%	0.49%	2.46%	0.99%	4.93%	1.48%	6.90%	5.42%	24.14%	
10											0.00%	0.00%	0.00%	0.99%	0.00%	1.48%	0.99%	0.99%	0.99%	5.42%	
11												0.49%	0.49%	0.49%	1.97%	3.94%	0.00%	5.42%	3.94%	16.75%	
12													0.00%	0.49%	0.00%	0.49%	0.49%	1.48%	0.00%	2.96%	
13														0.00%	2.46%	3.45%	1.97%	4.93%	1.48%	14.29%	
14															0.00%	0.49%	0.00%	0.49%	0.00%	0.99%	
15																0.99%	0.00%	0.00%	0.00%	0.99%	
16																	0.00%	0.00%	0.00%	0.00%	
17																		0.00%	0.00%	0.00%	
18																				0.00%	
19																					0.00%
	0.00%	0.00%	0.00%	0.00%	0.00%	0.49%	1.48%	3.45%	7.39%	6.40%	6.90%	3.94%	1.97%	4.43%	5.42%	16.26%	4.93%	23.15%	13.79%	100.00%	

**Table A.7: CC Autumn 2011, AM Period: 14 Trips, 366 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1		0.27%	0.27%	0.00%	0.82%	0.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.64%
2			0.27%	0.55%	0.82%	1.91%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.55%
3				0.27%	3.01%	8.47%	2.46%	2.73%	0.82%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	17.76%
4					1.37%	4.37%	3.83%	1.09%	0.82%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	11.48%
5						1.91%	0.82%	2.46%	0.55%	0.00%	0.00%	0.00%	0.55%	0.00%	0.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.56%
6							1.09%	1.09%	0.27%	0.27%	0.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.01%
7								0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
8									0.00%	0.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.27%
9										0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
10											0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
11												0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
12													0.00%	0.00%	0.27%	0.00%	0.00%	1.64%	0.27%	0.27%	0.00%	0.00%	2.46%
13														0.00%	0.27%	0.00%	0.27%	1.09%	0.82%	3.83%	0.00%	0.00%	6.28%
14															0.00%	0.55%	2.73%	1.09%	2.73%	0.00%	0.00%	0.00%	7.10%
15																0.00%	0.82%	3.28%	0.82%	0.27%	0.00%	0.00%	5.19%
16																	0.55%	2.19%	0.00%	3.55%	0.00%	0.00%	6.28%
17																		9.02%	4.10%	6.56%	1.91%	0.00%	21.58%
18																			0.00%	2.19%	1.09%	0.55%	3.83%
19																				0.82%	1.09%	0.00%	1.91%
20																					0.82%	0.27%	1.09%
21																						0.00%	0.00%
22																							0.00%
	0.00%	0.27%	0.55%	0.82%	6.01%	16.94%	8.20%	7.38%	2.46%	0.55%	0.27%	0.00%	0.55%	0.00%	0.82%	0.00%	2.19%	19.95%	7.10%	20.22%	4.92%	0.82%	100.00%

**Table A.8: CC Autumn 2011, PM Period: 12 Trips, 394 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1		0.00%	0.97%	0.00%	0.97%	3.24%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.18%
2			1.29%	0.97%	0.65%	1.62%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.85%
3				0.32%	1.94%	7.77%	1.94%	2.27%	0.00%	0.00%	0.00%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	14.56%
4					0.97%	6.15%	0.65%	2.91%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.68%
5						3.56%	1.94%	2.59%	0.32%	0.65%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	9.71%
6							0.00%	0.65%	0.65%	0.32%	0.32%	0.65%	0.00%	0.00%	0.32%	0.00%	0.00%	0.32%	0.32%	0.00%	0.65%	0.00%	4.21%
7								0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.32%
8									0.00%	0.00%	0.00%	0.00%	0.32%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.32%	0.00%	0.00%	0.97%
9										0.00%	0.65%	0.00%	0.00%	0.00%	0.00%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.97%
10											0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.32%
11												0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
12													0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
13														0.00%	0.00%	0.00%	0.00%	0.65%	0.32%	0.00%	0.00%	0.00%	0.97%
14															0.00%	0.00%	2.59%	3.56%	0.97%	0.97%	0.00%	0.00%	8.09%
15																0.00%	2.27%	7.44%	2.59%	1.29%	0.32%	0.00%	13.92%
16																	0.00%	0.97%	0.97%	1.62%	0.00%	0.00%	3.56%
17																		3.24%	5.18%	4.53%	1.62%	0.00%	14.56%
18																			0.00%	1.94%	1.29%	0.00%	3.24%
19																				0.65%	0.65%	0.00%	1.29%
20																					1.62%	0.65%	2.27%
21																						0.32%	0.32%
22																							0.00%
	0.00%	0.00%	2.27%	1.29%	4.53%	22.33%	4.85%	8.41%	1.29%	0.97%	0.97%	0.97%	0.65%	0.00%	0.65%	0.00%	5.50%	16.50%	10.36%	11.33%	6.15%	0.97%	100.00%



**Table A.11: CLN Winter 2012, AM Period: 6 Trips, 361 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
1		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.34%	1.39%	1.95%	0.28%	0.00%	0.28%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.24%
2			0.00%	0.00%	0.00%	0.00%	0.00%	1.67%	0.56%	0.84%	0.00%	0.28%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.34%
3				0.00%	0.00%	0.00%	0.00%	18.66%	3.34%	3.90%	1.95%	0.84%	1.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	30.92%
4					0.00%	1.11%	0.00%	8.08%	1.95%	2.23%	1.95%	0.84%	0.00%	0.00%	0.00%	0.28%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	16.43%
5						0.00%	0.00%	0.84%	0.00%	0.00%	0.28%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.11%
6							0.00%	0.28%	0.00%	0.00%	0.84%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.11%
7								0.56%	0.84%	0.28%	2.51%	0.28%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.46%
8									0.28%	1.11%	2.79%	0.84%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.01%
9										0.28%	2.23%	2.23%	3.06%	0.28%	0.28%	0.28%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.64%
10											1.11%	2.51%	2.79%	0.56%	0.00%	0.84%	1.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.91%
11												0.28%	1.67%	1.11%	0.00%	1.11%	0.28%	0.00%	0.28%	0.56%	0.00%	0.00%	0.00%	5.29%
12													0.00%	0.00%	0.00%	0.00%	0.28%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.28%
13														0.00%	0.00%	0.00%	0.84%	0.00%	1.11%	0.56%	0.28%	0.28%	0.28%	3.34%
14															0.00%	0.00%	0.28%	0.00%	0.56%	1.67%	0.00%	0.00%	0.28%	2.79%
15																0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
16																	0.00%	0.00%	0.00%	0.28%	0.00%	0.00%	0.00%	0.28%
17																		0.00%	0.00%	0.56%	0.00%	0.00%	0.00%	0.56%
18																			0.00%	0.28%	0.00%	0.00%	0.00%	0.28%
19																			0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
20																				0.00%	0.00%	0.00%	0.00%	0.00%
21																					0.00%	0.00%	0.00%	0.00%
22																						0.00%	0.00%	0.00%
23																							0.00%	0.00%
	0.00%	0.00%	0.00%	0.00%	0.00%	2.23%	0.00%	33.43%	8.36%	10.58%	13.93%	8.08%	8.91%	1.95%	0.28%	2.51%	2.79%	0.00%	1.95%	3.90%	0.28%	0.28%	0.56%	100.00%

