Bus Supervision Deployment Strategies and the Use of Real-Time AVL for Improved Bus Service Reliability

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ABSTRACT

Bus service reliability has always been a top concern for transit agencies and their customers. In the past however, service reliability has not been easy to address. The use of recovery times, advanced operator training, and street supervision has produced limited results. This research will focus on supervision deployment strategies and the use of real-time Automatic Vehicle Location (AVL) information in order to improve on the current supervision practice and enhance bus service reliability.

The Chicago Transit Authority's (CTA) real-time AVL pilot project for Route 20 Madison will serve as the case study in the evaluation of the effectiveness of real-time AVL. A simulation model of the route is developed based on archived AVL data and is used to predict the effects on service reliability when real-time AVL information is utilized by bus supervision. A week long experiment is also carried out to verify the model as well as to address the feasibility and scalability issues of the system.

The main conclusion of this research is that real-time AVL has great potential to improve service reliability as shown in the case study. Service restoration strategies previously impossible to execute are now available thanks to this new information stream. However, there are still many obstacles for network wide implementation, including the supervision communications structure, and manpower deployment questions. The flood of information into a central control center must also be addressed. Automation techniques and exception based reporting are suggested possibilities.

INTRODUCTION

For transit agencies that try and provide quality customer service, bus service reliability is one of their top priorities. Unfortunately, there are several factors detrimental to reliable bus service. Outside influences such as weather, traffic, and road construction can wreck havoc on even the best laid plans. Internally, poor planning, insufficient maintenance, and schedule adherence problems can work to undermine bus service reliability (Levinson, 1991).

To counteract these factors, transit agencies typically deploy field supervisors in conjunction with establishing a centralized control center as part of a bus service management program. The supervisors and the control center are then empowered to make real-time operating decisions regarding the buses on the street. Field supervisors can assist operators with defective equipment for example, or offer them instruction in order to restore "normal" bus service.

For a bus supervision force to be effective, they must have information on the routes they are responsible for. Information such as bus locations, headways, and schedule adherences, needs to be in the hands of those who can act on it, typically the field supervisors in most transit agencies. When armed with the most complete information, field supervisors are able to utilize a number of operations control strategies that can improve bus service reliability, such as holding, expressing, and short-turning.

Literature Review

Strathman et al. (2001) completed a thorough overview of operations control research in their paper covering a similar experiment at Portland, Oregon's Tri-Met. Strathman et al. cites a study by Abkowitz and Engelstein (1984) that finds it is the passengers waiting downstream of a control point who realize the benefits of control.

A report by Turnquist (1982) is cited for showing that the "Prefol" strategy of "holding a vehicle until the preceding headways is as close as possible to the following headway" is more beneficial than holding only to the scheduled headway. The "Prefol" strategy however requires information on the arrival time of the following vehicle – data real-time AVL information can provide.

Strathman et al. (2001) summarizes some of the contributions of prior operations control research. Most notable for this study are:

- "Holding is most likely to be more effective at earlier points along a route"
- "Decision rules should be developed to assist field supervisors in making choices to implement control or not"
- "Control should be analyzed using data from actual transit operations"

Levinson (1991) surveyed 20 North American transit agencies and summarized each agency's approach to bus supervision. Levinson comments on the importance of a "fast exchange of information" among supervisors to reduce response times.

CTA Real-Time Network Pilot Project

The Chicago Transit Authority (CTA) is currently in the process of implementing real-time automatic vehicle location (AVL) technology for its bus system. A pilot project is underway on the Route 20 Madison bus route that would report the location and schedule adherence of buses in real-time on a computer generated map in the control center. As shown in Figure 1, bus locations are reported by a circular icon superimposed on a map of Chicago. The icons update their positions and color several times per minute to reflect the bus locations and schedule adherences respectively.

