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Evaluation of Utah Transit Authority's Connection Protection System



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Table of Contents

	<u>Page</u>
ACKNOWLEDGEMENTS	vii
EXECUTIVE SUMMARY	viii
Introduction.....	viii
The Problem.....	viii
Evaluation Approach	ix
Quantitative Evaluation Findings	xii
Qualitative Evaluation Findings	xiii
Conclusions.....	xv
Recommendations.....	xviii
1.0 INTRODUCTION AND BACKGROUND	1
1.1 Introduction.....	1
1.2 Description of the Connection Protection System	1
1.3 Evaluation Approach	3
2.0 SYSTEM PERFORMANCE	7
2.1 Introduction.....	7
2.2 Overview of Approach.....	7
2.3 System Performance Data.....	10
2.3.1 Data Collection	10
Mobile Data Terminal.....	10
Manual Observation.....	12
Smart-bus	17
Other System Performance Data.....	17
2.3.2 Data Compilation	18
2.3.3 Data Limitations and Assumptions.....	234
2.4 Effectiveness of Connection Protection.....	27
2.4.1 Active Versus Inactive Connection Protection	28
2.4.2 Effect of CP “Hold Until” Messages	36
2.4.3 Analysis of Matched Bus Trips.....	44
2.4.4 Analysis of Minutes Held Past Scheduled Departure Time.....	45
2.5 Operational Aspects of System Performance	52
2.5.1 Compliance with CP “Hold Until” Messages.....	52
2.5.2 Relationship Between CP “Hold Until” Messages and Actual Lateness of the Train	54
2.5.3 Late Bus Arrivals	56
2.6 Summary of Findings.....	58

Table of Contents (Continued)

	<u>Page</u>
3.0 USER PERCEPTIONS: EVALUATION FINDINGS	61
3.1 Introduction.....	61
3.2 Overview of Approach.....	61
3.3 Bus Rider Surveys.....	62
3.3.1 Background.....	63
3.3.2 Train-to-Bus Transfer Rider Results.....	66
3.3.3 On-the-Bus Rider Results	71
3.4 UTA Bus Operator Surveys.....	75
3.4.1 Background.....	75
3.4.2 Operator Survey Results	76
3.5 UTA Bus Operator Interviews.....	84
3.5.1 Operator Interview Results	84
3.6 UTA Radio Control Coordinators and Route Supervisor Interviews.....	85
3.6.1 Interview Results	86
3.7 UTA Complaint Logs	88
3.7.1 Comment Log Findings	88
3.8 Summary of Findings.....	91
4.0 CONCLUSIONS AND RECOMMENDATIONS	94
4.1 Evaluation Hypotheses and Findings.....	94
4.2 Conclusions.....	99
4.3 Recommendations.....	102
REFERENCES.....	104

List of Appendices

Appendix A: UTA TRAX Train and Bus Schedules	A-1
Appendix B: UTA Rail-to-Bus Transfer Rider Survey	B-1
Appendix C: UTA Bus Rider Survey	C-1
Appendix D: Survey Coverage of Bus Trips	D-1
Appendix E: Frequency Distributions for Rail-to-Bus and On-Board Rider Surveys	E-1
Appendix F: UTA Bus Operator Internet and Paper Survey.....	F-1
Appendix G: Frequency Distributions for Bus Operator Surveys	G-1
Appendix H: UTA Bus Operator Representative Comments, Suggestions and Observations ..	H-1
Appendix I: UTA Bus Operator Interview Guide	I-1
Appendix J: UTA Route Supervisor and Radio Controller Interview Guide.....	J-1

Table of Contents (Continued)

	<u>Page</u>
<u>List of Tables</u>	
Table 2-1. Number of MDT Departure Times Recorded at Each TRAX Station.....	12
Table 2-2. Number of Bus Departure Times Recorded by Manual Observers at Each TRAX Station	17
Table 2-3. Types and Numbers of CP Messages Generated	20
Table 2-4. Examples of Time Windows Defined for MDT	21
Table 2-5. Number of Bus Trips Protected in at Least One Month and Not Protected in Another Month.....	22
Table 2-6. Pairings of Protected and Unprotected Bus Trips that Form the Matched Analysis Dataset.....	23
Table 2-7. Number of Unmatched Bus Trips and Late Train Events that had Both CP Active and Inactive During the Data Collection Period	29
Table 2-8. Adjusted Odds Ratios Comparing the Odds of a Successful Connection for Status of CP, Lateness of the Train, and TRAX Station.....	34
Table 2-9. Number of Unmatched Bus Trips and Late Train Events with CP Active that Both Received and did not Receive a “Hold Until” Message During the Data Collection Period	37
Table 2-10. Adjusted Odds Ratios Comparing the Odds of a Successful Connection for Status of CP, Lateness of the Train, and TRAX Station.....	41
Table 2-11. Summary of Late Train Events for Matched Bus Trips.....	45
Table 2-12. Number and Percentage of Successful Connections Among Matched Bus Trips...	45
Table 2-13. Adjusted Averages of the Hold Time in Minutes Past the Scheduled Departure Time Based Upon Estimated Model Parameters	50
Table 2-14. Pairwise Differences in the Average Hold Time in Minutes Past the Scheduled Departure Time Based Upon Estimated Model Parameters	51
Table 3-1. Distribution of Survey Respondents by TRAX Station and Rider Type.....	63
Table 3-2. Number and Percent of Protected Trips by TRAX Station and Rider Type.....	64
Table 3-3. Distribution of Survey Respondents by TRAX Station and Bus Trip.....	65
Table 3-4. Responses to the Operator Survey	76
Table 4-1. Hypotheses Addressed by the Evaluation.....	95

Table of Contents (Continued)

	<u>Page</u>
<u>List of Figures</u>	
Figure ES-1. Overall Evaluation Approach	xi
Figure 1-1. High Level CP System Configuration Diagram	3
Figure 1-2. UTA TRAX System Diagram.....	4
Figure 1-3. Overall Evaluation Approach	6
Figure 2-1. Layout of Millcreek TRAX Station and Location of Data Collectors.....	14
Figure 2-2. Layout of Historic Sandy TRAX Station and Location of Data Collectors	15
Figure 2-3. Layout of Sandy Civic Center TRAX Station and Location of Data Collectors..	16
Figure 2-4. Variables Included in Each Database Table	19
Figure 2-5. Comparison of Bus Departure Times Manually Recorded by Data Collectors....	26
Figure 2-6. Comparison of Bus Departure Times Recorded by Smart-buses to Bus Departure Times Recorded Through Manual Observation	27
Figure 2-7. Percentage of Connections that were Successful by Status of CP	30
Figure 2-8. Percentage of Connections that were Successful by Lateness of the Train.....	31
Figure 2-9. Percentage of Connections that were Successful by TRAX Station.....	31
Figure 2-10. Percentage of Connections that were Successful by Time of Day	32
Figure 2-11. Percentage of Connections that were Successful by Day of the Week.....	32
Figure 2-12. Adjusted Estimates and 95% Confidence Intervals of the Probability of a Successful Connection.....	35
Figure 2-13. Unadjusted Percentage of Successful Connections by Whether a “Hold Until” Message was Issued, Conditional Upon CP Being Active	38
Figure 2-14. Unadjusted Percentage of Successful Connections by Lateness of the Train, Conditional Upon CP Being Active.....	38
Figure 2-15. Unadjusted Percentage of Successful Connections by TRAX Station, Conditional Upon CP Being Active.....	39
Figure 2-16. Unadjusted Percentage of Successful Connections by Time of Day, Conditional Upon CP Being Active.....	39
Figure 2-17. Unadjusted Percentage of Successful Connections by Day of the Week, Conditional Upon CP being Active	40
Figure 2-18. Adjusted Estimates of the Probability of a Successful Connection by Whether a CP “Hold Until” Was Issued.....	42
Figure 2-19. Adjusted Estimates of the Probability of a Successful Connection by Lateness of the Train.....	42
Figure 2-20. Adjusted Estimates of the Probability of a Successful Connection by Day of the Week	43
Figure 2-21. Adjusted Estimates of the Probability of a Successful Connection by TRAX Station	43
Figure 2-22. Average Number of Minutes Bus Operators Held Buses Past the Scheduled Departure Time by Status of CP	47
Figure 2-23. Average Number of Minutes Bus Operators Held Buses Past the Scheduled Departure Time by Lateness of the Train.....	47

Table of Contents (Continued)

	<u>Page</u>
<u>List of Figures (Continued)</u>	
Figure 2-24. Average Number of Minutes Bus Operators Held Buses Past the Scheduled Departure Time by TRAX Station.....	48
Figure 2-25. Average Number of Minutes Bus Operators Held Buses Past the Scheduled Departure Time by Time of Day.....	48
Figure 2-26. Average Number of Minutes Bus Operators Held Buses Past the Scheduled Departure Time by Day of the Week.....	49
Figure 2-27. Conditional Distribution of Departures Before and After CP Suggested Departure Time.....	53
Figure 2-28. Percentage of Successful Connections by Compliance with CP Suggested Departure Times.....	54
Figure 2-29. Comparison of the Distribution of Train Arrival Times by Whether a CP “Hold Until” Message is Issued.....	55
Figure 2-30. Distribution of Bus Arrivals Relative to Scheduled Bus Departure Time During Late Train Events.....	56
Figure 2-31. Distribution of Bus Arrivals Relative to Scheduled Bus Departure Time During On-Time Train Events.....	57
Figure 3-1. BYU Student Interviewer Conducting Survey on UTA Bus.....	61
Figure 3-2. Train-to-Bus: Gender and Age.....	63
Figure 3-3. On-Board: Gender and Age.....	63
Figure 3-4. Train-to-Bus: How often do you ride the bus on a one-way trip in a typical week, Monday – Friday?	64
Figure 3-5. On-Board: How often do you ride the bus on a one-way trip in a typical week, Monday – Friday?	64
Figure 3-6. How many times have you missed your bus connection in the past month at this TRAX station?.....	66
Figure 3-7. If your train is late, does the bus driver wait for you?	67
Figure 3-8. What are you most likely to do when you miss your bus connection?.....	67
Figure 3-9. If you miss your bus connection, how long do you usually have to wait?	67
Figure 3-10. In the past month how often have you taken an earlier TRAX train to avoid a missed bus connection?.....	68
Figure 3-11. If your bus is late due to a late train arrival, do you ever miss your next bus transfer down the line?.....	68
Figure 3-12. Overall, how satisfied are you with connections from the TRAX train to your preferred bus?.....	69
Figure 3-13. How many times in the past month have you been on this bus when it arrived late at this station?	72
Figure 3-14. How many times in the past month has this bus waited past its scheduled departure for a late train?	73
Figure 3-15. When the train is late, does the bus operator discuss whether to wait with the bus passengers?.....	73

Table of Contents (Continued)

	<u>Page</u>
<u>List of Figures (Continued)</u>	
Figure 3-16. Is it a problem for you if your bus is delayed because of a late train connection?	73
Figure 3-17. If your bus departs late due to a late train arrival, do you ever miss your next bus transfer down the line?	73
Figure 3-18. How many times in the past month has this bus arrived late at your final destination?	74
Figure 3-19. Overall, how satisfied are you with how the bus operators deal with late train connections?	74
Figure 3-20. Length of Time Operating a UTA Bus	76
Figure 3-21. Number of CP “Hold Until” Messages Received in Past 30 Days	76
Figure 3-22. Number of Times CP “Hold Until” Message Received was not Needed	77
Figure 3-23. In the absence of a CP “hold until” message, how long are you willing to wait past your scheduled departure?	78
Figure 3-24. Bus Operator Opinions on Four Statements: Regular and Extra Board	79

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Executive Summary

Introduction

The Utah Transit Authority (UTA) implemented a Connection Protection (CP) system to improve the reliability of transfers from the higher frequency light rail TRAX trains to the lower frequency bus services. The CP system examines the status of TRAX trains and issues a “hold at {station name} until {time}” message to buses waiting at the connecting rail stations via the bus’ onboard Mobile Data Terminal (MDT), if the lateness of train is within a pre-determined threshold (e.g., three minutes). The system was completed and tested in January 2002 prior to the Winter Olympic Games in Salt Lake City.

The successful implementation and operation of the CP system has received attention from the Federal Transit Administration (FTA) and the U.S. Department of Transportation (USDOT) Intelligent Transportation System (ITS) Joint Program Office (JPO) to warrant a national evaluation study. The objectives of the evaluation are to assess and document the performance of the CP system and share the experience and lessons learned with UTA and other agencies that may be considering a similar system.