**Table A.12: CLN Winter 2012, PM Period: 12 Trips, 610 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
1		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.17%	0.00%	0.00%	0.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.66%
2			0.00%	0.00%	0.00%	0.00%	0.00%	0.17%	0.50%	0.00%	0.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.99%
3				0.00%	0.00%	0.00%	0.00%	1.49%	0.83%	0.83%	1.32%	0.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.96%
4					0.17%	0.17%	0.17%	0.83%	0.33%	1.65%	0.17%	0.17%	0.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.97%
5						0.00%	0.00%	0.66%	0.66%	0.00%	0.17%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.49%
6							0.17%	4.96%	5.95%	3.97%	2.98%	0.17%	0.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	18.51%
7								0.17%	0.00%	0.50%	0.83%	0.00%	0.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.82%
8									0.33%	0.66%	7.60%	0.83%	2.64%	0.50%	0.00%	0.17%	0.00%	0.00%	0.00%	0.00%	0.00%	0.17%	0.00%	12.89%
9										0.17%	4.30%	1.16%	1.32%	0.00%	0.00%	0.17%	0.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.60%
10											4.79%	2.98%	0.17%	0.17%	0.17%	0.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.17%	10.91%
11												0.66%	1.49%	0.00%	0.50%	0.33%	1.98%	0.17%	0.00%	1.49%	0.17%	0.33%	0.50%	7.60%
12													0.00%	0.00%	0.17%	0.33%	1.32%	0.00%	0.50%	0.17%	0.00%	0.17%	0.33%	2.98%
13														0.00%	0.00%	0.50%	1.16%	0.17%	0.66%	0.33%	0.17%	1.65%	0.83%	5.45%
14															0.00%	0.00%	0.33%	0.50%	0.33%	0.00%	0.83%	0.50%	0.50%	2.48%
15																0.00%	0.50%	0.00%	0.00%	0.17%	0.00%	0.17%	0.00%	0.83%
16																	0.00%	0.66%	1.16%	1.49%	0.00%	0.66%	1.16%	5.12%
17																		0.50%	0.50%	0.50%	0.99%	1.65%	1.16%	5.29%
18																			0.17%	0.17%	0.00%	0.50%	0.00%	0.83%
19																				1.32%	0.17%	1.98%	2.15%	5.62%
20																					0.00%	0.00%	0.00%	0.00%
21																						0.00%	0.00%	0.00%
22																							0.00%	0.00%
23																								0.00%
	0.00%	0.00%	0.00%	0.00%	0.33%	0.17%	0.33%	8.43%	8.60%	7.77%	22.98%	4.79%	9.42%	0.66%	0.83%	1.65%	6.45%	1.82%	3.47%	5.95%	1.49%	8.10%	6.78%	100.00%

**Table A.13: NE Winter 2012 Academic Term, AM Period: 4 Trips, 182 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
1		0.00%	0.00%	0.00%	0.00%	0.55%	0.00%	0.00%	4.40%	0.00%	0.55%	0.00%	0.55%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.04%	
2			0.00%	0.00%	0.00%	0.00%	0.00%	0.55%	3.85%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.40%	
3				0.00%	0.00%	1.65%	2.20%	2.75%	12.64%	3.30%	1.65%	0.55%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	24.73%	
4					0.00%	0.55%	0.00%	3.85%	13.19%	3.85%	1.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	22.53%	
5						0.00%	0.00%	0.00%	2.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.20%	
6							0.00%	0.00%	0.55%	1.10%	0.55%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.20%	
7								0.55%	1.10%	0.55%	0.55%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.75%	
8									0.55%	1.65%	0.55%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.75%	
9										0.00%	0.55%	0.00%	1.10%	0.00%	1.10%	0.00%	1.65%	1.65%	1.65%	7.69%	
10											0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.55%	0.00%	0.55%	
11												0.00%	2.75%	0.00%	3.85%	0.00%	1.10%	1.10%	0.55%	9.34%	
12													0.55%	0.00%	2.75%	2.20%	0.55%	0.00%	0.55%	6.59%	
13														0.00%	3.85%	1.65%	0.55%	0.55%	1.65%	8.24%	
14															0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
15																0.00%	0.00%	0.00%	0.00%	0.00%	
16																	0.00%	0.00%	0.00%	0.00%	
17																		0.00%	0.00%	0.00%	
18																			0.00%	0.00%	
19																				0.00%	
	0.00%	0.00%	0.00%	0.00%	0.00%	2.75%	2.20%	7.69%	38.46%	10.44%	5.49%	0.55%	4.95%	0.00%	11.54%	3.85%	3.85%	3.85%	3.85%	4.40%	100.00%

**Table A.14: NE Winter 2012 Academic Term, PM Period: 4 Trips, 162 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
1		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2			0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3				0.00%	0.00%	0.00%	0.00%	0.00%	1.88%	0.63%	1.25%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.75%
4					0.00%	0.63%	0.00%	1.88%	2.50%	0.63%	1.25%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.88%
5						0.00%	0.00%	1.25%	0.63%	0.63%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.50%
6							0.00%	1.88%	6.88%	2.50%	6.88%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	18.13%
7								0.00%	0.00%	0.00%	0.63%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.63%
8									0.00%	0.63%	3.75%	0.00%	1.88%	0.00%	0.63%	1.25%	0.63%	0.00%	2.50%	11.25%
9										0.63%	1.88%	0.63%	1.88%	0.00%	0.00%	4.38%	0.00%	3.75%	5.00%	18.13%
10											0.00%	0.00%	0.00%	0.63%	0.00%	1.25%	0.00%	0.63%	0.00%	2.50%
11												0.00%	0.63%	0.00%	0.63%	3.13%	0.00%	1.88%	0.63%	6.88%
12													0.63%	0.00%	3.75%	2.50%	0.00%	1.88%	0.00%	8.75%
13														0.00%	3.75%	8.75%	0.63%	5.63%	0.63%	19.38%
14															0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
15																0.00%	0.00%	0.00%	1.25%	1.25%
16																	0.00%	0.00%	0.00%	0.00%
17																		0.00%	0.00%	0.00%
18																			0.00%	0.00%
19																				0.00%
	0.00%	0.00%	0.00%	0.00%	0.00%	0.63%	0.00%	5.00%	11.88%	5.63%	15.63%	0.63%	5.00%	0.63%	8.75%	21.25%	1.25%	13.75%	10.00%	100.00%

**Table A.15: CC Winter 2012 Academic Term, AM Period: 12 Trips, 447 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1		0.00%	0.00%	0.22%	0.67%	1.12%	0.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.25%
2			3.37%	3.15%	2.47%	1.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.11%
3				0.00%	0.90%	2.25%	0.67%	0.45%	0.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.49%
4					1.12%	2.25%	1.57%	2.47%	0.00%	0.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.64%
5						1.12%	0.90%	2.25%	0.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.22%	0.00%	5.39%
6							2.02%	1.57%	2.70%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.22%	0.00%	6.52%
7								0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
8									0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.22%	0.00%	0.22%
9										0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.45%	0.00%	0.00%	0.22%	0.00%	0.00%	0.67%
10											0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
11												0.00%	0.00%	0.00%	0.00%	0.00%	0.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.22%
12													0.00%	0.00%	0.22%	0.00%	0.90%	1.35%	0.00%	0.22%	0.00%	0.00%	2.70%
13														0.00%	1.12%	0.00%	0.00%	1.35%	1.80%	3.15%	0.00%	0.00%	7.42%
14																0.00%	1.12%	4.72%	2.02%	3.37%	0.00%	0.00%	11.46%
15																	0.00%	0.45%	1.80%	0.90%	0.00%	0.00%	3.60%
16																		1.80%	1.57%	3.60%	0.00%	0.00%	6.97%
17																			8.99%	4.49%	9.21%	1.35%	24.04%
18																				0.00%	1.80%	0.45%	2.70%
19																					1.57%	0.00%	2.25%
20																						0.67%	1.35%
21																							0.00%
22																							0.00%
	0.00%	0.00%	3.37%	3.37%	5.17%	7.87%	5.39%	6.74%	3.82%	0.22%	0.00%	0.00%	0.00%	0.00%	1.57%	0.00%	3.15%	20.00%	10.34%	23.15%	4.72%	1.12%	100.00%