The pilot project involves outfitting 39 buses with the computing and communications gear necessary to track their location in real-time. Along with their location, buses also report their:

- Schedule adherence
- Bus identification number
- Run number
- Route
- Operator badge number
- Previous timepoint
- Next timepoint

The bus ID number, route and run number are reported within their respective bus icon. Schedule adherence is reported numerically within the icon as well as reflected in the icon color (yellow – more than 5 minutes late; orange – more than 1 minute early; green – 5 minutes or less late, 1 minute or less early). Operator and timepoint information is reported on a separate table located on a second computer screen.

In this study, a dispatcher at the control center will monitor Route 20 during the AM peak for four days utilizing the real-time AVL information. Operations control decisions are made by the control center and then passed on to the field supervisors for execution via cell phone. It is hypothesized that if field supervisors have real-time AVL information, by way of the control center in this study, then they can be more effective with their operations control strategies and this will result in more reliable bus service.

Route 20 Description

In the AM peak, Route 20 runs east-west along Madison Avenue from its western terminal at Austin to its eastern terminal at Columbus in the Chicago Loop. Due to the one way streets downtown, Route 20 eastbound east of Halsted runs on Washington Street. Heading west, Route 20 runs on Madison Avenue from Michigan Avenue. Figure 2 shows the alignment and boarding and alighting counts for Route 20.

The CTA has established several timepoints along the route. It is at these points where headway and schedule adherence data is sampled for the analysis of the route. Table 1 summarizes the key timepoints analyzed in this study.

During a normal weekday, there are two post supervisors on Madison Avenue and one mobile supervisor whose patrol area includes Route 20. The post supervisors are located at Pulaski and Ashland and are also responsible for the bus routes on their respective cross streets.

Eleven eastbound runs were selected for this study and their schedule can be found in Table 2. The scheduled headway for each run is 5 minutes. The scheduled eastbound running time is 60 minutes plus 8-10 minutes of recovery time at the Columbus terminal. Before departing Austin, five of the eleven eastbound trips first pull directly out of the garage and have 3 minutes of recovery time. The other six eastbound trips have 8 minutes of recovery time at Austin following their previous westbound trip.

Demand for Route 20 is characterized by two peak load points – one just west of Kedzie, and the other at Halsted. The load profile which was measured over three AM peak periods from November 17-19, 2003 is shown in Figure 3. On the y-axis is the cumulative observed load and on the x-axis are the key timepoints from west to east.

Most of the drop in load at Kedzie can be attributed to two schools in the vicinity. Lower passenger activity between Kedzie and Ashland is a reflection of the relatively light development in this area. Loads build up again between Ashland and Halsted along a new residential and mixed use corridor until the Metra commuter rail station when passengers begin to alight in the Loop.

DATA

The CTA keeps a large database of archived AVL data accessible by its Bus Location Information System (BLIS) interface. The BLIS data is compiled daily at the timepoint level and reports arrival and departure times at terminals, and arrival times at timepoints. Every bus on Route 20 is equipped to report to the BLIS system in addition to the real-time AVL system.

Headway data for the 11 eastbound runs is collected for the experiment week, April 25-28, 2006, and a baseline week, April 18-21, 2006.

Service Reliability Metrics

Service reliability on Route 20 will be measured by headway regularity at the key timepoints. During the AM peak, the route is classified as a high frequency route since it has scheduled headways of 5 minutes. For this type of route passengers tend not to bother with a timetable, and to them, headway regularity is much more important than schedule adherence when waiting for a bus.

Two metrics will be used in the discussion of headway regularity – the *headway ratio distribution* and the *coefficient of variation for headway* at each timepoint. The headway ratio is the observed headway divided by the scheduled headway. Headway ratios less than one indicate a headway that is less than scheduled, while headway ratios greater than one indicate a headway greater than scheduled. Presented in this analysis will be the distribution of headway ratios at each timepoint. With perfectly regular service all trips observed at each timepoint would have a headway ratio of 1.0. This ideal distribution would result in a mean headway ratio of 1.0, and a standard deviation of 0.