Battelle was selected in September 2002 to conduct the evaluation. Brigham Young University (BYU) in Provo, Utah, and individuals identified by the Salt Lake County Aging Services (SLCAS) office were contracted by Battelle to provide various field data collection support to the evaluation.

This report is one in a series of documents produced by this evaluation. Useful references on the evaluation approach and detailed methods can be found in:

Evaluation Plan: Utah Transit Authority Connection Protection System, Prepared by Battelle for the ITS Joint Program Office, Federal Highway Administration, August 27, 2003.

Detailed Test Plans: Evaluation of Utah Transit Authority Connection Protection System, Prepared by Battelle for the ITS Joint Program Office, Federal Highway Administration, October 31, 2003.

This report focuses on the results of the specific evaluation activities and provides conclusions based on the findings from the analysis of system performance and feedback from users, and recommendations for making further improvements to the Connection Protection system.

The Problem

TRAX trains run on a regular schedule at 15-minute intervals and connect with many different UTA buses at the various stations throughout the day along the light rail route. TRAX trains can be delayed by traffic congestion or other causes in downtown Salt Lake City at the beginning of their trip, or elsewhere along their route due to time needed by disembarking and embarking

passengers. When this happens, late train arrivals can propagate down the line, depending on the ability of the train to make up some or all of its lost time. A relatively small number of TRAX trains are late overall (about 2% of all train trips experience late train events), but when a train does arrive late at its station, a consequence can be that passengers on the TRAX wishing to transfer to a particular bus may miss their connection. UTA instituted an automated CP program to instruct the operators of the connecting buses to hold until after the late TRAX train has arrived in order to ensure successful connections. This evaluation was designed to assess the performance of the system and the responses of both riders and operators to their connection experiences in general and to the CP program in particular.

Evaluation Approach

Based on the findings of an exploratory analysis conducted in the early stage of the evaluation, four TRAX stations (Millcreek, Midvale Center, Historic Sandy, and Sandy Civic Center) that receive most of the CP messages were identified as sites for the evaluation. The rationale for site selection can be found in the Detailed Test Plans. Briefly, these TRAX stations comprise the majority of protected bus trips and have the largest number of late train events.

There were two main evaluation components; namely, a quantitative and a qualitative assessment of CP with the overall objective of determining the impacts of CP on the UTA transit system and its riders. The objective of the quantitative portion of the evaluation was to assess the impacts of CP using system performance data (i.e., data that measure various aspects of the transit system, such as arrival and departure times). The objective of the qualitative portion of the evaluation was to assess the perception of users, including bus riders, bus operators, UTA supervisors, and radio control coordinators. The qualitative assessment was largely conducted through surveys and in-person interviews.

Ideally, an evaluation of CP would be conducted by tracking the movements of each individual train passenger as he/she departs the train and boards a bus, enabling a passenger-by-passenger determination of whether a successful train-to-bus connection has occurred. That is, this approach would be to enumerate all passenger movements from train-to-bus and use this information as the foundation for estimating the percentage of transfers that were successful. However, this approach is difficult in practice to implement because there usually are multiple buses that different train passengers are meeting. Tracking each individual passenger from the train to the bus would require resources that were beyond the scope of this evaluation. Rather than tracking individual train passengers to measure success, the quantitative evaluation relied upon tracking the movements (departures) of buses in relation to the train arrivals as a surrogate measure of a successful connection. This was done on a limited basis focusing on selected TRAX stations and connecting bus routes for those conditions in which a late train event would trip the CP threshold, resulting in sending a “hold until” message. Anecdotal evidence suggests that train passengers, walking at a normal pace, could depart from the train and reach the farthest bus departure point in roughly 60-120 seconds at all of the TRAX stations considered in this evaluation. Two different requirements on the *bus departure time* were employed to define a “successful” connection: 1) requiring that the bus departs at least 120 seconds after the train arrives (i.e., the bus must hold at the TRAX station for at least 120 seconds after the train arrives), and 2) requiring that the bus departs at least 180 seconds after the train arrives.

Generally speaking, one would expect more bus departures to meet the definition of a “successful” connection to be recorded under the 120-second definition than the 180-second definition, because the requirements for how long the bus needs to wait following the train arrival for the departure to be classified as a “success” is less restrictive. That is, the 180-second definition is more conservative in measuring successful connections than the 120-second definition.

Evaluating the effectiveness of the CP system to improve successful connections of passengers from train to waiting buses necessarily requires the accurate measurement of bus departure times, and the linking of those departures to the train arrival times. Accurately measuring bus departure times under reasonable cost and logistical constraints, without impacting operations is a challenging task because each possible approach has cost or operational limitations. Three complementary data collection methods were used to capture bus departure times in this evaluation: 1) bus operator manually signaling each bus departure time by entering a code on the Mobile Data Terminal (MDT), 2) collection of automated bus departure times by UTA buses that are equipped with technology (i.e., “Smart-buses”), and 3) manual data collection by independent observers at the TRAX station of the bus departure times.

The qualitative component of the evaluation, on the other hand, surveyed a high percentage of passengers on selected bus trips at three of the same TRAX stations covered by the quantitative evaluation. An important difference in design, however, is that these surveys assessed rider experiences over the prior month taking account of *all* their transfer experiences, not just those associated with late train events and some bus trips. This portion of the evaluation, therefore, covers the full range of potential connections, with and without CP operating, and for all combinations of train and bus timing. These fundamental differences must be taken into account when comparing results derived from the quantitative and qualitative components of the evaluation.

The two portions of the analysis provide different but complementary perspectives on the overall objective of assessing the impact of CP, and findings from these two approaches are integrated to arrive at conclusions and recommendations. Figure ES-1 summarizes the interrelation between the two different portions of the evaluation, and the methods that were used to obtain the data.

A number of hypotheses were established to guide the evaluation inquiry, and the full set of hypotheses is presented in Table 4.1 in Section 4 of the report.

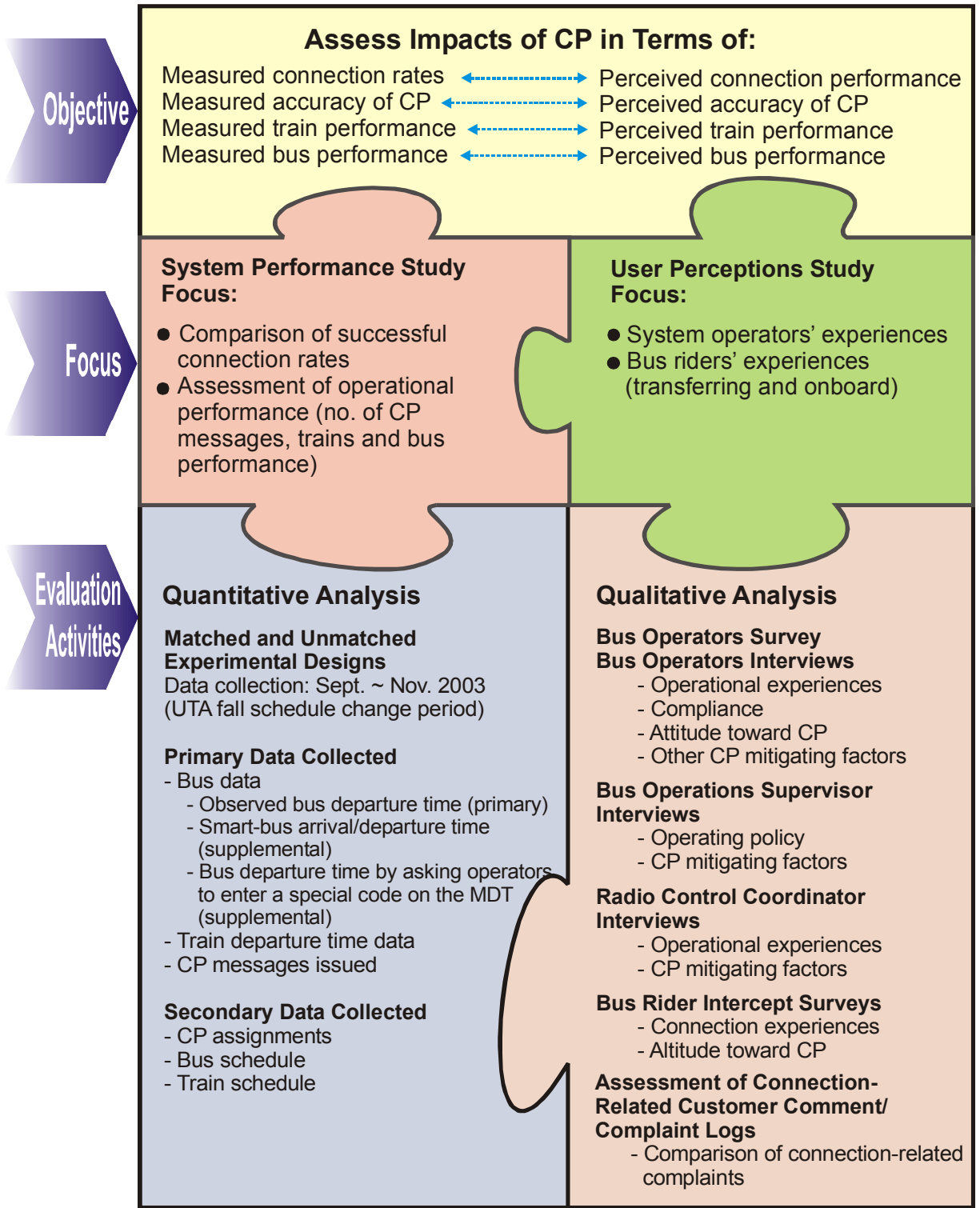


Figure ES-1. Overall Evaluation Approach

Quantitative Evaluation Findings

Based upon the system performance data, CP does significantly increase the percentage of successful train-to-bus connections. Train riders meeting a bus trip when CP was active and a “hold until” message was issued to the bus operator were 3.1 times more likely to have a successful connection than were train riders meeting the same bus trips when CP was inactive under the requirement that a bus needed to depart more than 120 seconds after the train arrived to be considered a successful connection. Under the 180-second requirement, train riders were 3.9 times more likely to have a successful connection than were train riders meeting the same bus trips when CP was inactive. Both results were statistically significant. Additionally, train riders meeting a bus when CP was active and a “hold until” message was issued were two to three times more likely to have had a successful connection than train riders meeting a bus when CP was active but a “hold until” message was not issued, which was also statistically significant. Finally, train riders meeting a bus trip when CP was active, but no “hold until” message was issued are 1.0 to 1.2 times more likely to have had a successful connection than train riders meeting a bus trip when CP was inactive, which was not statistically significant. These results indicate that significant improvements were observed only when actual “hold until” messages were issued, and hypothesized improvements because of increased awareness and sensitivity by bus operators simply through activation of CP could not be substantiated with the collected system data.

Bus operators tended to hold the buses longer past their normal scheduled departure time when a CP “hold until” message was issued than when a “hold until” message was not issued. This result was significant for comparisons where CP was active (roughly one minute longer on average), but not significant when compared to late train events where CP was inactive (41 seconds longer on average).

Day of the week was a significant predictor of the average length of time that the bus operators held the buses past their scheduled departure times for a late train event. Bus operators tended to hold the buses longer in the latter part of the week (Wednesday – Friday) than in the earlier part of the week (Monday – Tuesday) with differences ranging from 37 seconds to 2.7 minutes.

During the course of the evaluation, there were several instances where CP was not operational. Certainly, there are going to be times when any computer system will experience a malfunction, or when UTA may want to turn CP off for selected bus trips. However, there were at least two periods (late Summer and in October) where CP was not activated for all but a few routes due to an oversight in CP assignments. Increasing the reliability of the system, including establishing a protocol for review of CP assignments, would increase the effectiveness of CP. It is important to note that UTA staff were intensely focused on the opening of a new rail extension, hosting the APTA Annual meeting immediately prior to the data collection period, and in the process of reconfiguring management and functional responsibilities of UTA staff. Therefore, these events may be anomalies and may not reflect normal UTA operations.

Compliance or accepting the recommendation for alternative departure times issued by CP is an important component of the success of CP in increasing successful bus-to-train connections. Only 51.3% of bus operators that were sent a suggested departure time by CP departed after the

suggested departure time. However, if 100% of the operators followed the suggestions of CP, then the percentage of successful connections would be increased by 28% to 57% for the 180- and 120-second requirement respectively. These results indicate that increasing compliance may increase the impact of CP on successful connections.