**Table A.16: CC Winter 2012 Academic Term, PM Period: 14 Trips, 489 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1		0.00%	0.62%	1.03%	0.00%	1.64%	0.21%	0.21%	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.11%
2			2.67%	1.64%	1.44%	1.44%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.19%
3				1.03%	1.23%	9.65%	0.82%	3.08%	0.00%	0.00%	0.00%	0.62%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	16.43%
4					0.21%	6.78%	1.23%	0.62%	0.41%	0.00%	0.00%	0.00%	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	9.86%
5						8.62%	1.23%	4.52%	0.21%	0.00%	0.00%	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	15.20%
6							0.21%	1.03%	0.82%	0.00%	0.41%	0.41%	0.21%	0.00%	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.49%
7								0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.41%
8									0.00%	0.00%	0.00%	0.21%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.41%	0.00%	0.21%	0.00%	1.03%
9										0.00%	0.00%	0.21%	0.00%	0.00%	0.00%	0.00%	0.62%	0.00%	0.00%	0.00%	0.00%	0.00%	0.82%
10											0.00%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%
11												0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%
12													0.00%	0.00%	0.00%	0.00%	0.21%	0.21%	0.00%	0.00%	0.00%	0.00%	0.41%
13														0.00%	0.00%	0.00%	0.41%	0.21%	0.21%	0.00%	0.00%	0.00%	0.82%
14															0.00%	0.00%	1.64%	0.62%	1.23%	0.62%	0.00%	0.00%	4.11%
15																0.62%	2.67%	3.49%	2.26%	0.41%	0.00%	0.00%	9.45%
16																	0.00%	1.85%	0.82%	0.41%	0.00%	0.00%	3.08%
17																		4.52%	5.13%	4.52%	1.23%	0.00%	15.40%
18																			0.41%	0.62%	1.44%	0.21%	2.67%
19																				1.44%	0.82%	0.62%	2.87%
20																						1.03%	1.85%
21																							0.41%
22																							0.00%
	0.00%	0.00%	3.29%	3.70%	2.87%	28.13%	3.70%	9.45%	1.85%	0.00%	0.41%	1.44%	1.44%	0.21%	0.62%	0.62%	5.75%	10.88%	10.47%	8.01%	5.13%	2.05%	100.00%

**Table A.17: CLS Spring 2012, AM Period: 4 Trips, 247 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.22%	0.00%	0.41%	0.00%	0.81%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.44%
2			0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.81%	0.00%	0.00%	0.00%	0.41%	0.00%	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.63%
3				0.00%	0.00%	0.41%	0.00%	0.00%	1.22%	0.81%	0.00%	0.81%	0.41%	0.00%	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.07%
4					0.41%	0.81%	0.00%	2.44%	7.32%	0.81%	0.41%	1.63%	1.63%	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	15.85%
5						0.00%	0.41%	0.00%	0.00%	0.00%	0.00%	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.22%
6							0.00%	0.41%	0.81%	0.00%	0.41%	0.81%	0.41%	0.00%	0.81%	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.07%
7								0.00%	0.41%	0.00%	0.00%	0.00%	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.81%
8									0.00%	0.41%	0.41%	1.22%	1.22%	0.00%	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.66%
9										0.00%	0.00%	0.00%	0.00%	0.00%	0.41%	2.85%	2.03%	2.03%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.41%
10											0.00%	0.00%	0.41%	0.00%	0.00%	0.00%	0.00%	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.81%
11												0.00%	0.00%	0.00%	0.81%	0.41%	0.00%	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.63%
12													0.00%	0.00%	0.41%	2.85%	2.03%	2.03%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.13%
13														0.00%	1.22%	2.85%	0.41%	3.66%	0.41%	0.81%	1.22%	0.00%	0.00%	0.00%	10.57%
14															0.41%	1.22%	0.41%	1.63%	0.00%	0.00%	0.41%	0.81%	0.00%	0.00%	4.88%
15																6.10%	1.63%	6.91%	0.00%	4.88%	1.63%	0.00%	0.41%	0.41%	21.95%
16																	0.00%	0.81%	0.00%	0.41%	1.22%	0.00%	0.81%	0.00%	3.25%
17																		0.41%	0.00%	2.85%	0.41%	0.41%	0.00%	0.41%	4.47%
18																			0.00%	4.07%	0.81%	1.63%	1.22%	0.81%	8.54%
19																				0.41%	0.41%	0.00%	0.00%	0.00%	0.81%
20																					0.41%	0.00%	0.41%	0.00%	0.81%
21																						0.00%	0.00%	0.00%	0.00%
22																							0.00%	0.00%	0.00%
23																								0.00%	0.00%
24																									0.00%
	0.00%	0.00%	0.00%	0.00%	0.41%	1.22%	0.41%	3.25%	11.79%	2.03%	1.63%	4.88%	5.69%	0.41%	5.28%	13.82%	4.47%	16.26%	0.41%	13.41%	6.91%	2.85%	3.25%	1.63%	100.00%

**Table A.18: CLS Spring 2012, PM Period: 10 Trips, 473 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1		0.00%	0.21%	0.00%	0.00%	0.00%	0.21%	0.21%	0.21%	0.00%	0.00%	0.00%	0.00%	0.43%	0.21%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.71%
2			0.00%	0.00%	0.00%	0.00%	0.43%	0.43%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.07%
3				0.00%	0.21%	0.21%	0.21%	0.21%	0.00%	0.00%	0.00%	0.21%	0.43%	0.21%	0.43%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.14%
4					0.00%	0.21%	0.43%	0.21%	0.21%	0.00%	0.00%	1.50%	0.86%	0.00%	0.00%	0.21%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.85%
5						0.00%	0.00%	0.43%	0.21%	0.00%	0.00%	0.64%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.50%
6							0.00%	1.28%	0.00%	0.00%	0.21%	0.64%	0.64%	0.86%	1.28%	0.43%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.35%
7								0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
8									0.21%	0.43%	0.00%	2.36%	0.43%	0.00%	3.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.64%
9										0.00%	0.00%	0.00%	0.21%	0.00%	0.21%	0.21%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.86%
10											0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.21%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.86%
11												0.00%	0.00%	0.00%	0.43%	0.00%	0.43%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.86%
12													0.00%	0.00%	0.64%	0.21%	0.64%	0.43%	0.00%	0.43%	0.21%	0.00%	0.00%	0.00%	2.57%
13														0.00%	1.28%	2.14%	2.57%	0.86%	0.64%	0.21%	0.86%	0.00%	1.28%	0.86%	10.71%
14															0.21%	0.43%	0.64%	0.64%	0.00%	0.21%	1.28%	0.43%	0.64%	0.00%	4.50%
15																1.07%	3.43%	2.78%	0.21%	0.64%	3.43%	0.43%	4.07%	2.14%	18.20%
16																	0.21%	0.21%	0.43%	0.64%	2.78%	0.86%	1.93%	1.93%	8.99%
17																		0.43%	0.00%	1.07%	4.71%	1.71%	1.71%	1.07%	10.71%
18																			0.21%	0.43%	6.21%	0.64%	4.71%	3.00%	15.20%
19																				0.00%	0.00%	0.21%	0.00%	0.00%	0.21%
20																					0.86%	0.00%	1.71%	1.50%	4.07%
21																						0.00%	0.00%	0.00%	0.00%
22																							0.00%	0.00%	0.00%
23																								0.00%	0.00%
24																									0.00%
	0.00%	0.00%	0.21%	0.00%	0.21%	0.43%	1.28%	2.78%	0.86%	0.43%	0.21%	5.35%	2.57%	1.71%	7.92%	5.14%	8.57%	5.78%	1.50%	3.64%	20.34%	4.07%	16.27%	10.71%	100.00%