The coefficient of variation is defined as the standard deviation of headways divided by the mean scheduled headway. This value is measured at each timepoint and ranges from 0 to 1 with a higher value indicating a more dispersed distribution. Ideally, the coefficient of variation at each timepoint would be 0, indicating deterministic headways.

The Transit Capacity and Quality of Service Manual (TCRP Report 100) has established level of service grades based on the coefficient of variation of headways and the probability of bunched buses as shown in Table 3. As the coefficient of variation increases, the probability of bunched buses goes up, and the level of service goes down.

STUDY DESIGN

This study focused on using the real-time AVL system to improve eastbound service reliability during the AM peak hour along the CTA's Route 20 Madison. The findings and strategies cited in the literature review are brought into this study, namely Turnquist's (1982) "Prefol" strategy.

Four post supervisors were placed along Route 20 at Austin, Pulaski, Kedzie, and Ashland. One of the authors took a position as a dispatcher in the control center and had access to the real-time AVL information. The dispatcher's only responsibility was Route 20. Each post supervisor was given a cellular phone and the dispatcher had a standard land line telephone.

The post supervisors were given no special directives except for the Austin supervisor. Austin was instructed to have eastbound runs depart every 4-5 minutes from the terminal unless told otherwise by the dispatcher. The dispatcher's primary objective was to monitor service along Route 20 and to look for any signs of unreliability – service gaps, bus bunching, late garage pullouts, or missing runs.

If the dispatcher anticipated that a westbound trip would not be able to reach Austin in time to make its 5 minute headway eastbound, the Austin supervisor would be notified immediately. This allows the supervisor to employ Turnquist's (1982) "Prefol" strategy and split the gap across the delayed bus's leader and follower. For example, if run 5073 was missing from the street, its follower, run 5052, would experience a 10 minute headway. To prevent this from happening, the dispatcher would instruct the Austin supervisor to hold run 5001 until 0731, then move up run 5052 to 0738, and run 5055 to 0744, thereby creating several smaller headways in the place of one big one.

The dispatcher would continue to monitor service as the runs traveled east to look for the formation of service gaps. If any headway became greater than 6 minutes, the appropriate supervisor at Kedzie or Ashland would be called to hold the run in front of the gap by 1-2 minutes to once again split the gap. No holding was executed at Pulaski due to the fact that this was near the first peak load point and holding a full bus was considered to be detrimental to service.

By promoting even headways at Austin and attempting to maintain them at Kedzie and Ashland, it was hypothesized that headways would become less variable throughout the route.

RESULTS

During the 4 days of the experiment, the dispatcher was able to intervene at Austin and split the gap in four cases where a run was either held in or was not going to have enough recovery time before heading eastbound. In each case, the supervisor at Austin would not have known of the approaching service gaps and therefore would not have been able to act if it were not for the real-time information called in from the dispatcher. The result of these four actions was that a potentially large headway was split across two or more runs.

Runs with headways less than 4 minutes were acted upon at Kedzie and Ashland a total of eight times. The supervisors at these timepoints were instructed to hold the runs 1-2 minutes. These runs were not held to prevent bus bunching per se, but rather to close a large headway following behind them. Although some runs could have been held longer, a decision was made not to because they were estimated to have several passengers on board who would be inconvenienced. More cases of buses with headways less than 4 minutes did occur but were not acted upon since the gap behind them was less than 6 minutes.

Compared to the same four days during the previous week, headway variation was lower at each timepoint during the experiment week. As shown in Figure 4, headway variation was at its lowest at Austin for both weeks, with the experiment week producing a 21% lower variation than the previous week. Headway variation then begins to climb at each subsequent timepoint downstream, a result that is consistent with earlier studies (Strathman et al., 2002).