The mechanism for determining when to send a suggested departure time (“hold until”) message to bus operators was not associated with the actual lateness of the train at the TRAX station. This results in issuing “hold until” messages when the trains are less than one minute late and failure to issue “hold until” messages when trains are more than two minutes late. The effectiveness of CP in reducing the number of missed train-to-bus connections could be improved if a more accurate decision process was employed.

Qualitative Evaluation Findings

Overall, riders transferring from train to the bus and on-board passengers at the TRAX stations report a high level of satisfaction with their connection experience. For the transferring passengers on all trips (both protected and unprotected), 86% said they were “very” or “somewhat” satisfied. On the other hand, transferring riders who report missing one or more connections in the past month are three times more likely to say they are dissatisfied (22%) compared with those who have not missed any connections (6%), a statistically significant difference. All the statistical tests in the qualitative analysis are based on a Chi Square comparison of percentage differences or differences of means tests at a 95% confidence level. However, riders who were surveyed on trips that were CP protected were only slightly more likely to report being “somewhat” or “very” satisfied (87%) compared with those who were not on CP protected trips (85%), a difference that is not statistically significant. The likelihood that riders who are not connecting to a CP protected bus trip will report a high number of missed connections at their TRAX station (4 or more in past 30 days) is twice as great as riders on CP protected trips. Overall, 41% of transferring riders report missing one or more connections on bus trips under CP versus 47% for trips without CP. While these effects suggest a small but positive effect of CP as measured by rider reports of trip satisfaction and connection success, the differences are not statistically significant.

The lack of a significant difference in both reported connection success and satisfaction with connection experience for both CP protected and non-protected trips is likely in part related to the fact that bus operators say they are very likely to wait for connecting passengers *regardless of whether or not they receive a CP “hold until” message*. Only 8% of operators say they will “never” wait without a CP message, and 47% say they “always” wait. Even though there is a difference in perspective between the operators and transferring passengers regarding reported wait behavior, it appears that most bus operators will wait most of the time for two or more minutes for connecting rail passengers.

An important factor that influences the willingness of operators to wait for late trains is the tightness of their bus schedule. Regular operators who agree that their routes are so tightly scheduled that it is difficult for them to wait are about half as likely to say they always wait compared with operators who do not report tightly scheduled routes (38% versus 69%). That is, seven out of ten regular operators say they always wait if their schedules are not too tight;

otherwise, only four in ten will wait if they perceive their schedules to be tight. Open-ended comments and suggestions from the operators included many related to their perception of a need for better scheduling.

Over all the bus operators, about half (49%) agree with the idea that CP should be used on more routes than it is now. Fewer than one in five operators disagree with that idea, and the rest are neutral. If endorsement that CP should be extended to additional routes can be interpreted as operator support for the CP program, then these results are decidedly mixed, with the operators evenly split on the matter.

About half of all the operators (49%) agree that tight scheduling often causes them to arrive late at the TRAX stations. Over half of the riders on the bus (53%) report that they have been on a bus when it arrived late at the TRAX station one or more times in the past month. To the extent that many buses are arriving late at the station, this is expected to account for many of the successful connections that otherwise would have been at risk of being missed if the bus had arrived and departed on schedule, assuming no CP message is issued. In such situations when a CP message is issued, it is likely to be perceived by the bus operator as unnecessary when the bus is late enough to pick up late-arriving TRAX passengers anyway. In fact, the bus operators reported that 64% of all the CP messages they received were unnecessary, either because the train had made up time and arrived close enough to schedule, or presumably because the bus was late enough in arriving that the connection was successful without needing any additional wait time, or perhaps because no passengers actually transferred from the train when it did arrive.

While CP offers clear benefits to TRAX passengers trying to make connections to buses, passengers arriving at the TRAX station or boarding from the station's park-and-ride depend on the bus leaving on time and adhering to its schedule along the way. When CP causes the bus to wait, that jeopardizes later bus-to-TRAX and bus-to-bus connections down the line for the bus riders. Waiting past the scheduled departure at the TRAX station is associated with missing other transfer connections and with being late arriving at their final destination, and riders who have these experiences are less likely to say they are satisfied compared with those who do not. There is some evidence that suggests that CP may make it more likely that a bus rider will experience one or more late arrivals at their final destination, so this needs to be factored in to an overall assessment of the impact or benefit of CP. In fact, the bus operators report their perception of the inequity of a CP message that requires them to wait for an uncertain number of connecting passengers knowing that the passengers already on their bus will potentially be negatively affected by the wait time.

In summary, the rider and operator surveys and interviews suggest that CP is a useful tool that can help operators better meet the needs of their customers, but operator judgment is a key ingredient in determining when and how long to wait with or without a CP message, and in balancing the effects of bus schedule constraints, current on-time status of their bus, observed TRAX train status, and the needs of their on-board riders versus the needs of their likely TRAX transfer riders. CP is perceived to make a difference in only some of the CP protected trips, for a number of reasons: 1) TRAX apparently can often make up lost time after a CP message is issued, 2) most operators are conditioned to waiting where possible such that more than half the time they consider CP messages that have been issued to have been unnecessary, and they wait

most of the time even when no CP message was issued, 3) many riders elect to take an earlier TRAX train specifically to avoid the risk of missing their connection, and 4) due to tight scheduling, buses often arrive behind schedule at TRAX stations making it easy to pick up late arriving TRAX passengers without additional wait time.

Conclusions

Conclusions are based on the findings from the evaluation of system performance and feedback from users, and recommendations by riders and operators for making further improvements to the Connection Protection system. Because the quantitative assessment relied on directly measured system performance and the qualitative assessment relied on the stated preferences and opinions of users of the system based on individual experience (both riders and operators), differences in findings can be expected on aspects of the CP system. Furthermore, the quantitative assessment was able to examine only a limited subset of train/bus events, namely, those involving sufficiently late trains associated with bus trips for which accurate departure times were available. Thus, connections from trains that were on time or less than a minute late were not covered, even though connections from them could be at risk due to tight scheduling or buses failing to wait. It is therefore difficult to compare the quantitative evaluation results, based on surrogate measures of connection “potential” using a limited sample of exclusively late train events, with the qualitative findings based on rider and operator experience with rail-to-bus connections involving relatively few actual late train events.

The following general conclusions are based on an integration of the findings drawn from the qualitative and quantitative components of this evaluation:

CP improves the probability of successful train-to-bus connections

Based upon the system performance data, CP does significantly increase the percentage of likely successful train-to-bus connections, given a late train event. Train riders meeting a bus trip when CP was active and a “hold until” message was issued to the bus operator were 3.1 to 3.9 times (depending upon the definition of a successful connection) more likely to have a successful connection than were train riders meeting the same bus trips when CP was inactive, a finding that is statistically significant. Also, train riders meeting a bus trip when CP was active, but no “hold until” message was issued are 1.0 to 1.2 times more likely to have had a successful connection than train riders meeting a bus trip when CP was inactive.

Bus operators tended to hold the buses longer past their normal scheduled departure time when a CP “hold until” message was issued than when a “hold until” message was not issued. This result was significant for comparisons where CP was active (roughly one minute longer on average), but not significant when compared to late train events where CP was inactive (41 seconds longer on average).

Overall satisfaction among riders with connection experience is generally high; operator opinion on the value of CP is mixed.

For the most part, bus riders are unaware of the CP program; they only know whether or not they make successful connections. Riders transferring from train to the bus and riders on the bus report a high level of satisfaction with their connection experience. Not surprisingly, those who have missed connections tend to be the least satisfied. About half (49%) of the bus operators agree with the idea that CP should be used on more routes than it is now. Fewer than one in five operators disagree with that idea, and the rest are neutral. If endorsement that CP should be extended to additional routes can be interpreted as operator support for the CP program, then these results are mixed, with the operators evenly split on the matter.

The level of reported rider satisfaction is only weakly related to whether the bus trip is CP protected.

Riders who were surveyed on trips that were CP protected were only slightly more likely to report being “somewhat” or “very” satisfied (87%) compared with those who were not on CP protected trips (85%). Riders connecting to bus trips unprotected by CP were twice as likely to report a high number of missed connections compared with those connecting to CP protected bus trips. Missed connections under CP are somewhat less likely than missed connections without CP operating (41% versus 47%). While these effects suggest a small but positive effect due to CP as measured by rider reports of trip satisfaction and connection success, none of these differences is statistically significant. The presumptive benefits of CP are positive but of less magnitude as measured in the qualitative component of the evaluation than in the quantitative component.

Bus operators report a high number of unnecessary CP messages received.

Operators were asked how many situations in the past 30 days where they got a “hold until” message was the train actually on time or close enough to on time that they didn’t need to hold after all. The bus operators reported that this occurred with almost two-thirds (64%) of all CP “hold until” messages they received. Thus, a high proportion of these messages apparently were perceived to be unnecessary, presumably because the train made up time and was not late enough to cause missed connections, or because no train showed up after waiting, or because no riders transferred to the bus, or perhaps because the bus was running behind the schedule.

CP effectiveness is less than it could be, due to:

- Periods of non-operational CP. During the course of the evaluation, there were at least two instances where the CP system was non-operational for significant periods of time (at least three weeks). For example, during most of October 2003, and unbeknownst to the evaluation team at the time, CP was inactive, and this was the main period of time over which riders and operators were being asked to reflect on CP performance and benefit. This may have had the effect of reducing the reported benefits of CP in this evaluation.

- Low operator compliance with CP “hold until” messages. Only 51.3% of bus operators who were sent a suggested departure time (i.e., a “hold until” message) by CP, departed after the suggested departure time. However, if 100% of the operators followed the suggestions of CP, then the percentage of successful connections would be *increased* by 28% to 57% for the 180- and 120-second requirement, respectively, raising the overall percentages of successful late train event connections to 99.3% and 85.3%.
- Lack of accuracy in issuance of a CP “hold until” message. There was no statistically significant difference in the distribution of train arrival times between bus trips that received a CP “hold until” message and bus trips that did not, given that CP was active. That is, there are a significant percentage of late train events where a “hold until” message could be issued (i.e., the train is more than two minutes late) but is not, and a significant percentage of late train events where a CP “hold until” message is issued but the train is only slightly late (less than one minute). Related to this finding is the high percentage of CP messages judged by the bus operators as being unnecessary (64%).
- Failure of some bus operators to log on to their MDT. The number of operators who forget or otherwise fail to log onto their MDT is reportedly low. Nevertheless, some CP messages will be at risk of not being received in these circumstances, thereby further limiting the potential effectiveness of connection protection.
- Many experienced transfer riders have learned to take an earlier train in order to avoid missing their bus connection. 63% of the train-to-bus transfer riders report that they at least sometimes take an earlier TRAX train to be sure they make their connection, and one-quarter of them (26%) do this for most or all of their trips. There is no difference in the proportion of riders who do this by whether their bus trip is CP protected or not. The potential benefit of CP to riders is reduced to the extent that more than half of all transferring riders feel a need to travel 15 minutes earlier than normal to be assured of making their connection.

Most bus operators will wait most of the time to pick up train passengers, regardless of whether they receive a CP “hold until” message.

Only 8% of operators say they “never” wait without a CP message, and 47% say they “always” wait. The reported willingness to wait most of the time makes it more difficult to detect an independent effect of CP on propensity to wait. This willingness to wait is a positive endorsement of UTA management’s customer orientation that they frequently communicate to all their bus operators as an “expected” way to behave toward their passengers. Scheduling constraints appear to be the main factor limiting willingness to wait. Bus operators expressed concern that the advantages to transferring passengers of waiting for late trains is offset by the disadvantages to on-board passengers who are put at risk of missing their later connections or on-time arrival.

The CP system is a relatively low cost “insurance policy” to help increase connection success.

CP is an intelligently integrated system that aims to improve the reliability of rail-to-bus connections. The cost of the CP system is relatively low compared to other transit ITS systems. The moderate capital cost is achieved by utilizing the existing system data (e.g., train status, schedules, etc.) and the delivery mechanism (e.g., Mobile Data Terminal, radio data server, bus and train radio systems) already deployed for other ITS functions. The operating and maintenance costs also are moderate because the CP operation is fully automated without the need for human intervention.

CP targets relatively rare late train events to improve the probability of successful connections. This rationale was affirmed by the evaluation data that there were only 4,641 (2%) recorded late train events (out of over 187,000 arrivals) that subsequently triggered 1,508 “hold until” messages during the three months of data collection. Despite its marginal benefits compared to other transit ITS functions (e.g., train control systems, computer-aided dispatch), CP fills an important niche in a combined light rail and bus transit system. As shown in this evaluation, CP improves the probability of successful rail-to-bus connections, especially for the high transfer TRAX stations, evening or last bus service, and low frequency bus routes where the adverse consequence of missing a connection is high. The value of such a system is significant.