**Table A.19: CLN Spring 2012, AM Period: 6 Trips, 312 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
1		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.32%	0.64%	0.96%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.88%
2			0.00%	0.00%	0.00%	0.00%	0.00%	2.24%	0.32%	0.96%	1.28%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.81%
3				0.00%	0.00%	0.00%	0.00%	13.46%	5.77%	2.88%	4.81%	0.64%	0.64%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	30.45%
4					0.00%	0.96%	0.00%	6.41%	1.92%	1.92%	1.92%	1.28%	0.96%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	15.38%
5						0.00%	0.00%	1.60%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%
6							0.00%	1.60%	1.60%	0.64%	0.00%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.17%
7								0.00%	0.96%	0.00%	0.96%	0.64%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.88%
8									1.28%	0.00%	2.88%	0.32%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.81%
9										0.32%	2.56%	2.56%	0.96%	0.00%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.73%
10											1.28%	2.56%	1.28%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.45%
11												1.92%	1.28%	0.64%	0.32%	1.28%	1.28%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	7.05%
12													0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
13														0.00%	0.32%	0.00%	0.00%	0.32%	2.56%	0.96%	0.64%	0.64%	0.00%	5.45%
14															0.00%	0.64%	0.64%	0.00%	1.92%	0.96%	0.00%	0.00%	0.00%	4.17%
15																0.00%	0.32%	0.32%	0.00%	0.00%	0.32%	0.00%	0.00%	0.96%
16																	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
17																		0.00%	0.64%	0.00%	0.64%	0.00%	0.64%	1.28%
18																			0.32%	0.00%	0.00%	0.00%	0.00%	0.32%
19																				0.64%	0.00%	1.28%	0.00%	1.92%
20																					0.32%	0.00%	0.00%	0.32%
21																						0.00%	0.00%	0.00%
22																							0.00%	0.00%
23																								0.00%
	0.00%	0.00%	0.00%	0.00%	0.00%	3.21%	0.00%	25.32%	12.50%	7.37%	16.67%	9.94%	6.09%	0.96%	0.64%	2.24%	2.24%	0.96%	5.45%	2.56%	1.28%	2.56%	0.00%	100.00%

**Table A.20: CLN Spring 2012, PM Period: 12 Trips, 610 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
1		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.79%	0.79%	0.00%	0.59%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.17%
2			0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	0.39%	0.59%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.18%
3				0.20%	0.20%	0.00%	0.00%	0.79%	0.59%	0.39%	0.59%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.76%
4					0.00%	0.00%	0.20%	1.57%	0.79%	0.98%	1.18%	0.20%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.12%
5						0.00%	0.20%	1.18%	0.20%	0.39%	0.39%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.56%
6							0.00%	2.56%	2.56%	1.57%	3.54%	0.20%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	10.83%
7								0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
8									0.59%	2.17%	5.51%	0.59%	2.56%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	11.61%
9										0.20%	4.72%	1.97%	2.36%	0.00%	0.00%	0.20%	0.39%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.84%
10											5.31%	1.77%	3.15%	0.20%	0.20%	0.00%	1.18%	0.00%	0.20%	0.00%	0.00%	0.00%	0.39%	12.60%
11												0.20%	3.15%	0.20%	0.20%	0.00%	5.51%	0.20%	1.57%	0.00%	0.59%	0.59%	0.59%	12.40%
12													0.39%	0.00%	0.00%	0.00%	0.20%	0.00%	0.20%	0.20%	0.39%	0.20%	0.20%	1.77%
13														0.00%	0.20%	0.00%	1.38%	0.79%	0.39%	3.35%	0.98%	2.95%	1.57%	11.61%
14															0.00%	0.00%	0.39%	0.00%	0.39%	0.98%	0.20%	0.98%	0.79%	3.74%
15																0.00%	0.00%	0.59%	0.00%	0.20%	0.00%	0.39%	0.00%	1.18%
16																	0.00%	0.00%	0.20%	3.74%	0.00%	0.98%	1.18%	6.10%
17																		0.20%	0.20%	2.17%	0.39%	0.39%	0.20%	3.54%
18																			0.00%	0.00%	0.00%	0.00%	0.20%	0.20%
19																				0.59%	0.20%	0.00%	0.00%	0.79%
20																					0.00%	0.00%	0.00%	0.00%
21																						0.00%	0.00%	0.00%
22																							0.00%	0.00%
23																								0.00%
	0.00%	0.00%	0.00%	0.20%	0.20%	0.00%	0.39%	6.89%	5.71%	6.10%	22.44%	5.12%	12.01%	0.59%	0.59%	0.39%	9.06%	1.77%	1.77%	12.80%	2.17%	6.69%	5.12%	100.00%

**Table A.21: NE Spring 2012, AM Period: 6 Trips, 224 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
1		0.00%	0.00%	0.00%	0.00%	0.45%	0.00%	0.00%	1.79%	0.00%	0.45%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.68%	
2			0.00%	0.00%	0.00%	0.45%	0.00%	0.45%	2.23%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.13%	
3				0.00%	0.00%	0.89%	0.00%	1.79%	16.96%	0.89%	0.45%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	20.98%	
4					0.00%	3.13%	0.00%	5.36%	20.98%	4.02%	0.45%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	33.93%	
5						0.00%	0.00%	1.34%	0.45%	0.00%	0.45%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.23%	
6							0.00%	0.45%	3.57%	0.00%	1.34%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.36%	
7								0.00%	1.34%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.34%	
8									0.89%	0.45%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.34%	
9										0.00%	0.00%	0.00%	0.00%	0.45%	0.00%	0.45%	0.00%	0.89%	0.00%	1.79%	
10											0.00%	0.00%	0.00%	0.00%	0.89%	0.00%	0.00%	0.45%	0.00%	1.34%	
11												0.45%	0.00%	0.00%	4.46%	0.45%	0.45%	1.34%	0.00%	8.48%	
12													0.45%	0.00%	4.46%	1.34%	0.45%	1.79%	0.00%	8.48%	
13														0.00%	4.02%	1.79%	0.00%	0.89%	0.45%	7.14%	
14															0.00%	0.00%	0.45%	0.00%	0.00%	0.45%	
15																0.45%	0.45%	0.45%	0.00%	1.34%	
16																	0.00%	0.00%	0.00%	0.00%	
17																		0.00%	0.00%	0.00%	
18																				0.00%	
19																					0.00%
	0.00%	0.00%	0.00%	0.00%	0.00%	4.91%	0.00%	9.38%	48.21%	5.36%	3.12%	0.45%	1.79%	0.45%	13.84%	4.46%	1.79%	5.80%	0.45%	100.00%	