Modeling Experience

A Monte Carlo simulation was created in Microsoft Excel to predict the effects of the experiment's supervision strategy. 4 weeks of archived AVL data from February and March 2006 was used to extract timepoint-to-timepoint travel time distributions and Austin departure times for the 11 runs in question. The simulator then recreated the 11 runs based off of this distribution to create "one day" of data. 30 simulated "days" were run through the simulation to find the baseline headway distribution at each timepoint and the headway distribution after implementing the supervision strategy.

From Excel, an F-test Two Sample for Variances test was conducted at each timepoint to compare the simulated baseline headway distribution against the observed 4 week headway distribution. The standard deviation of the distributions was found not to be significantly different at each timepoint except for Michigan at the 0.05 level.

After the simulation was verified to accurately depict reality, the supervision strategy of control at Austin, Kedzie, and Ashland was simulated. As shown in Figure 5, the simulation predicted a lower variation at Austin than what was actually achieved. It also predicted a much lower variation at Ashland than what occurred during the experiment. This can be attributed to the fact that not every service gap was detected by the dispatcher and holding at Ashland was much less aggressive during the experiment than what was modeled in the simulation.

DISCUSSION

This study was able to show a reduction in headway variability versus the baseline week at each of the timepoints leading up to the Loop. Controlling the departure headway at Austin and working with the real-time AVL information to prevent large headways helped to set the stage for better reliability downstream. The real-time AVL information came into play again at Kedzie and Ashland when working to close gaps from in front.

During the experiment however, it proved difficult for the dispatcher to detect every service reliability problem – delays, bus bunches, and service gaps – even though there were only 11 runs to monitor on a single route. There were some hardware and software issues such as buses not reporting in to the real-time AVL system, or reporting incorrect information, but the underlying issue was that there was just too much information for one person to process in real-time. The status of the runs at four different timepoints had to be constantly monitored. If it was determined that a service gap is forming at Austin for example, the attention of the dispatcher would be focused on formulating an action, then contacting the Austin supervisor to execute it. Meanwhile, the situation at the other three timepoints could not be simultaneously monitored until the Austin situation was resolved.

Despite this difficulty, a reduction in headway variability was still achieved as shown in Figure 4. By controlling the headways departing Austin, headway variability remained lower than the baseline at each subsequent timepoint. The spike in headway variability at Halsted during the baseline week was not apparent during the experiment week and this could be at least partially attributed to the supervisory actions upstream at Kedzie and Ashland.

CONCLUSION

This study has shown how the use of real-time AVL information could benefit service reliability along high frequency bus routes. When all headways and bus locations are known in real-time, better decisions can be made regarding the use of operations control strategies. This led to lower headway variability at every timepoint as demonstrated in the experiment.

Automating the service monitoring process would prove useful, especially if this type of real-time AVL system is to be scaled up to the entire bus network. Exception based reporting, where service gaps and delays would automatically be highlighted, would allow dispatchers and supervisors to spend most of their time managing service as opposed to monitoring it.

Training of supervisors and dispatchers will be important in the deployment of real-time information. Currently, the personnel are used to an environment without this level of information and will need the proper training to be able to take advantage of it. Standard operating procedures regarding the most common service disruptions will have to be adjusted to utilize the new real-time AVL information.

The way the real-time information is distributed will be important for scalability as well. During the experiment, field supervisors were given information via a cellular phone connection to a dispatcher monitoring the service. This type of communications and information sharing structure is clearly unsustainable when attempting to manage an entire network. The telephone or radio capacity necessary would be too expensive, and the number of dispatchers to monitor service too great. Instead, real-time AVL information could be communicated wirelessly to handheld personal digital assistants (PDA) given to supervisors. This way supervisors will have the information literally at hand and will not have to wait to be called on by the dispatcher.

ACKNOWLEDGEMENTS

The authors acknowledge the support of the Chicago Transit Authority in sponsoring this research and for providing access to their Real-Time Network Pilot Project. In addition we would like to thank Jason Lee, Angela Moore, and Wai-Sinn Chan at the CTA for their tremendous effort in making the experiment run as smoothly as possible and for assisting in the data collection efforts. Thanks to Edward Brandis at Clever Devices as well for help in conducting the experiments.