Recommendations

Recommendations are based on the quantitative and qualitative findings and conclusions with recognition of the limitations of the available data and analyses. They are presented in the spirit of suggestions for consideration not only by UTA but also for other transit operators who may be considering implementing a similar connection protection program in their area.

Provide for reliable, continuous monitoring of system performance. Mainly due to lack of oversight during this period of internal reorganization and transitioning of responsibilities, the UTA CP system was non-functional for substantial periods of time during the evaluation period, apparently without anyone at UTA knowing that the system was “down.” Procedures to establish a defined responsibility path, especially during times of transition, should be implemented to eliminate these preventable down times from occurring.

Consider changes in management integration of CP. This could include an assessment of the complex interdependencies between ITS systems, and of the responsibilities for various components of the system that must be effectively linked and coordinated. Examples include separate database components in different parts of the organization, and the multiple positions in the organization with responsibility for the CP assignment data. Also, seek to be sure there is a common understanding throughout UTA regarding recommended wait times among the radio control coordinators, UTA management, and bus operators, consistent with the CP algorithm-based instructions.

Increase compliance through training and education. UTA has worked diligently to create a culture of customer service in all aspects of its program, including CP. However, the quantitative analysis suggests that there is still a significant level of non-compliance among

operators who wait less time than a CP “hold until” message suggests. Part of the solution, as suggested by findings from the operator survey and interviews, may lie in increasing the reliability of the CP messages (increase trust), adjusting schedules to accommodate such waits (more equitable treatment of transfer riders and on-board riders; less pressure on operators from tight schedules), and further clarifying UTA policy regarding wait decisions versus schedule adherence, considering the consequences for both transferring and on-board passengers.

Improve the predictive accuracy of CP messages. Inaccurate messages have led many operators to say that the majority of CP messages they receive are not needed. A major reason for this is assumed to be due to trains’ ability to make up time between stations. Options for addressing this problem may include reducing the forecasting horizon to less than three TRAX stations in advance of the anticipated connection, or sending out a follow-up message to rescind the “hold until” message when it is determined that the train no longer meets the lateness threshold.

Review bus schedules with respect to their effects on connection success. Consider selectively providing more schedule slack to accommodate more comfortable waits at TRAX stations, or at least the capacity to make up lost time at critical points in the bus trips. Assess why many bus trips are reported by riders to be behind schedule and seek solutions where problems are found.

Seek to obtain and integrate information about bus location with train location in fine-tuning the CP algorithm. When buses are running late, a CP message may not be needed. When a train makes up lost time, a CP message may not be needed. When a later bus on a given trip can more efficiently pick up passengers from a late train, a CP message may not be needed. Given the lack of real-time bus location information, the current CP algorithm does not consider the bus status in the computation. As UTA considers the Automatic Vehicle Location (AVL) system for its bus fleet in the future, it is highly desirable to incorporate bus status as part of the CP parameters.

Increase rider awareness of UTA efforts to increase connection success. Both riders and operators expressed concerns in the qualitative evaluation surveys that bus and rail schedules were not adequately coordinated, that buses were often late, and that the CP program was “one sided” in its focus on rail-to-bus transfers and not bus-to-bus or bus-to-rail. These kinds of concerns could be mitigated by providing more information and rationale about the CP program.

1.0 Introduction and Background

1.1 Introduction

The Utah Transit Authority (UTA) implemented a Connection Protection (CP) system to improve the reliability of transfers from the higher frequency light rail TRAX trains to the lower frequency bus services. The CP system examines the status of TRAX trains and issues a “hold at {station name} until {time}” message to buses waiting at the connecting rail stations via the bus’ onboard Mobile Data Terminal (MDT), if the lateness of train is within a pre-determined threshold (e.g., 3 minutes). The system was completed and tested in January 2002 prior to the Winter Olympic Games in Salt Lake City.

The successful implementation and operation of the CP system has received attention from the Federal Transit Administration (FTA) and the U.S. Department of Transportation (USDOT) Intelligent Transportation System (ITS) Joint Program Office (JPO) to warrant a national evaluation study. The objectives of the evaluation are to assess and document the performance of the CP system and share the experiences and lessons learned with other agencies that may be considering a similar system.

Battelle was selected in September 2002 to conduct the evaluation. Brigham Young University (BYU) in Provo, Utah, and individuals identified by the Salt Lake County Aging Services (SLCAS) office were contracted by Battelle to provide various field data collection support to the evaluation. A kickoff meeting, attended by the evaluation team and the UTA CP project team, was held in the UTA office at Salt Lake City, Utah, in November 2002.

In order to understand how the CP system works and to provide guidance to the overall evaluation design, an exploratory analysis using operations data provided by the UTA was performed in February 2003. The purpose of the exploratory analysis was to investigate the data availability and quality. Based in part upon the results of the exploratory analysis, an evaluation plan [Ref. 1] was developed in March 2003. Following the acceptance of the evaluation plan, detailed plans [Ref. 2] for the individual evaluation tests were developed and accepted by the FTA and FHWA in October 2003.

The data collection began in September 2003 and ended in November 2003, coinciding with the UTA fall schedule change period. Data analysis and reporting were completed in February 2004.

1.2 Description of the Connection Protection System

UTA’s Connection Protection system was designed to improve the reliability of transfers from the light rail train, TRAX, to the connecting buses. The CP system constantly monitors the train schedule adherence status by examining the estimated arrival times for the next three stations. If the lateness of train is within a pre-determined threshold (e.g., three minutes), a “hold until...” instruction is sent to the connecting buses via the onboard MDT.

A beneficial attribute of UTA's CP system is the intelligent integration of a number of existing systems and data, which greatly reduced the project's capital cost. For example, the estimated train arrival time data are produced for real-time train status displays at the light rail stations by a subsystem developed by Geo Focus. The transmission of "hold until" instruction messages is achieved using the existing MDT as part of the voice/data radio system equipment in place on all UTA buses. The CP messages are sent automatically in the same way as other data messages from the Radio Control Coordinator to the bus operators. The major capital cost of the CP system is the cost of the computer server, CP program, and the interface peripherals with other systems. Transcore served as the developer and the system integrator of the CP project.

The CP system is essentially a computer program that takes relevant data (e.g., estimated train arrival time, train schedule, bus schedule) from other systems and determines if a late train would jeopardize bus connections at down-line stations. When a potentially missed connection is identified and the delay of the train is within a threshold (e.g., 3 minutes), the CP system looks up the information of the particular bus (using the bus schedule and radio log-on database¹) and sends a "hold until..." message to the onboard MDT using UTA's radio dispatch communication system.

As shown in Figure 1-1, the train status data are provided by the Global Positioning System (GPS) receiver on the light rail trains. The train location and time stamps are transmitted to the UTA train control facility using the 800 Mhz voice/data radio system deployed for train operations. Estimated time to arrival (ETA) is calculated based on the real-time train status data for all downstream stations by a prediction algorithm. ETA information is transmitted to and displayed on the electronic signs located at all train platforms.

The CP system uses the ETA, compared with the train schedule, to identify the late trains. When the predicted lateness of a TRAX train (for each of the three down-line stations) is within the predetermined threshold and connecting buses are expected (based on CP assignment data that define which connecting bus to protect and the individual thresholds), the CP system then generates a "hold until" message for each of the protected buses.

To send the message, the CP system looks for the radio ID of the bus from a database on the UTA bus operations radio data server. If the bus' radio is logged on (note that bus operators are supposed to log on to the radio system by entering their badge ID on their MDT at the beginning of their shift), the CP message will be sent to the MDT on the connecting bus. If the bus operator fails to log on or incorrectly logs on to the radio system, the CP message will not be sent and subsequently will be archived in the system for later diagnosis.

Operationally, the CP messages are triggered by the late train events. One late train could potentially trigger multiple CP messages to hold one or more buses at each of the three down-line stations, based on the CP assignment. Because there are no dedicated hardware requirements, CP can be applied to all UTA buses equipped with the radio system.

¹ A lookup table on the Radio Data Server indicates the buses that are currently logged on to the radio system. Bus operators are required to log on to the radio system to enable data messaging using their MDT.

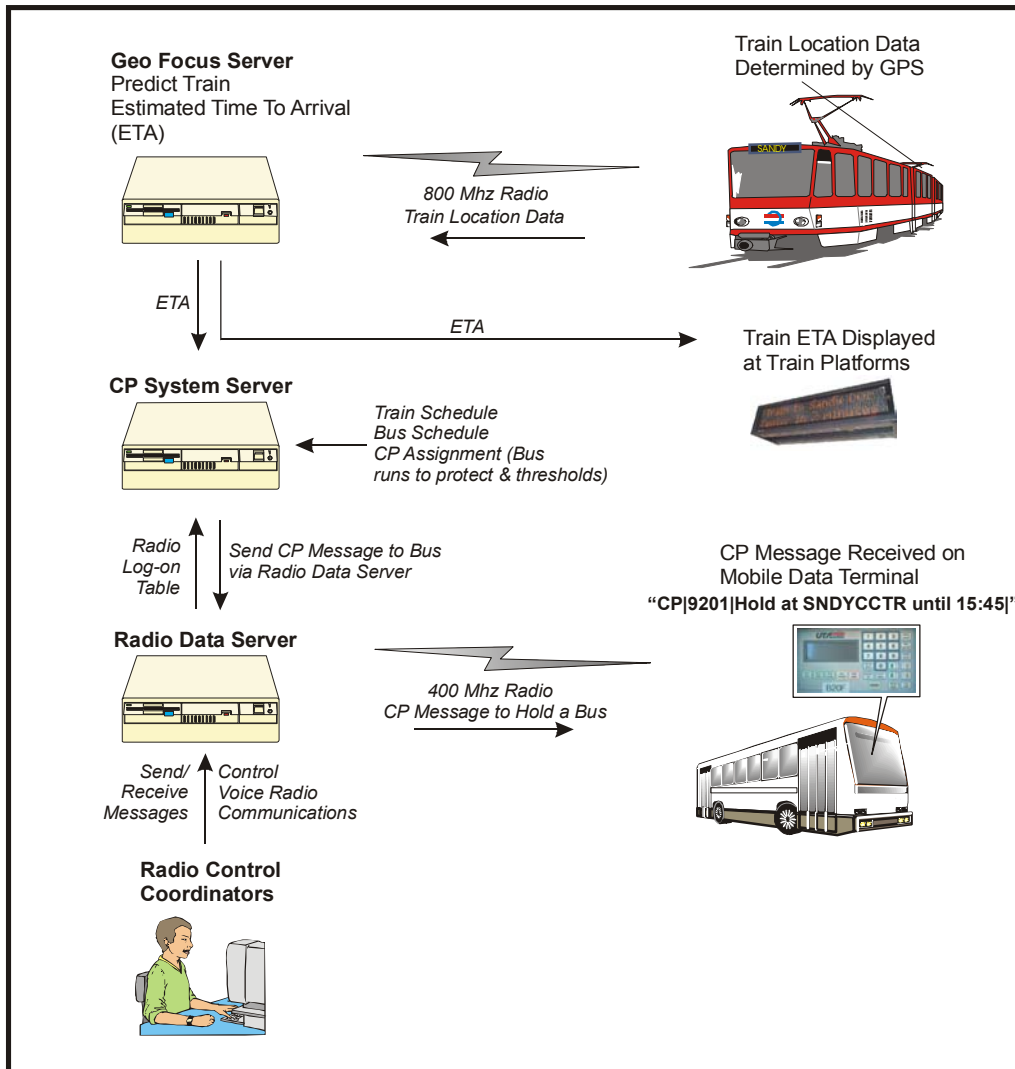


Figure 1-1. High Level CP System Configuration Diagram

The CP system is flexible in terms of which transfer locations and times to protect. For example, a bus route may be protected only for a certain period of the day. In addition, internal parameters such as the threshold of train lateness (typically 3 minutes) also can be adjusted by individual transfer location and time. For example, to protect the connection of a last bus, the threshold might be increased in order to hold the bus longer until the train's arrival, because the consequence for passengers of missing the last bus of the day is much more severe.

1.3 Evaluation Approach

As of the time of this evaluation, CP was applied only to the North-South TRAX line between Ballpark to the North and Sandy Civic Center to the South, including 11 stations. Because the CP system was designed to protect the transfers to buses of certain frequency and service type, only selected bus trips at TRAX stations were protected by CP during the evaluation period.