**Table A.22: NE Spring 2012, PM Period: 14 Trips, 522 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
1		0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.39%	0.39%	0.58%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.55%	
2			0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.78%	0.19%	0.00%	0.39%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.55%	
3				0.00%	0.19%	0.19%	0.19%	0.39%	2.52%	0.97%	0.39%	0.39%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.24%	
4					0.00%	0.39%	0.58%	0.78%	0.97%	2.33%	1.55%	0.58%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.18%	
5						0.58%	0.00%	0.39%	0.19%	0.39%	0.19%	0.58%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.33%	
6							0.19%	0.58%	3.30%	3.88%	1.17%	0.78%	0.19%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.10%	
7								0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
8									0.19%	0.39%	0.58%	0.19%	0.00%	0.00%	0.19%	1.55%	0.00%	1.17%	1.17%	5.44%	
9										0.00%	0.78%	0.78%	0.00%	0.19%	0.19%	1.94%	1.94%	5.24%	4.47%	15.53%	
10											0.00%	0.00%	0.00%	0.78%	0.00%	0.39%	0.00%	0.58%	0.39%	2.14%	
11												0.78%	1.17%	0.58%	1.36%	4.85%	0.58%	3.88%	2.14%	15.34%	
12													0.39%	0.19%	1.94%	5.24%	2.33%	1.94%	1.17%	13.20%	
13															0.19%	2.33%	4.66%	0.78%	6.80%	17.28%	
14																0.00%	0.00%	0.00%	0.00%	0.00%	
15																	1.17%	0.19%	0.78%	0.97%	
16																		0.00%	0.00%	0.00%	
17																			0.00%	0.00%	
18																				0.00%	
19																					0.00%
	0.00%	0.00%	0.00%	0.00%	0.19%	1.36%	0.97%	2.72%	8.35%	8.74%	4.66%	4.47%	1.75%	1.94%	6.02%	19.81%	5.83%	20.39%	12.82%	100.00%	

**Table A.23: CC Spring 2012, PM Period: 4 Trips, 98 Total Passengers**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1		0.00%	1.05%	0.00%	1.05%	1.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.16%
2			2.11%	2.11%	5.26%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.47%
3				1.05%	1.05%	6.32%	0.00%	4.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	12.63%
4					1.05%	9.47%	0.00%	2.11%	0.00%	0.00%	0.00%	0.00%	0.00%	1.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	13.68%
5						3.16%	1.05%	4.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.42%
6							0.00%	1.05%	0.00%	1.05%	0.00%	0.00%	0.00%	0.00%	1.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.16%
7								0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
8									0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
9										0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
10											0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.05%	0.00%	0.00%	0.00%	0.00%	1.05%
11												0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
12													0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
13														0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
14															0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
15																0.00%	1.05%	0.00%	5.26%	3.16%	0.00%	0.00%	9.47%
16																	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
17																		5.26%	4.21%	1.05%	1.05%	0.00%	11.58%
18																			0.00%	2.11%	4.21%	0.00%	6.32%
19																					3.16%	0.00%	3.16%
20																						3.16%	0.00%
21																							0.00%
22																							0.00%
	0.00%	0.00%	3.16%	3.16%	8.42%	20.00%	1.05%	11.58%	0.00%	1.05%	0.00%	0.00%	1.05%	0.00%	1.05%	0.00%	6.32%	9.47%	14.74%	7.37%	11.58%	0.00%	100.00%

**Appendix B: CTL assignments and exam questions developed and used in courses during academic year 2011-2012**

On the following pages, the various course assignments, projects, and exam questions are included. They include:

Exam Question used in *Civil/Environmental Engineering 540: Civil and Environmental Engineering Systems*

Assignment used in *Civil Engineering 570: Transportation Engineering and Analysis*

Exam Questions used in *Civil Engineering 570: Transportation Engineering and Analysis*

Part I of Project used in *Civil Engineering 670: Urban Public Transportation*

Part II of Project used in *Civil Engineering 670: Urban Public Transportation*

**The Ohio State University**  
**Autumn Quarter 2011**  
**CE/EnE 540: CIVIL AND ENVIRONMENTAL ENGINEERING SYSTEMS**

Exam III: Wed. Dec. 7, 2011

**Problem 6 (6 pts)**

Consider a change from the “basic” CABS bus scheduling LP problem in which there are now to be four buses scheduled on the CC route. As a reminder, this is the “four-bus” problem you were to run in Lindo. The formulation of this problem is presented as “Exhibit 6” on the next page.

a. (2 pts) What is the scheduled time between consecutive buses traveling on the same route?

b. (2 pts) Which routes have travel or dwell times with non-zero dual variables?

c. (2 pts) If the bus required at least 7.2 minutes to travel on the first portion of the CC route (*i.e.*,  $TCI \geq 7.2$ ), what would you expect to be the new optimal headway between buses on the same route?

Exhibit 6 LP Formulation of the Four-bus CABS Bus Scheduling Problem

min H

subject to

! 1 Physical facts for headway and cycle time

(1)  $TN1+TN2+TN3+DN1+DN2+DN3-RTN=0$

(2)  $TS1+TS2+TS3+DS1+DS2+DS3-RTS=0$

(3)  $TC1+TC2+TC3+DC1+DC2+DC3-RTC=0$

(4)  $RTN-4H=0$

(5)  $RTS-4H=0$

(6)  $RTC-4H=0$

! 2 Lower bounds on travel times and dwell times

! Constraints for CLN

(7)  $TN1 \geq 9.2$

(8)  $TN2 \geq 15.4$

(9)  $TN3 \geq 5.6$

(10)  $DN1 \geq 0.25$

(11)  $DN2 \geq 0.25$

(12)  $DN3 \geq 0.25$

! Constraints for CLS

(13)  $TS1 \geq 13.4$

(14)  $TS2 \geq 9.6$

(15)  $TS3 \geq 6.6$

(16)  $DS1 \geq 0.25$

(17)  $DS2 \geq 0.25$

(18)  $DS3 \geq 0.25$

! Constraints for CC

(19)  $TC1 \geq 6.2$

(20)  $TC2 \geq 7$

(21)  $TC3 \geq 12.6$

(22)  $DC1 \geq 0.25$

(23)  $DC2 \geq 0.25$

(24)  $DC3 \geq 0.25$

! 3 Even inter route headways

(25)  $STN=0$

(26)  $STS-0.5H=0$

(27)  $TN1+DN1-0.5H-STC-TC1-DC1=0$

(28)  $STS+TS1+DS1-0.5H-STC-TC1-DC1-TC2-DC2=0$

End

**The Ohio State University**  
**Winter Quarter 2012**  
**CE 570: TRANSPORTATION ENGINEERING AND ANALYSIS**

Assignment #2: CABS OD flow and travel time analysis from CTL data  
Date handed out: Wed. Jan. 18, 2012  
Date due: Mon. Jan. 30, 2012

### **Background**

OSU's Campus Area Bus Service (CABS) has been recently instrumented with several sensor systems. These systems allow bus arrival information to be provided to travelers, CABS staff to better operate the service, researchers to study the behavior of bus systems, and students to learn about bus systems in an hands-on manner. For the latter two purposes, the instrumented system serves as a field lab known as the Campus Transit Lab (CTL).

There are two main sensor systems we are concerned with in this assignment: Automatic Passenger Counters (APC) and Automated Vehicle Location (AVL) systems. APC systems measure the number of passengers boarding and alighting at each bus stop. AVL systems measure the location and time of each bus at a high frequency.

A "bus trip" is defined to be one complete traversal by a bus on a route from one end of the route (the starting terminal) to the other end of the route (the ending terminal). The CABS Campus Loop South (CLS) route forms a loop. To simplify the analysis, all four stops on West Campus are grouped to form one stop. As shown in Figure 1 depicting the CLS route, stop 4 represents the grouping of all boardings at stops 1 through 4 and is considered to be the starting terminal of the route, and stop 21 represents the grouping of all alightings at stops 1 through 4 and is considered to be the ending terminal of the route. This simplification is reasonable because it is very unlikely for travelers to start their trips (*i.e.*, board) east of the grouped West Campus stops, travel westbound through the West Campus stops, and end their trips (*i.e.*, alight) east of the grouped West Campus stops.