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Figure 1 Actual Screenshot from CTA Real-Time AVL

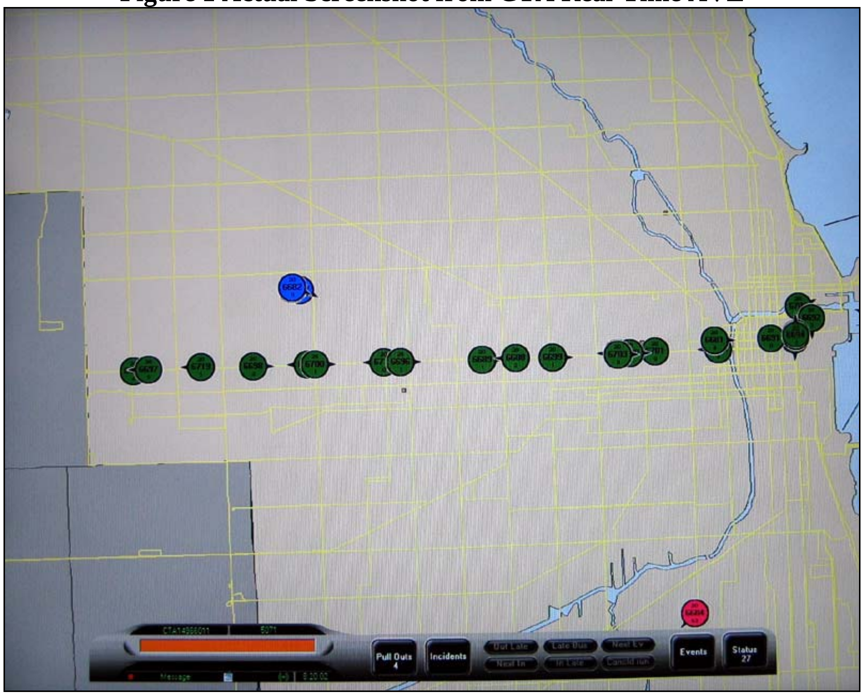

Figure 2 Route 20 map (Schwarcz, 2004)