UTA has expressed its intent to expand the CP program to include more bus trips and the other TRAX line (i.e., East-West University line).

Based on the findings of the exploratory analysis conducted in the early stage of the evaluation, four TRAX stations (Millcreek, Midvale Center, Historic Sandy, and Sandy Civic Center) that received most of the CP messages were identified as candidate sites for the evaluation. The rationale for the selection can be found in the Detailed Test Plans. Briefly, however, these TRAX stations comprise the majority of protected bus trips and historically have had the largest number of late train events. Figure 1-2 presents an annotated light rail system map indicating the study locations of various evaluation activities.

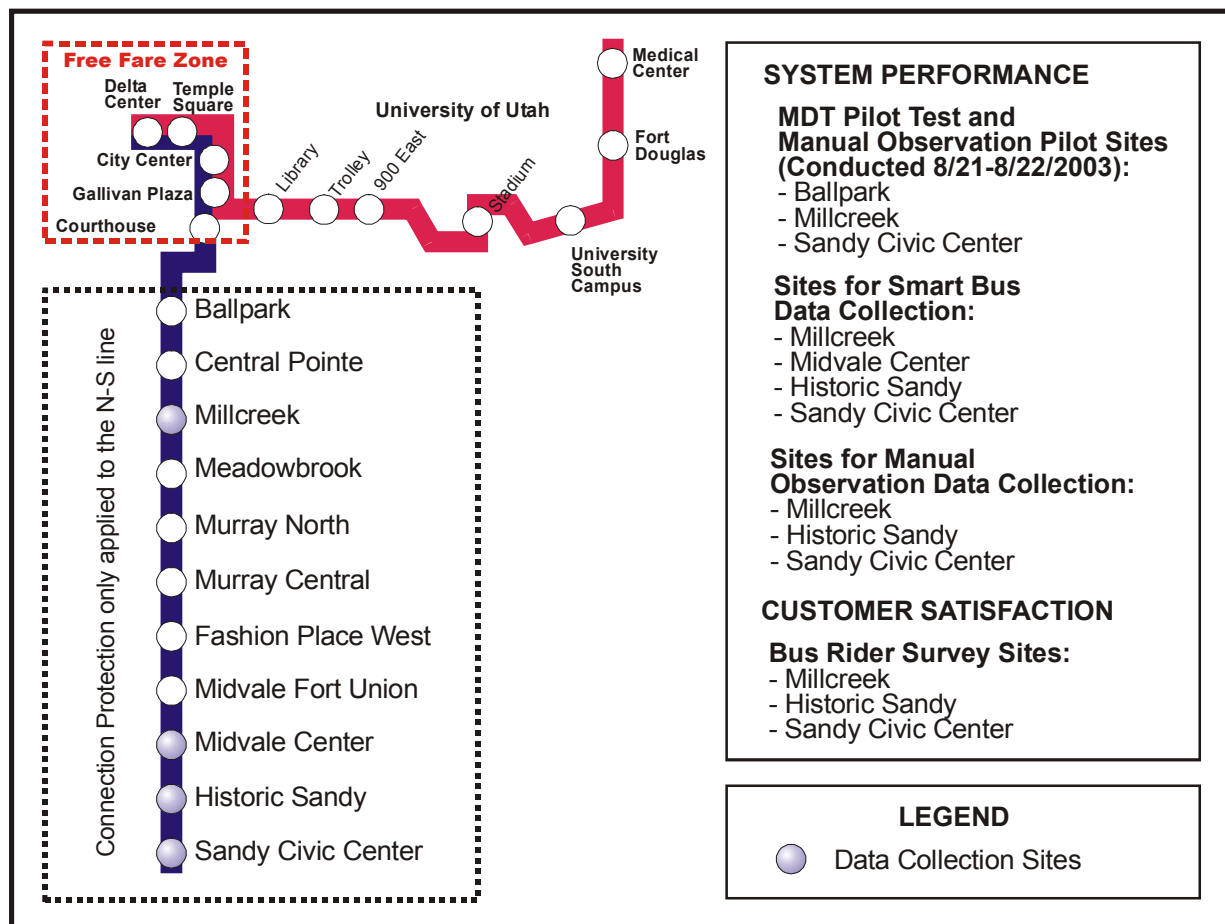


Figure 1-2. UTA TRAX System Diagram

There were two main evaluation components; namely, a quantitative and a qualitative assessment of CP with the overall objective of determining the impacts of CP on the UTA transit system and its riders. The objective of the quantitative portion of the evaluation was to assess the impacts of the CP using system performance data (i.e., data that measure various aspects of the transit system such as arrival and departure times). The objective of the qualitative portion of the evaluation was to assess the perception of users, including bus riders, bus operators, UTA

supervisors, and radio control coordinators. The qualitative assessment was largely conducted through surveys and personal interviews.

The two portions of the analysis therefore provide different perspectives on the overall objective of assessing the impact of CP. Figure 1-3 summarizes the interrelation between the two different portions of the evaluation and the methods that were used to obtain the data.

Section 2 presents the results of the quantitative assessment (System Performance Evaluation). Results of the qualitative assessment (User Perceptions Evaluation) are presented in Section 3. A discussion of overall findings and recommendations is provided in Section 4.

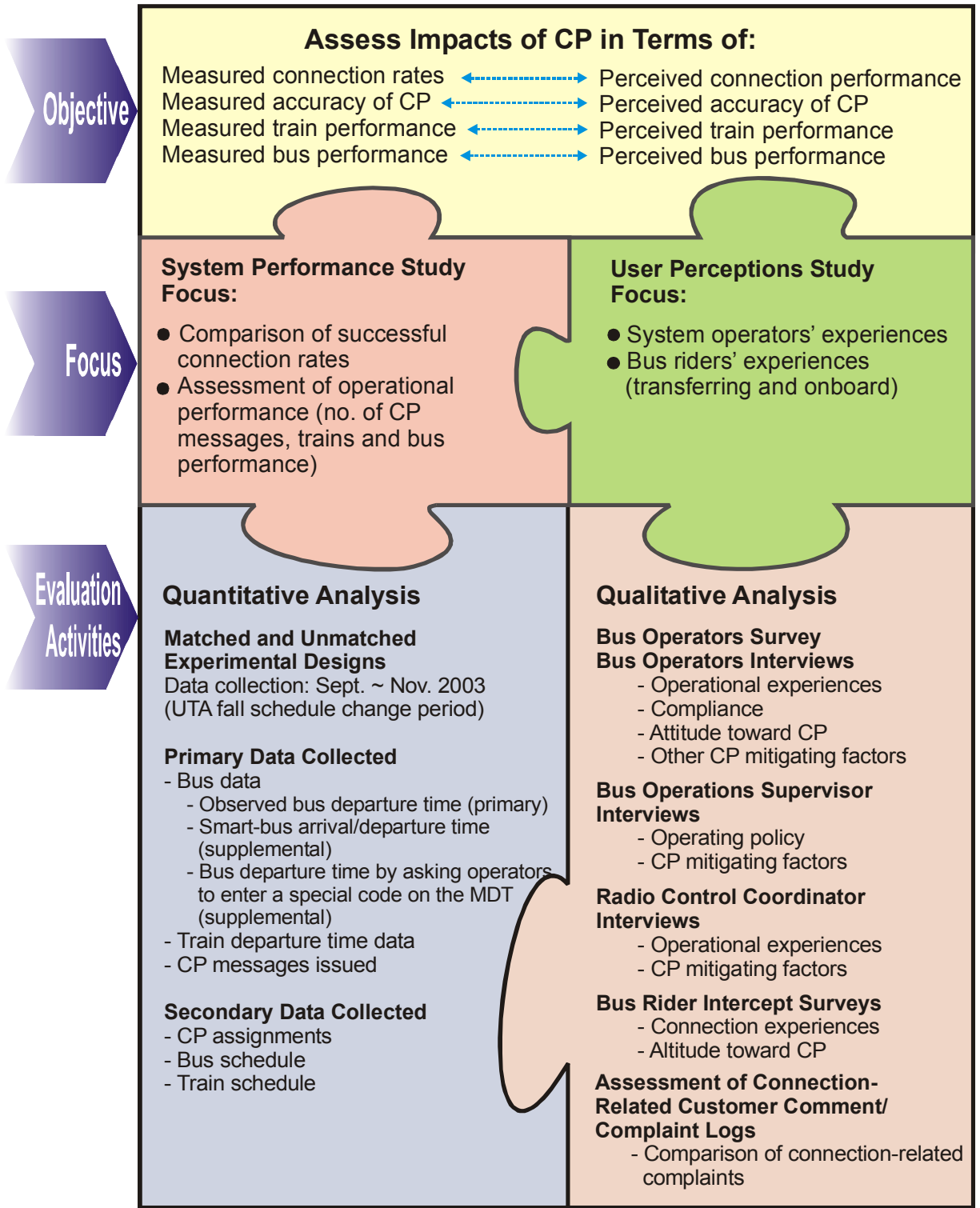


Figure 1-3. Overall Evaluation Approach

2.0 System Performance

2.1 Introduction

The primary objective of the evaluation of the performance of the CP system is to evaluate the ability of the CP system to prevent missed train-to-bus transfer connections. A secondary objective of the evaluation of system performance is to evaluate operational aspects of the system performance. However, this does not include an evaluation of the specific hardware and software that comprise the CP system. Rather, particular emphasis was on evaluating the extent to which the CP system consistently operates the way that it was designed from an overall perspective.

2.2 Overview of Approach

Ideally, an evaluation of CP would be conducted by tracking the movements of each individual train passenger as he/she departs the train and boards a bus, enabling a passenger-by-passenger determination of whether a successful train-to-bus connection has occurred. That is, this approach would be to enumerate all passenger movements from train-to-bus and use this information as the foundation for estimating the percentage of transfers that were successful. However, this approach is difficult in practice to implement because there are multiple buses that train passengers are meeting. Tracking each individual passenger from the train to the bus would require resources that were beyond the scope of this evaluation. Rather than tracking individual train passengers to measure success, the quantitative evaluation relied upon tracking the movements (departures) of buses in relation to the train arrivals as a surrogate measure of a successful connection. Anecdotal evidence suggests that train passengers, walking at a normal pace, could depart from the train and reach the farthest bus departure point in roughly 60-120 seconds at all of the TRAX stations considered in this evaluation. Two different requirements on the *bus departure time* were employed to define a “successful” connection: 1) requiring that the bus departs at least 120 seconds after the train arrives (i.e., the bus must hold at the TRAX station for at least 120 seconds after the train arrives), and 2) requiring that the bus departs at least 180 seconds after the train arrives. A further discussion on the two different requirements for defining a successful connection is provided in Section 2.3.3.

Evaluating the effectiveness of the CP system to improve successful connections of passengers from train to waiting buses necessarily requires the accurate measurement of bus departure times and the linking of those departures to the train arrival times. Accurately measuring bus departure times under reasonable cost and logistical constraints without impacting operations is a challenging task because each possible approach has cost or operational limitations. Three complementary data collection methods were used to capture bus departure times in this evaluation: 1) manual data collection by independent observers at the TRAX station of the bus departure times, 2) collection of automated bus departure times by UTA buses that are GPS/APC² equipped (i.e., “Smart-buses”), and 3) bus operator manually signaling each bus departure time by entering a code on the MDT.

² Global Positioning System and Automatic Passenger Counter

Manual data collection through observation was conducted at three TRAX stations (Millcreek, Historic Sandy, and Sandy Civic Center) between 3:00 p.m. and 7:00 p.m. weekdays to supplement the MDT and Smart-bus data collection and to provide a means for assessing the quality of the other two methods of data collection. With this method, two independent observers manually recorded the arrival and departure times for every bus at each of the three TRAX stations.

Smart-bus data collection consisted of assigning GPS/APC-equipped buses to specific bus routes and capturing the equipment-recorded arrival and departure times. Information on both arrival and departure times is available from these buses. However, only a limited number of buses were available for use in the evaluation.

Data collection through the MDTs consisted of having bus operators indicate their departures from a TRAX station by sending a predetermined message through their MDT. Because every bus, and hence every operator, has the capability to indicate departures using the MDT, this data collection approach could have had coverage at all TRAX stations. However, this data collection method was dependent upon the participation of bus operators and required that radio control coordinators manually enter the times indicated by the bus operators into the radio log. Additionally, departure times were available only to the minute resolution. Ultimately, participation by the bus operators was minimal and inconsistent, and only a relatively few bus departure times were measured using MDTs.

Data on bus departures were collected from the various sources, as described above. Data were collected for as many bus trips as possible over the three-month data collection period, including instances where CP was only minimally operational (e.g., September 30, 2003, through November 5, 2003).