### **Problem 1**

APC data on an *Autumn 2010* CLS bus trip are sent to you via e-mail in the form of an Excel file. Different data are being sent to different students, so make sure to work with the data sent to you.

- (a) In a well labeled and numbered or lettered appendix, present a hard copy of the data sent to you, including the "header information." In the main body of the report, you should write something like, "The APC data used in Problem 1 appear in Appendix A".
- (b) Apply the Iterative Proportional Fitting (IPF) method to estimate the stop-to-stop origin-destination (OD) passenger flows for the specific bus trip APC data sent to you using Excel (or other software such as MATLAB if you prefer). In addition to the zero entries of the seed matrix discussed in class, a seed value of zero should also be included for flow from stop 4 to 21 reflecting the assumption that no one makes a single trip starting (boarding) at one of the West Campus stops and ending (alighting) back at one of the West Campus stops. Conduct a total of three pairs of iterations, where each pair consists of one row and one column adjustment (*i.e.*, conduct iterations 1a, 1b, 2a, 2b, 3a, and 3b). Present the passenger flow estimates you arrive at upon completing iteration 3b in the form of a table (matrix). (Include the results of all the iterations in a second well-labeled appendix, label it "Appendix B".) Show an example calculation for at least one cell value going through a row and column adjustment.

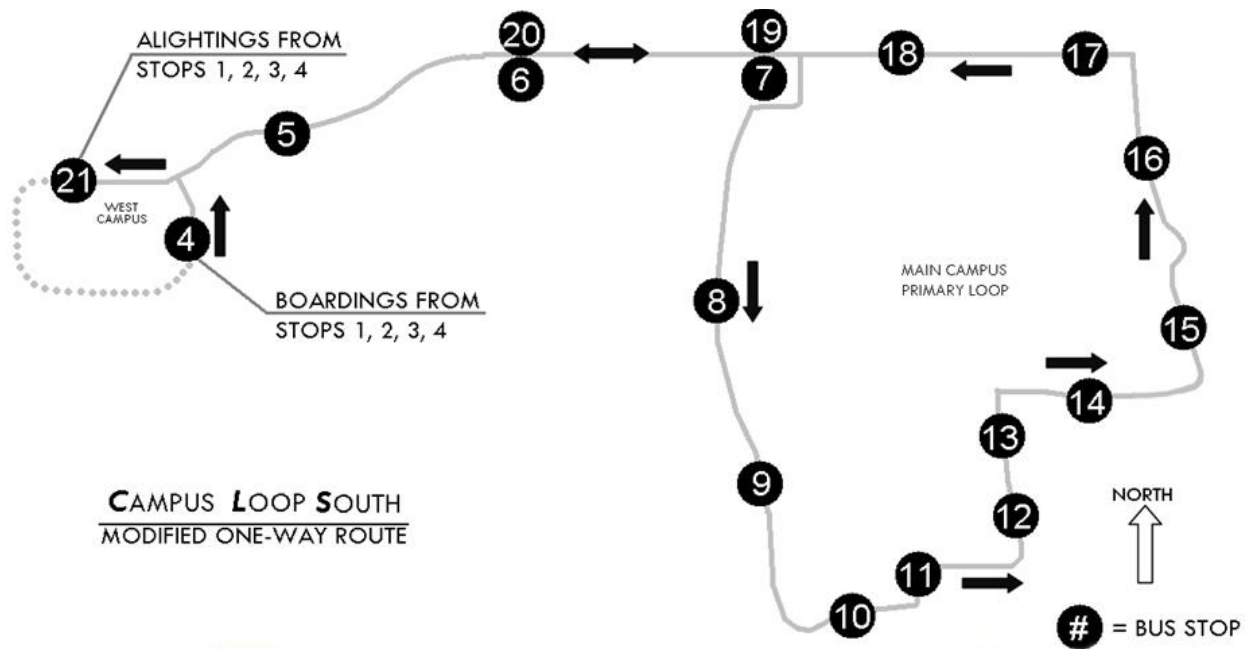


Figure 1: Campus Loop South (CLS) route map

- (c) Based on the number of passengers traveling to each destination stop from the West Campus starting terminal (grouped stop 4) determined under (b) above, determine the conditional probability that a passenger who boarded at the West Campus starting terminal will alight at each destination stop (*i.e.*, stops 5 through 20). Present your results in a well-labeled table, explain the logic behind your calculations, and use an example calculation to help in the explanation.

### Problem 2

AVL data on many *Autumn 2010* CLS bus trips are used to calculate the following: (i) expected (or average) time it takes a bus to travel from one stop to the next (where the travel time equals the arrival time at the next stop minus the departure time from the previous stop) and, (ii) expected (or average) dwell time at each stop (where dwell time equals the departure time from a stop minus the arrival time to that same stop). The results are shown in Tables 1 and 2.

For each destination stop, determine the expected time *in minutes* that it takes a passenger to arrive at her or his stop once the bus has left the West Campus starting terminal. That is, find the expected line-haul time from West Campus (stop 4) to each destination stop (stops 5 through 20). Present the results in a well-labeled table, explain the logic behind your calculations, and show at least one example calculation.

### Problem 3

Using your solutions from Problems 1 and 2 above, find the expected line-haul time for a random passenger boarding at the West Campus starting terminal. (The expected line-haul time represents the expectation considered across all possible destination stops.) Present and show your calculation.



Table 1: Expected Stop-to-Stop Travel Times for Autumn 2010

From Stop	To Stop	Time (sec)
Carmack 1 (4)	Blankenship Hall (5)	105.70
Blankenship Hall (5)	AG Campus (EB) (6)	86.04
AG Campus (EB) (6)	St John Arena (EB) (7)	58.51
St John Arena (EB) (7)	Drake Union (8)	111.13
Drake Union (8)	Cannon and 12th (SB) (9)	100.36
Cannon and 12th (SB) (9)	Med Center and Cannon (EB) (10)	108.51
Med Center and Cannon (EB) (10)	Med Center and 9th Ave (11)	50.59
Med Center and 9th Ave (11)	Neil and 10th Ave (12)	81.11
Neil and 10th Ave (12)	Mack Hall (13)	71.65
Mack Hall (13)	Hale Hall (14)	117.94
Hale Hall (14)	Ohio Union (NB) (15)	113.23
Ohio Union (NB) (15)	Arps Hall (16)	102.88
Arps Hall (16)	North Dorms (17)	105.35
North Dorms (17)	Fisher College (18)	85.52
Fisher College (18)	St John Arena (WB) (19)	64.67
St John Arena (WB) (19)	AG Campus (WB) (20)	59.16

Table 2: Expected Dwell Times for Autumn 2010

Stop Name (Stop Number)	Dwell Time (sec)
Blankenship Hall (5)	5.12
AG Campus (EB) (6)	16.48
St John Arena (EB) (7)	8.02
Drake Union (8)	14.53
Cannon and 12th (SB) (9)	9.81
Med Center and Cannon (EB) (10)	5.74
Med Center and 9th Ave (11)	6.55
Neil and 10th Ave (12)	16.74
Mack Hall (13)	23.72
Hale Hall (14)	12.48
Ohio Union (NB) (15)	7.78
Arps Hall (16)	25.62
North Dorms (17)	20.50
Fisher College (18)	34.82
St John Arena (WB) (19)	8.63
AG Campus (WB) (20)	24.31

#### Problem 4

The stop-to-stop travel times and stop dwell times extracted from AVL data on 150 *Autumn 2011* CLS bus trips are also sent to you via e-mail in the form of an Excel file organized in two separate sheets, one containing the stop-to-stop travel times for the 150 bus trips and the other containing the dwell times for the 150 bus trips. (Note: You do not need to provide these data in your report.)