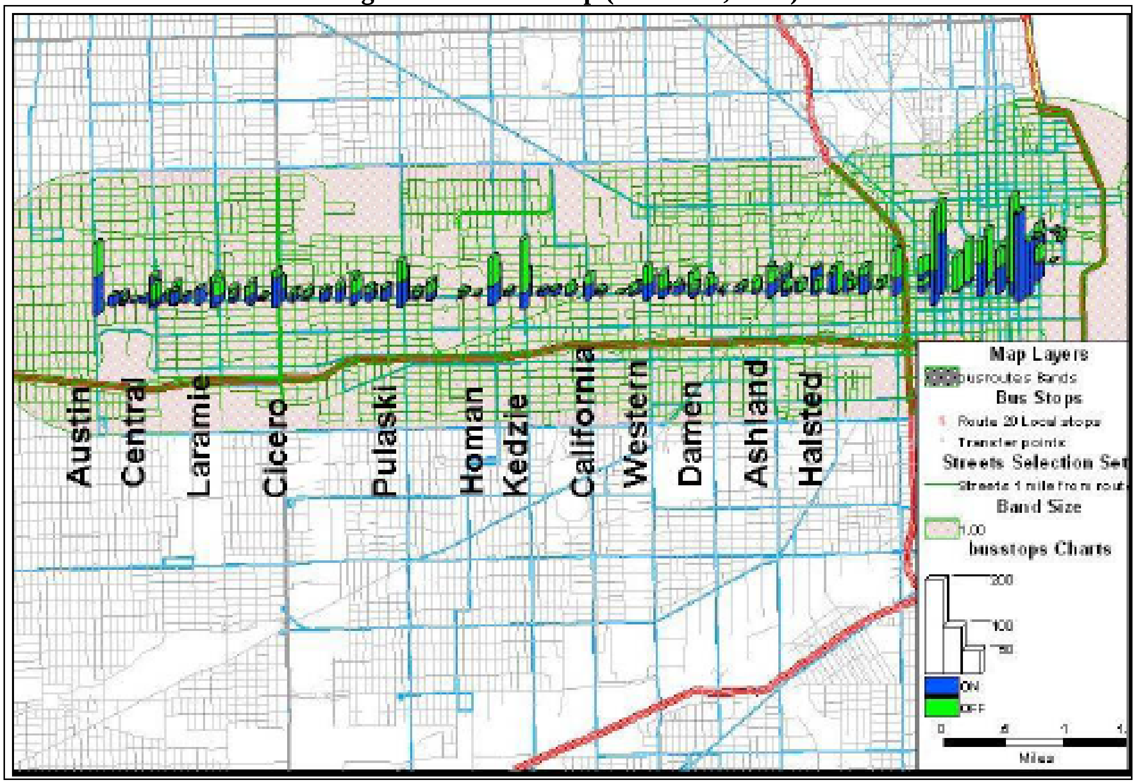

Table 1 Key timepoint information

	Austin	Cicero	Pulaski	Kedzie	Ashland	Halsted	Michigan	Columbus	Total
Distance from preceding timepoint (miles)	---	1.5	1.0	1.0	2.0	1.0	1.3	0.6	8.4
Scheduled travel time from preceding timepoint (minutes)	---	9.0	7.0	6.0	11.0	7.0	13.0	7.0	60.0

Table 2 Schedule information for runs chosen for operations control

Run	Schedule Departure Time from Austin	Scheduled Arrival Time at Columbus	Prior Westbound Trip	Recovery Time at Austin
5058	725	825	Garage Pullout	3 minutes
5001	730	830	Full trip from the Loop	7.5 minutes
5073	735	835	Garage Pullout	3 minutes
5052	740	840	Full trip from the Loop	7.5 minutes
5055	745	845	Garage Pullout	3 minutes
5053	750	850	Full trip from the Loop	7.5 minutes
5009	755	855	Garage Pullout	3 minutes
5014	800	900	Full trip from the Loop	9.5 minutes
5071	805	905	Full trip from the Loop	7.5 minutes
5074	810	910	Full trip from the Loop	5.5 minutes
5010	815	915	Garage Pullout	3 minutes