All system performance data were collected during the Fall 2003 “change period” so that bus routes, train times, etc. would be consistent throughout the entire data collection period. Data collection with the Smart-buses occurred between September 2, 2003 and November 21, 2003. Data collection via manual observation and the MDTs began October 1, 2003, and October 17, 2003, respectively, and ended November 21, 2003. Additional system information also was collected during the three-month data collection period. Most of the data required for the evaluation of system performance already were routinely collected as part of UTA’s normal course of operations. The additional data that were used for the evaluation of system performance included:

- TRAX Schedules – scheduled train departure times at each of the TRAX stations.
- Bus Schedules – scheduled bus departure times for each bus route that intersects a TRAX station.
- CP Assignments – bus trips (route/time combinations) at each TRAX station that have been designated for CP protection. These data are prepared as part of UTA’s normal operations.

- CP Message Logs – CP messages generated by the CP system. These data are captured by UTA as part of normal operations.
- Train Data – Arrival and departure times for trains at each of the TRAX stations. All light rail trains operated by UTA are equipped with GPS receivers that are used to record the real-time location of each train. UTA maintains a train tracking system that electronically collects these GPS data and monitors the performance of each train. Pertinent data (train identifier, scheduled and actual arrival/departure times, etc.) were queried from the train tracking system.

As discussed above, all of these data sources were developed as part of the normal operation of the CP system. A more detailed examination of each data source and a discussion of how these data were combined to form data suitable for statistical analysis are described in Sections 2.3.1 and 2.3.2.

Four different analyses were conducted using different sets of data to evaluate the effectiveness of CP. Generally, the statistical analyses consisted of descriptive statistics and use of repeated measures analysis of variance (ANOVA) models. The ANOVA models were used to identify factors that were significantly related to a successful connection and included adjustments for the inherent correlation in the data due to observing multiple observations on the same bus trip over time. Additional details on each of the four analyses are described in detail in Section 2.4. A brief summary is provided for each analysis below.

Unmatched “With and Without” Data Analysis. Over the course of the data collection period assignments of the routes where CP was active varied. For example, a route that had an active CP protection in September may not have had active CP in November (and vice versa). Additionally, CP was not active for any routes except for the Provo-bound routes (811 and 812) from September 30, 2003, through November 5, 2003. Therefore, data on the bus departure times during late train events were collected for many bus routes both when CP was active (i.e., “With”) cases and when CP was inactive (i.e., “Without”) cases. Because multiple observations were collected during the data collection period, each bus trip was able to serve as its own baseline reference level and did not have to be “matched” to a similar bus trip where CP was inactive to use as a reference level. Logistic regression models with repeated effects were used to examine the effect of the status of CP (CP was active and a “hold until” message was issued, CP was active and a “hold until” message was not issued, or CP was inactive) as well as other covariates such as TRAX station, weekday, time of day, and lateness of the train on the probability of a successful train-to-bus connection.

Unmatched “With and Without” Analysis for Effects of Issuing a “Hold Until” Message. There were some bus routes where information was obtained only when CP was active (e.g., route 811). These bus trips were not included in the first analysis because each one could not serve as its own control or reference level in the absence of CP. Therefore, a second analysis was conducted using only those bus trips where CP was active to investigate whether the impact of issuing a suggested “hold until” message differed under the condition that CP was active. As with the first analysis, this analysis was conducted using logistic regression and the unmatched bus trips.

Matched “With and Without” Analysis. There were 14 bus trips that were identified prior to the data collection where a bus trip that had CP active could be matched to a bus trip where CP was inactive. For two bus trips to be considered a match, they had to have identically scheduled departure times at the same TRAX station (i.e., they were both associated with the same train). With these data, each bus trip where CP was active (i.e., “With” cases) had a corresponding bus trip where CP was inactive to serve as a reference or control level (i.e., “Without” cases). Comparisons were made between the percentages of bus trips where a successful connection occurred between the “With” and “Without” cases.

Analysis of Hold Times. The amount of time that a bus operator holds the bus after the normal departure time is a separate surrogate for successful connections. If CP increased effectiveness, it would be reasonable to expect that the average length of time that the bus operator holds the bus in a late train event would be longer when a CP “hold until” message is issued than when a CP “hold until” message is not issued or when CP is inactive.

In addition to evaluating effectiveness, descriptive statistics were prepared to summarize operational aspects of the CP system. These analyses included investigations into compliance with CP-issued “hold until” messages and the ability of the CP system to accurately and correctly identify late train events.

2.3 System Performance Data

System performance data that were used to evaluate the effectiveness of CP were collected from a number of different sources. Section 2.3.1 discusses the collection of these data. Once the data had been collected, extensive manipulation and combining of the data was necessary to develop databases suitable for statistical analysis. Section 2.3.2 describes the processes used to combine information from different sources. It also is important to understand the limitations and resulting necessary assumptions that were applied to the collected data (Section 2.3.3).

2.3.1 Data Collection

As introduced in Section 2.2, three complementary data collection methods were used to collect bus departure and arrival data from buses. In addition, other data needed for the evaluation were obtained from UTA’s existing data systems. Details on how all of these data were collected are provided in this section.

Mobile Data Terminal

Mobile data terminals are communication devices that are equipped on all UTA buses to enable communication between bus operators and radio dispatchers for normal business activities. UTA felt that they could be easily utilized by bus operators to signify departure times from each TRAX station. This method required participation by both the bus operators and the radio dispatchers. Each time that a bus operator transmitted a Code 34 message (an unused data text message in the radio log system that was used as a surrogate for “bus departure”) radio control

coordinators needed to acknowledge the message and mark it (via the computer) with the time that the message came in (which may have been earlier than the time that it was acknowledged).

Radio control coordinators were informed of the importance of entering complete and accurate data. Bus operators were notified of the procedures through their Operations Supervisors. A memo from UTA's ITS Manager (and technical contact for the CP Evaluation) described the implementation to the Operations Managers and asked their support in conveying the need for participation by the bus operators. It also emphasized that the data collection was solely for the purpose of evaluating the CP system and that the data would not be used for any other purposes. The exact instructions to be given to the operators were:

Immediately before departure from the TRAX station, after the doors are closed, but before the bus is moving, the operator should send text message #34 "Loss of Traction" to Radio Control Coordinator (RCC) (some radios may have a different message programmed, but message 34 should be sent anyway).

The actual mechanics of transmitting and receiving the message were as follows:

1. Bus operator pressed a sequence of keys ("Code", "3", "4", "Send") on the MDT.
2. Message (along with timestamp) appeared on the RCC's computer screen.
3. RCC entered the time of the incoming message, bus block number, and code "34" into the radio log, which was maintained on a separate computer that was located next to the computer that displays the incoming messages. The logged message was automatically time-stamped with the time that it was entered.

Although this manual process was subject to error, the UTA radio system was not capable of automatically recording messages to the radio log. Another drawback of using the MDTs was that UTA encountered delays in getting word out to all of the bus operators and dispatchers to begin collecting data. As a result, the MDT data collection was utilized only from October 17, 2003, through November 21, 2003.

Generally, there was very low participation by operators. Out of 33,722 scheduled bus trips that departed from targeted TRAX stations on weekdays during the 26 days that the MDT data collection method was utilized, only 1,308 trips had a recorded MDT departure time. Table 2-1 summarizes the number of messages received per TRAX station.

Table 2-1. Number of MDT Departure Times Recorded at Each TRAX Station

TRAX Station	Expected Bus Trip Departures*	MDT-Recorded Bus Trip Departures
Ballpark	1,612	166
Central Pointe	3,536	1
Millcreek	3,718	131
Meadowbrook	4,316	1
Murray North	2,028	2
Murray Central	2,600	27
Fashion Place West	3,796	70
Midvale Fort Union	1,586	185
Midvale Center	2,808	540
Historic Sandy	2,574	0
Sandy Civic Center	5,148	172
Total	33,722	1,308**

* based on daily trips for 26 weekdays between October 17 and November 21

** includes 13 cases for which bus route (thus TRAX station) was not identified

Manual Observation

Collecting data via manual observations was conducted by hiring individuals identified by the Salt Lake County Aging Services (SLCAS) office. These individuals were paired up into three teams of two, and each team was assigned one of the three targeted TRAX stations. Because of the cost implications of hiring data collectors, a decision was made to limit this data collection to the last two months of the evaluation and to focus it on the three TRAX stations identified during the March 2003 exploratory analysis [Ref. 1] as receiving the most CP messages. These stations were Millcreek, Historic Sandy, and Sandy Civic Center. For the same reason, the afternoon rush was selected as the time of day to conduct the data collection. As a result, the teams were asked to record the arrival and departure times for all buses traveling through their assigned stations between 3:00 p.m. and 7:00 p.m. each weekday between October 1, 2003, and November 21, 2003.

Prior to data collection on the first day, a training session was held at the SLCAS office to explain the purpose of the study and the specific instructions for collecting the data. Each individual was provided with a radio-controlled atomic clock (which in theory would provide the exact same time as UTA's system clocks), a set of pre-printed data collection forms that listed

the times that each bus was expected to arrive at the respective TRAX stations, instructions on using the clock and collecting data, and a schematic of the TRAX stations showing where each bus was assigned to stop. The data collectors were instructed to independently record the arrival and departure times (i.e., members of each team were told to record the times separately and not compare notes) so that a measure of inter-recorder reliability could be estimated. In addition, the definitions of departure time and arrival time listed below were explained. The data collectors also were told that the departure times were far more important than the arrival times, thus if there were any difficulties capturing both due to too many buses arriving and departing at once, to record the departure times at the expense of the arrival times.

- Arrival Time – time at which bus pulls up to the designated drop-off spot and opens doors to allow passengers to disembark.
- Departure Time – time at which bus pulls out of its designated pick-up location (typically different from the drop-off spot) after all passengers have boarded.

A coordinator within the SLCAS office agreed to serve as the supervisor for the manual data collectors. This individual was responsible for recruiting the data collectors, collecting the data sheets and shipping them to the Evaluation Team on a weekly basis, and serving as point of contact in case problems occurred or questions arose in the field. In addition, because the manual observations were scheduled to occur every weekday from October 1, 2003, through November 21, 2003, an extra individual was hired to serve as a substitute if one of the regular observers got sick or otherwise could not work on a particular night. The coordinator arranged for the substitute to work as needed.

Overall, the manual data collection efforts went extremely well. The data collectors were very happy to have the steady work and were very conscientious in performing their jobs. During the first night of data collection, members of the Evaluation Team traveled between TRAX stations to ensure that all data collectors understood their jobs and did not have any questions. Minor confusion occurred with some of them at the very beginning of the night, but after questions were answered they were able to complete the data collection forms correctly and without additional help.

As with any field data collection program, minor incidents occurred with the manual data collectors (slight turnover in staff, need for work schedule adjustment, etc.). However, these incidents were all resolved with no impact on the overall data collected.

Figures 2-1 through 2-3 illustrate the layout of the three TRAX stations monitored by the manual observers. These figures are copies of the schematics that were provided to the data collectors, except that they now have been annotated to show where the data collectors stationed themselves most of the time. Prior to the start of data collection, the Evaluation Team visited each TRAX station to determine the best viewpoints to observe all of the bus stops. Data collectors were instructed to observe from these points, but were given the leeway to move to other points as long as they were not obstructed from observing all of the stops.