- (a) Calculate the average stop-to-stop travel times and the average dwell times based on the provided *Autumn 2011* AVL information on the 150 bus trips using Excel (or other software, such as MATLAB, if you prefer). (Recall, in Excel you could use the function `AVERAGE(...)` to calculate the average.) Present your results in two (well-labeled) tables, one for stop-to-stop travel times and the other for stop dwell times, similar to Tables 1 and 2 of this assignment. To validate your solutions, the average stop-to-stop travel time from stop 11 to stop 12 is 94.65 sec, which falls approximately in the middle range of the average stop-to-stop travel times, and the average dwell time at stop 16 is 21.85 sec, which falls approximately in the middle range of the average dwell times. Briefly compare the *Autumn 2011* average stop-to-stop travel times and stop dwell times with those of *Autumn 2010* (shown in Tables 1 and 2).
- (b) Calculate the standard deviation of the stop-to-stop travel times and the standard deviation of dwell times based on the provided *Autumn 2011* AVL information on the 150 bus trips using Excel (or other software such as MATLAB if you prefer). (Recall, in Excel you could use the function `STDEV(...)` to calculate the standard deviation.) Present your results in two tables, one for stop-to-stop travel times and the other for stop dwell times – feel free to combine the results of this question with those of part (a) above in the same tables. Either way, make sure to label your tables and column headings clearly. To validate your solutions, the standard deviation of stop-to-stop travel time from stop 17 to stop 18 is 29.64 sec, which falls approximately in the middle range of the standard deviations of stop-to-stop travel times, and the standard deviation of dwell time at stop 13 is 17.53 sec, which falls approximately in the middle range of the standard deviations of dwell times.
- (c) Based on the results from part (b) above, identify the stop-to-stop segment that has the largest standard deviation of travel time and the stop that has the largest standard deviation of dwell time. Indicate both that segment and that stop on the map of the CLS route. (Consider this a figure, so it should be labeled appropriately. It can be labeled by hand.) A map like that of Figure 1 is sent to you via e-mail for you to print and use in providing your answer to this question.

**The Ohio State University  
Winter Quarter 2012**

**CE 570: TRANSPORTATION ENGINEERING AND ANALYSIS**

Exam 1 (50 points)  
Date: Feb. 10, 2012

**Problem 3**

- a. (2 pts) APC systems on CABS measure the total number of passengers boarding and alighting through each of the two doors of a bus. The totals measured for each door are then converted to the number of passengers alighting and the number of passengers boarding, for a given bus at a given stop, by assuming that passengers alight using the rear door of the bus and board using the front door of the bus. Circle “T” if true, or “F” if false:

T                  F

- b. (1 pt) All CABS buses are equipped with APC systems but only a certain percentage of the buses are equipped with AVL systems. Circle “T” if true, or “F” if false:

T                  F

**Problem 4**

After some number of iterations, the IPF OD flow estimates for a bus trip consisting of six stops are shown in Table 4.1.

Table 4.1: IPF OD flow estimates

		Alighting stop # ( <i>i</i> )					
		1	2	3	4	5	6
Boarding stop # ( <i>j</i> )	1	0.00	0.00	2.72	4.39	8.59	9.15
	2	0.00	0.00	3.28	5.31	10.40	11.06
	3	0.00	0.00	0.00	3.30	6.47	6.89
	4	0.00	0.00	0.00	0.00	5.54	5.90
	5	0.00	0.00	0.00	0.00	0.00	0.00
	6	0.00	0.00	0.00	0.00	0.00	0.00

- a. (3 pts) Based on the results shown in Table 4.1, determine the probability that a random passenger alights at stop 5 given that s/he boarded at stop 2. Show your calculations.
- b. (2 pts) Based on the results shown in Table 4.1, determine the probability that a random passenger alights at stop 5 given that s/he boarded at *either stop 1 or stop 2*. That is, we are interested in the probability of passengers coming from stops 1 or stop 2 and alighting at stop 5. Show your calculations.
- c. (4 pts) Table 4.2 below shows the APC boarding and alighting counts for the same bus trip for which IPF OD flow estimates are shown in Table 4.1 above. Determine the IPF OD flow estimate for cell (3,5) by applying the *next* adjustment (only *one* adjustment) to the cell value 6.47 from Table 4.1. Show your calculations.

Table 4.2: APC counts for a bus trip

		Alighting stop # ( <i>i</i> )						APC ons
		1	2	3	4	5	6	
Boarding stop # ( <i>j</i> )	1							31
	2							30
	3							14
	4							8
	5							0
	6							0
APC offs		0	0	6	13	31	33	

# CE 670 Urban Public Transportation

## Winter 2012

Project – Part I: Campus Area Bus Service Operations – Data Collection  
Date handed out: Thurs. Jan. 19, 2012  
Date due: Tues. Jan. 31, 2012

### Instructions

This project deals with the service provided by and operations of routes operated by Campus Area Bus Service (CABS). You are to form 5 teams, 3 teams with *four* students per team and 2 teams with *three* students per team. Each team should have *exactly one* CE graduate student, *exactly two* CE undergraduate students, and *at most one* CRP or Geography student.

The project consists of two parts: (I) data collection, and (II) analysis. Each team should submit a comprehensive report addressing each part. The reports should reflect the team's own *independent* work.

In addition, each team member should submit one "Peer- and Self-evaluation Form" in relation to each of the other members of the team (three copies of this form are included at the end). Please submit these completed forms to me separately (i.e., do not include them with your team's report). *The individual team member project grade will be partly based on this submission.*

### Data Collection

Each team will study a specific route as indicated in Table 1. Field data should be collected such that the *reference stop* shown in Table 1 for each team is observed for a *continuous* 2.5-hour period. You are to schedule your data collection to cover the class times (2.30-4.18p) on Tues Jan 24 or Thurs Jan 26. *The CLN-1 and CLN-2 teams should not collect data on the same day and time. Similarly, the CC-1 and CC-2 teams should not collect data on the same day and time.* (If for a good reason a team is unable to collect data to cover the class time, the alternate time must be cleared with the instructor and the selected 2.5-hour period must be between 7.00a and 6.00p on a weekday.) Make sure you record and report the time period you select along with the corresponding date.

The CABS web site provides route maps, the locations of all the stops, and scheduled headways (durations between bus arrivals). Visit this site at <http://tp.osu.edu/cabs/> to access this information. In addition, the Transportation Route Information Program (TRIP) provides real-time information on expected arrival times of buses at stops in a list format and the location of the buses in a map format. Visit this site at <http://tp.osu.edu/cabs/trip.shtml> to access this information.

You are collecting data in order to analyze and estimate models of passenger waiting times, stop dwell times (stationary times spent at stops by buses), and cycle times (times it takes buses to traverse the entire length of a route). You are to also

compare the data you collect in the field with automatically collected data you will be provided at a later point.

Team	Route	# of students	Reference Bus Stop (Stop ID)
CLN-1	Campus Loop North	4	Hamilton Hall (33)
CLN-2	Campus Loop North	4	Koffolt Lab (58)
CLS	Campus Loop South	4	Ohio Union (NB) (43)
CC-1	Central Connector	3	Knowlton Hall (57)
CC-2	Central Connector	3	Mack Hall (41)

Table 1: Routes and Reference Bus Stop for Each Team

The number of buses scheduled on each team’s route is equal to the number of students in each team. However, sometimes the number of buses operating on a route is reduced by one depending on staffing availability. In the event that at the time of data collection all scheduled buses are in operation, each student will be riding one of these buses for the purpose of data collection. Otherwise, the “left-out” student should be stationed at the *reference stop* shown in Table 1 for each team for the duration of the data collection.