Figure 3 Route 20 demand profile

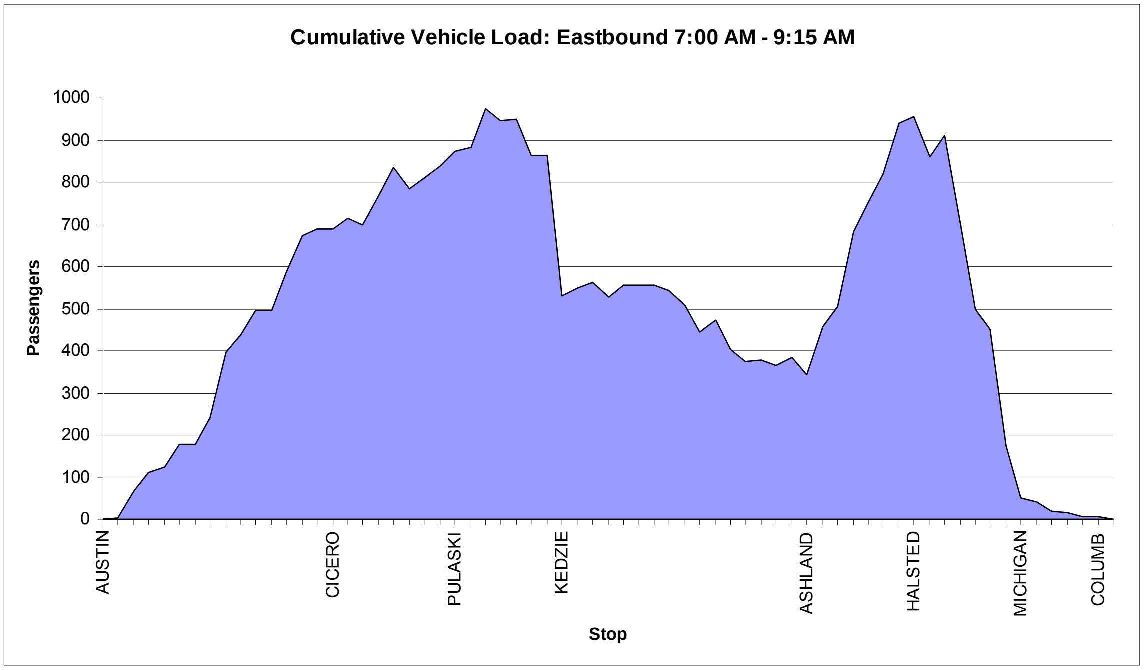

Table 3 Transit level of service by headway regularity

Level of Service	Coefficient of Variation of Headway	Probability	Comments
A	0.00 - 0.21	< 1%	Service provided like clockwork
B	0.22 - 0.30	≤ 10%	Vehicles slightly off headway
C	0.31 - 0.39	≤ 20%	Vehicles often off headway
D	0.40 - 0.52	≤ 33%	Irregular headways, with some bunching
E	0.53 - 0.74	≤ 50%	Frequent bunching
F	≥ 0.74	> 50%	Most vehicles bunched

Figure 4 Headway variation at each timepoint during the experiment week and baseline week

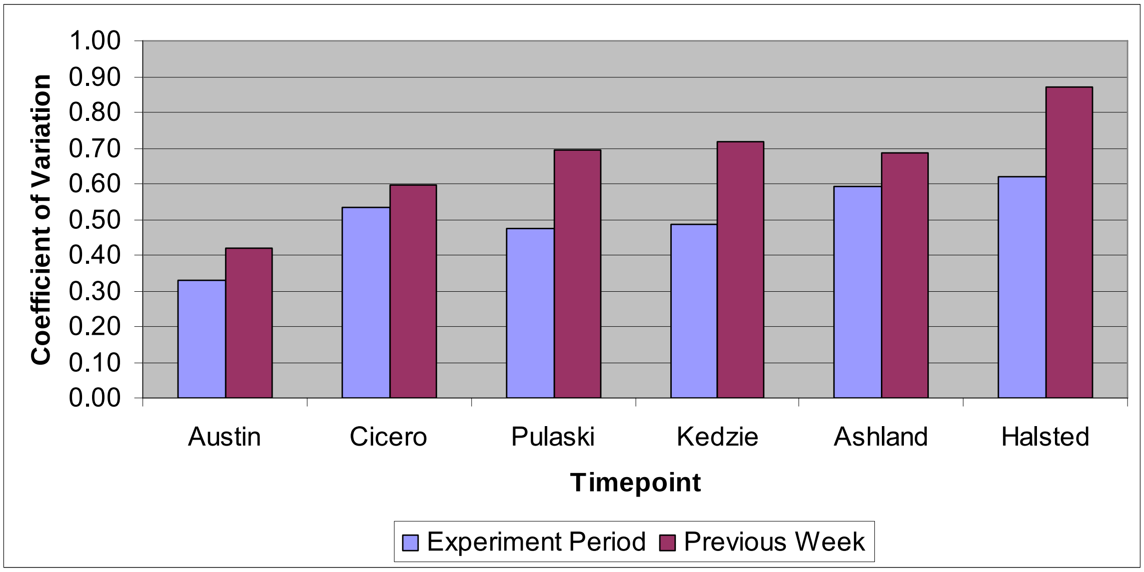

Figure 5 Headway variation at each timepoint during the experiment period and as simulated