3300 South - Millcreek UTA TRAX - Sandy Line

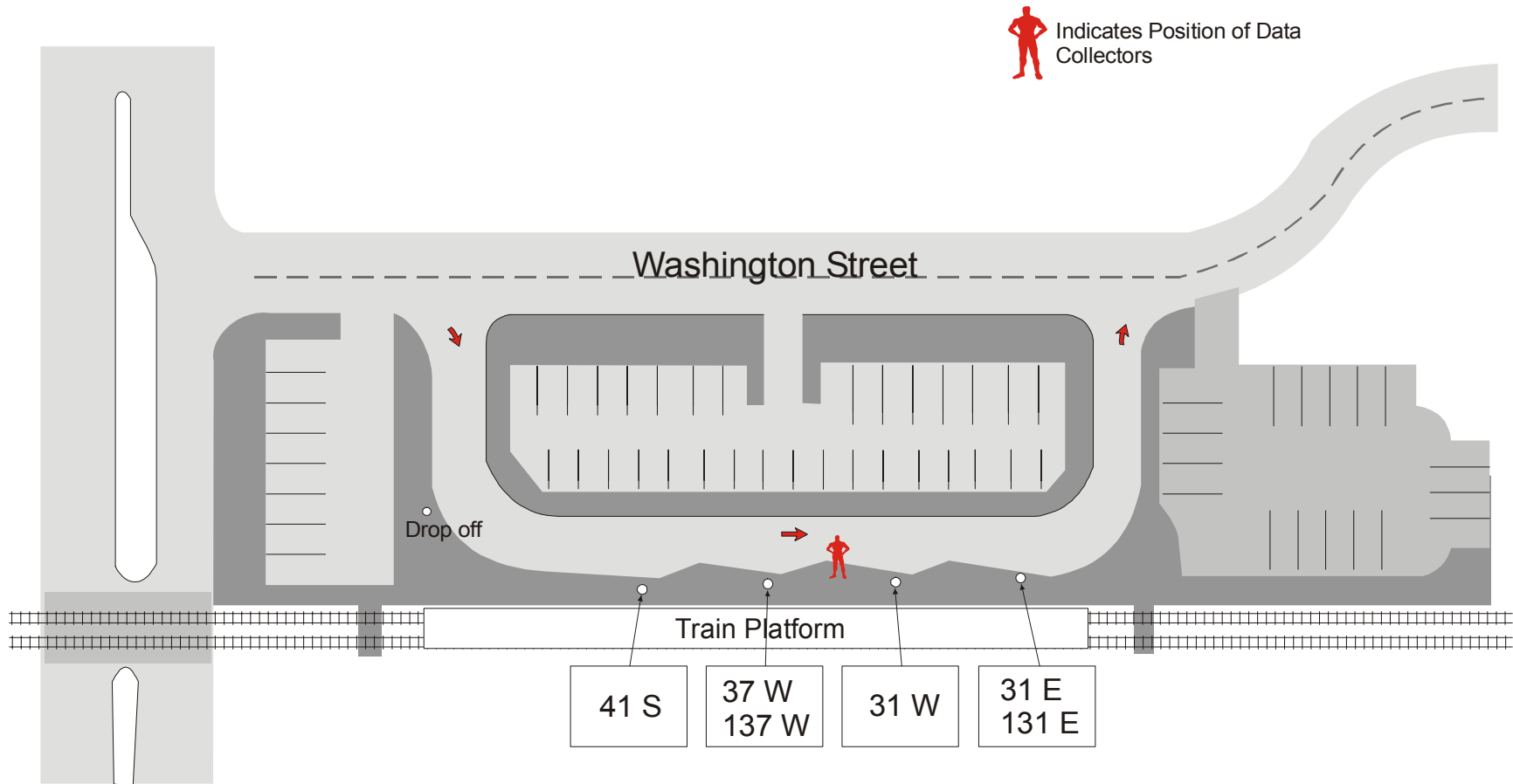


Figure 2-1. Layout of Millcreek TRAX Station and Location of Data Collectors

9000 South - Historic Sandy UTA TRAX - Sandy Line

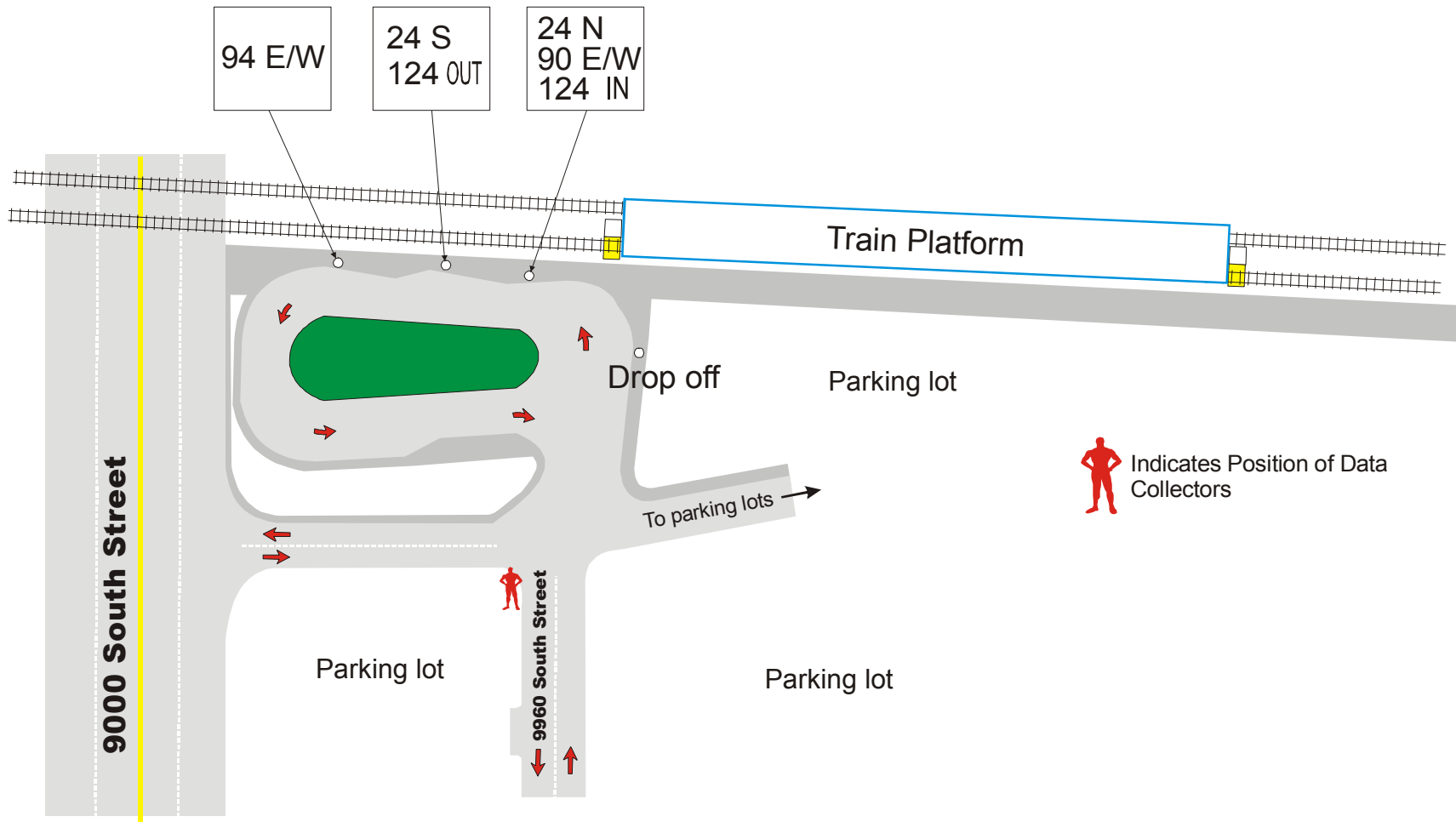


Figure 2-2. Layout of Historic Sandy TRAX Station and Location of Data Collectors

10000 South - Sandy Civic Center UTA TRAX - Sandy Line

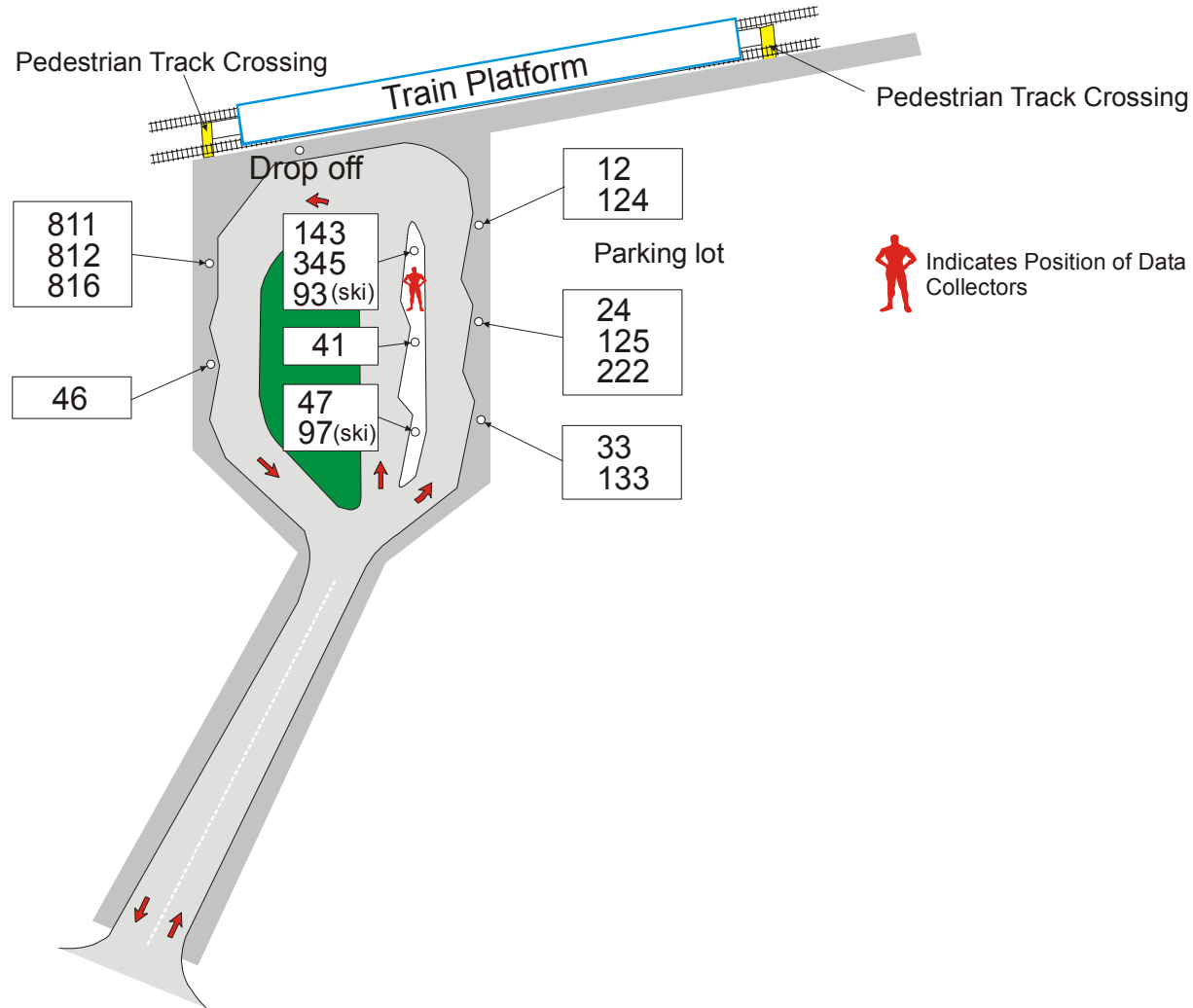


Figure 2-3. Layout of Sandy Civic Center TRAX Station and Location of Data Collectors

The data sheets provided to the data collectors were printed for all scheduled buses between 2:30 p.m. and 7:30 p.m. This was done so that if the data collectors arrived early or stayed late for any reason, they could go ahead and record any buses that arrived or departed. Recording these extra bus trips was completely voluntary; data collectors were required to record bus times only during their assigned four-hour shift. Table 2-2 lists the number of bus departures recorded by each data collector at each TRAX station.

Table 2-2. Number of Bus Departure Times Recorded by Manual Observers at Each TRAX Station

TRAX Station	Expected Bus Trip Departures*	Manual Observer #1	Manual Observer #2
		Number of Departures Recorded**	Number of Departures Recorded**
Millcreek	1,520	1,548	1,414
Historic Sandy	1,102	1,204	1,235
Sandy Civic Center	2,166	1,954	1,842
Total	4,788	4,706	4,491

* based on daily trips between 3:00 p.m. and 7:00 p.m. for 38 weekdays between October 1 and November 21

** includes any departures that were recorded between 2:30 p.m. and 7:30 p.m.

Smart-bus

The term “Smart-bus” refers to buses that are GPS/APC-equipped and can therefore capture equipment-recorded arrival and departure times. Details on how the Smart-bus technology works are discussed in Section 2.3.3.

There were 41 Smart-buses used during the evaluation. Due to the limited number of these buses and the logistical considerations for how these buses are assigned to specific bus routes, these buses were assigned to the same bus routes for the entire three-month data collection period. Although the Smart-buses also collected data on weekends, only weekday data were included in the evaluation.

Table 2-6 in Section 2.3.2 details the 14 pairs of bus trips that were identified prior to the evaluation as cases for which a “With CP” and “Without CP” analysis could be performed. Smart-buses were assigned to the 28 bus trips represented in this table. Because the Smart-buses collect data for all trips that operate throughout the day, additional bus trips intersecting TRAX stations also were covered by buses assigned to these trips. Overall, Smart-buses collected data for 979 different weekday bus trips that intersected TRAX stations.