Data collection *starts* and *ends* at the reference stop. One member of the team should be designated to collect data while standing at the reference stop as soon as the first member of the team boards the first arriving bus on your route. This designated member will continue collecting data from the reference stop until all team members have boarded successive buses. If the number of buses on the route is as scheduled, this team member then boards the next bus and continues the data collection while riding the bus like the other team members. Otherwise, this designated team member will be the “left-out” student who remains at the reference stop collecting data from that perspective. The data collection ends when the last student who boards makes it back to the reference stop 2.5 hours after the first student boards the reference stop.

Whether riding a bus or observing buses while stationed at the reference stop, the *minimum* data requirements are the following:

- bus number,
- number of passengers on the bus (passenger load) upon starting the data collection on each bus,
- bus arrival and departure times *at each stop* including the time the bus spends letting passengers on and off and the time the bus spends stationary without any boarding and alighting activity should this occur,
- number of passengers boarding and number alighting *at each stop*, and
- passenger loads upon both bus arrival and departure when collecting data from the reference stop.

Bus arrival times observed in the field should be based on the first door to open and departure times on the last door to close or the instant the bus departs. Should a bus spend more time than needed to allow passengers to board and alight, make a note of this extra time. The doors may or may not remain open in the absence of boarding and alighting activity. What is relevant is to make a distinction between the time for boarding and alighting activity and the time with no such activity before the bus departs. Passenger loads (number of passengers on a bus), and to a lesser extent the number of passengers boarding and alighting, might be difficult to measure at times. In such cases, try to approximate these values as best as you can and indicate that you are conducting an approximation in such cases. Times should be recorded to the nearest second. *Finally, all team members should synchronize their watches shortly before data collection to the time indicated on the TRIP website.*

Well before collecting any data, however, it is strongly recommended that members of each team meet to organize their data collection effort in terms of addressing matters such as deciding on the period of time during which data will be collected, specifying the type of data to collect in the field, and designing and producing data collection forms. It is also highly advisable that team members conduct a dry-run together prior to the actual data collection effort to ensure that nothing has been overlooked, avoid making mistakes during data collection, and maintain consistency during data collection.

## **Report**

For part I the report should include the following:

- description of the field data collection effort,
- route map with reference stop indicated,
- name of student collecting data on each bus and reference stop,
- sample data collection forms,
- description of the data collected,
- tabulation of the collected raw data, and
- raw data saved in Excel and e-mailed to the instructor <mishalani@osu.edu>.

The report should be *single-sided* and *double-spaced* with *1-inch margins* (all sides).

The Excel file should be named as follows: <CE670\_WI\_2012\_TeamName\_Data.xlsx>.

The “TeamName” is as shown in the first column of Table 1.

**CE 670 Urban Public Transportation**  
**Winter 2012**  
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I urge you to provide feedback to your teammates as your work progresses. Your objective is to aim for providing a positive evaluation of each other at the end of the process. You should submit these evaluation forms (one in relation to each of your team-mates) to me independently of your team's report. Nevertheless, I encourage you to discuss your evaluation with your teammates. This, however, is only a recommendation and is not a requirement.

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2. Your team's name:
3. Name of team member you are evaluating:
4. Please score the team member named above on a scale of 1 to 7 (1 = unacceptable, 2 = poor, 3 = mediocre, 4 = fair, 5 = good, 6 = very good, 7 = excellent) with regard to the following:
  - a. Contribution to and performance on data collection preparation: Score = \_\_\_\_.
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# CE 670 Urban Public Transportation

## Winter 2012

Project – Part II: Campus Area Bus Service (CABS) Operations – Analysis

Date handed out: Thurs. Feb. 16, 2012

Date due: Tues. March 6, 2012

### Instructions

In part II of this project, continue to work with your team and use the data you collected in part I to address the various problems. Each team should submit a comprehensive report describing the analysis and results. If you need to refer to any materials you submitted in your part I report, please include those materials again in your part II report.

The report should be *single-sided* and *double-spaced* with *1-inch margins*, and use a *font size of 12*. Once again, the report should be the team's own *independent work*.

In addition, each team member should submit one peer- and self-evaluation form (three copies of this form are included at the end) in relation to each of the *other* members of the team. Please submit the forms to me separately (*i.e.*, do not include them with your team's report). *The individual team member project grade will be partly based on this submission.*

### Problem 1: Bus Headways and Passenger Wait Times

- a. Based on your field observations, determine all the headways at your reference bus stop plus three additional stops of your choosing. The set of four stops should be roughly evenly distributed along the length of the route. You might consider other factors in making your choice. Briefly justify your selection. (*CC-1 team: consider your reference stop plus the only other additional stop you observed data at; naturally, the last three sentences above do not apply to you.*)
- b. Estimate the headway probability density function (pdf) using an histogram at each of the four (*two for CC-1 team*) bus stops of question (a) above. Also estimate the headway *empirical* cumulative density function (cdf) at *each* of the bus stops. Describe the nature of these functions.
- c. Based on your estimates of the headway means and variances, determine the mean passenger waiting time at *each* of the bus stops. Compare *half* the estimated mean headway with the mean passenger waiting time for each bus stop. Discuss the significance of this comparison and interpret your results.
- d. Compare the estimated headway pdfs and *cdfs across* the stops. Compare the mean passenger waiting times *across* the stops. Interpret your results.

## Problem 2: Bus Dwell Times

In this exercise you are to formulate and estimate one or more bus dwell time functions (models), which describe bus dwell times for your reference bus stop. The dwell time is the time a vehicle requires to discharge and take on passengers at a stop including opening and closing doors and the holding time (*i.e.*, the *additional* time spent standing beyond the time necessary to allow passengers to board and alight).

- a. Use ordinary least squares regression for your estimation (using Excel is recommended, but you may use any other statistical software tool). Justify your choice of explanatory variables and model specification. Present interesting models you have estimated but may decide not to recommend for use in predicting dwell times. Depending on the nature of your data, consider developing models for dwell time and models for dwell time *less* the holding time.
- b. Critically assess the quality of your estimated model(s) and justify your decisions regarding the models you chose to adopt and the ones you decided not to adopt.

## Problem 3: Bus Running Times

- a. Estimate the bus running time (as measured with respect to your reference stop) pdf and cdf (again, using a histogram and an ecdf).
- b. Is the number of busses *scheduled* to operate on the route you are studying reasonable given the *published* headway for your route? Make any necessary assumptions and justify your answer.

## Problem 4: AVL and APC data vs. Field Data

In this exercise you are interested in comparing the Automatic Vehicle Location (AVL) and Automatic Passenger Count (APC) data covering the same time period and service you observed in the field. The AVL and APC data will be provided to you in an Excel file via e-mail.

- a. Compare the field bus arrival and departure times for the stops you analyzed in Problem 1 to the corresponding information collected through the AVL technology.
- b. Compare the field passenger boarding and alighting counts for the stops you analyzed in Problem 1 to the corresponding information collected through the APC technology.

Assess the accuracy of the AVL and APC data in questions (a) and (b) above at the individual datum level. That is, you are to examine differences in the data at the specific bus and stop levels before calculating any summary statistics. In other words, you are not to aggregate the data before examining the differences.

**Problem 5: Recommendations**

- a. Based on your answers to the above questions, what are the problems or issues that you think CABS should be made aware of?
- b. Based on your answer to question (a) above, what are the recommendations you have for CABS with regard to improving operations, service, and passenger information provision, if any? Whether you recommend improvements or not, please justify your answer.

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