Other System Performance Data

Additional system performance data was obtained from UTA’s Information System (IS) group responsible for maintaining and implementing the data systems behind CP. These data are discussed below.

Train Schedules: Data on the scheduled train stops at each station were necessary to plan which TRAX stations would be monitored during the evaluation and to determine the adherence to the schedule by the trains. UTA provided spreadsheets containing the August-November 2003 train schedules. Although the extension of the University TRAX route was opened on September 30, 2003, the train schedules at the TRAX stations of interest to the evaluation remained constant during the data collection period.

Bus Schedules: Data on the scheduled bus stops at each station were necessary to plan which TRAX stations would be monitored during the evaluation and to determine the adherence to the schedule by the buses. UTA provided spreadsheets containing the August-November 2003 bus schedules. Although the extension of the University TRAX route was opened on September 30, 2003, the bus schedules at the TRAX stations of interest to the evaluation remained constant during the data collection period.

CP Assignments: Data on the particular bus trips that were assigned protection by the CP system were necessary to plan which bus trips would be monitored during the evaluation and to determine the performance of the CP system when a late train occurs. Spreadsheets containing these data were provided by UTA at three times: 1) prior to the start of the data collection period (corresponds to September data); 2) when the new TRAX extension opened (corresponds to October data); and 3) after it was discovered that the majority of intended bus trips were not protected in October (corresponds to November data).

CP Messages: Data on the CP messages that were generated were necessary to determine the performance of the CP System when a late train occurs. A spreadsheet containing all CP messages generated during the data collection period was provided on a monthly basis by UTA.

Late Train Data: Data on the actual arrival of trains were needed to identify those trains that arrived late at the TRAX station. These data were obtained by UTA from queries run against its train tracking databases. These results of these queries contained all trains identified by the train tracking software as arriving at least two minutes late to a TRAX station. Spreadsheets containing these results were provided on a monthly basis. However, due to a computer server failure at UTA in October, all instances of late trains between October 2, 2003, and October 22, 2003, were lost. In addition, UTA was unable to provide late train data for the first two weeks of September. Thus, late train data were available for only a portion of the three-month data collection period.

2.3.2 Data Compilation

As described in Section 2.3.1, various types of data were used in the evaluation of system performance. These data were combined into three SAS datasets for use in the analyses discussed in Section 2.4. This section documents the process that was used to create these analytical datasets.

Eight tables in the Access database served as the basis for the data used in the analyses. Figure 2-4 shows the variables included in each of these tables.

TrainSchedule	BusSchedule	CPLog	CPAssign
SignID	SignID	LogDate	SignID
TrainDirection	BusDirection	LogTime	TrainBlock
TrainRoute	BusRoute	BusRoute	TrainTrip
Sequence	Sequence	BusTrip	TrainRoute
ScheduleTime	ScheduleTime	Bus	TrainDepartNode
NodeAbbr	NodeAbbr	Operator	TrainDirection
TrainBlock	BusBlock	NodeAbbr	TrainTripTime
TrainTrip	BusTrip	MinuteLate	TrainNodeTime
ServiceID	ServiceID	MissedFlag	BusBlock
	EndOfLine	Comments	BusTrip
		OldETA	BusRoute
		NewETA	BusDepartNode
		BusBlock	BusDirection
		BusNodeTime	BusTripTime
			BusNodeTime
			NodeID
			CategoryNum
			ServiceID
			NodeAbbr
			Exclude

LateTrains	SmartBuses	ManualData	MDT
Train Number	NodeAbbr	ID	DepartureDate
NodeAbbr	BusRoute	DataCollector	DepartureTime
TrainDirection	BusDirection	CollectionDate	Problem
ArrivalTime	TripDate	NodeAbbr	BusBlock
DepartTime	ScheduleTime	BusRoute	BusRoute
MinutesLate	ArrivalTime	BusDirection	BusUnit
DwellSecs	DepartTime	ScheduleTime	BusDirection
Comments	VehicleID	ArrivalTime	Comments
	ServiceID	NoArrivalTimeFlag	
		DepartTime	
		NoDepartTimeFlag	
		Comment	

Figure 2-4. Variables Included in Each Database Table

Prior to creating the analytical datasets, all data were subjected to a series of quality control checks in order to identify any unusable data. The CP assignment data necessitated the most examination. It was discovered that there were some obviously erroneous assignments made (e.g., CP was assigned to a bus that was scheduled to depart two hours before the train was scheduled to arrive, a bus that was scheduled to depart at the exact same time as the train, etc.). A total of 28 assignments were deemed to be invalid and were excluded from any analyses. Also, the CP message log data had three different types of CP messages; two of which were not used in any analyses. Table 2-3 shows the number of messages generated for each type of CP message. Only the “hold until” messages were utilized in the analyses.

Once the usable data were determined, a series of Access queries and SAS[®] programs were written to subset and combine the data into analytical datasets. In general, these analytical datasets necessitated that data for each late train that occurred be paired with bus data for those buses that were scheduled to meet the train and with any CP assignment and CP message data applicable to those bus trips. The various steps required to match the train and bus data are described below. Unless otherwise indicated, all work was done using SAS[®]. The specific data included in each of the analytical datasets are described in the respective subsections that follow.

Table 2-3. Types and Numbers of CP Messages Generated

Message Type	Message Description	Message Example	Number of Messages Received
“Hold Until”	Valid hold message issued to bus	CP 9201 Hold at SNDYCCTR until 15:45	1,602
“Missed”	Hold message generated that could not be issued to bus (e.g., train was too late)	MC 0138 Missed MILLCREK Train (504/357995) 5:24:00	468
“Discarded”	Hold message generated but could not be associated with a bus (e.g., operator was not logged in to MDT)	Discarded=CP 9735 Hold at HISTSN DY until 18:27	410

Step 1: Merging Late Train and Train Schedule Data

The starting point for creation of the analytical datasets was to merge the late train data with the train schedule data. In order to create a variable on which to merge the data, the number of minutes late was subtracted from the actual departure time on each late train observation to create a “scheduled departure time” variable. This variable and the corresponding ScheduleTime variable in the train schedule data were then used to merge the two datasets, retaining observations only if a late train occurred (i.e., schedule information was not kept for train trips that were never late). Note that the merging of these databases was accomplished through linking of scheduled departure times, but the statistical analyses utilized the actual train arrival times. Because of round-off error due to the fact that the late train data were reported only to the minute (see further discussion in 2.3.3), an additional minute was subtracted from the “scheduled departure time” of those late train observations for which no match was found in the train schedule data. The resulting times were used to re-merge these observations with the train schedule data, yielding matches being made for all but two late train observations. These remaining two observations were excluded from further processing.

Step 2: Merging Train and CP Assignment Data

Once the train data were combined, it was necessary to merge them against the CP Assignment data in order to identify those late train events that were linked to protected (or corresponding unprotected) bus trips. Two variables from the train schedule data (TrainTrip and NodeAbbr) were used in this merge. “TrainTrip” uniquely identifies each trip that the train made throughout the day, and “NodeAbbr” corresponds to the individual TRAX stations. Obviously, not every train is linked with a protected (or corresponding unprotected) bus trip, thus only a fraction of late train events were of interest for the analyses (exact number depends on particular analytical dataset). These late train events were the only ones retained in the dataset after this merge.

Step 3: Merging Train and Bus Data

Once the train and CP assignment data were combined, it was possible to merge them with bus arrival/departure time data collected via the three different methods (Manual Collection, Smart-

bus, MDT). For the manual collection data, the bus arrival/departure times recorded by the two independent data collectors first were combined into one observation per bus trip. Cases for which buses appeared at the TRAX station but were not scheduled to (e.g., bus may have dropped passenger off at station even though it was not scheduled to stop there) were removed during this step. Five variables (NodeAbbr, BusRoute, BusDirection, TripDate, ScheduleTime) were used in this merge.

The Smart-bus data was the next to be merged with the train data. The same five variables were used for this merge as well.

Finally, the MDT data were merged with the train data. Because the radio dispatchers did not typically record the bus route and bus direction in the MDT log, a separate set of Access queries were written, as described in the remainder of this paragraph, to assign these pieces of information to the MDT observations. First, the bus schedule data were sorted by bus block and scheduled time. Following this, time windows were created around each set of identical bus route/direction records within a bus block. The time windows equally split the difference in time between the last observation of one set of records and the first observation of the next set of records within the bus block. For the first set of records within the bus block, the beginning of the time window was set to 4:00 a.m.; while the ending of the time window for the last set of records was set to 11:59 p.m. Table 2-4 shows the time windows that were defined for one particular bus block. The MDT records then were compared (keying on bus block) against these time windows to identify the particular time window that encompassed the logged MDT time. The bus route/direction corresponding to this time window was assigned to the MDT record. This process assigned bus route/directions to all but 13 MDT observations.

Table 2-4. Examples of Time Windows Defined for MDT

Bus Block	Bus Route	Bus Direction	Time Window	
			Beginning	End
1015	41	Northbound	4:00:00 a.m.	5:37:30 a.m.
1015	37	Westbound	5:37:30 a.m.	7:04:30 a.m.
1015	41	Southbound	7:04:30 a.m.	8:36:30 a.m.
1015	33	Northbound	8:36:30 a.m.	9:32:00 a.m.
1015	33	Southbound	9:32:00 a.m.	10:12:30 a.m.
1015	41	Northbound	10:12:30 a.m.	11:16:30 a.m.
1015	41	Southbound	11:16:30 a.m.	12:36:00 p.m.
1015	33	Northbound	12:36:00 p.m.	1:32:00 p.m.
1015	33	Southbound	1:32:00 p.m.	2:12:00 p.m.
1015	41	Northbound	2:12:00 p.m.	3:07:00 p.m.
1015	37	Westbound	3:07:00 p.m.	4:30:30 p.m.
1015	41	Southbound	4:30:30 p.m.	5:57:30 p.m.
1015	41	Northbound	5:57:30 p.m.	11:59:00 p.m.

The SAS program performing the merges created a ± 9 -minute window around the DepartureTime for each MDT observation (one new observation per one-minute increment). These new observations were then matched against the bus schedule table using bus route, bus route, and bus direction in addition to the time variable. Observations that were successfully matched were assigned the corresponding TRAX station and bus schedule time. These observations were then merged with the late train data in a similar fashion as described for the other two bus data types. For merges of all types of bus data, only those bus trips that matched targeted late train events were retained.

Step 4: Merging Train and CP Message Log Data

Finally, the combined train and bus data were merged against the CP Message Log data in order to identify whether or not each late train event had a CP message issued and to obtain the details of each issued message. Four variables from the message log data (Date, NodeAbbr, BusRoute, BusDirection) were used in this merge. Multiple messages issued for the same trip were combined onto one observation per trip.

“Unmatched” Data (see Section 2.4)

The unmatched dataset included data for those cases where a bus trip was protected during at least one of the evaluation months and was not protected in at least one of the other months. Table 2-5 lists the number of bus trips protected in each of the three months that were unprotected in the other months.

Table 2-5. Number of Bus Trips Protected in at Least One Month and Not Protected in Another Month

Month Protected	Month Unprotected		
	September	October	November
September	--	53	19
October	1	--	0
November	134	180	--

Access queries were written and run against the CP Assignment table to identify those bus trips protected in one month, but not the others. Results of these queries were used as input to the CP Assignment merging discussed above in Step #2.

There were a total of 809 observations included in this dataset. Note that at the time of analysis, this dataset was further reduced to account for bus trips without recorded departure times, etc. (see discussion in Section 2.4).

“CP Active” Data (see Section 2.4.2)

A dataset containing data for late train events corresponding to all bus trips that were protected during the three-month data collection period was created.

The CP assignment table was used as input to Step #2 above to identify those bus trips that were assigned CP. Note that this dataset includes cases that were not found in the “unmatched” data. For instance, most trips for Route 811 were protected for the entire three-month period, thus they would not have been included in the unmatched data (i.e., there was not a corresponding month of no-CP to pair with the CP protections). On the other hand, this dataset has fewer observations (484) than the unmatched data because the corresponding unprotected trips are not included.

“Matched” Data (see Section 2.4.3)

The matched dataset included data for fourteen pairs of bus trips that were identified in the test plan as cases suitable for a “with and without” analysis. These were cases in which a projected bus trip was paired with an unprotected bus trip that was meeting the same train at exactly the same time. Because CP was accidentally turned off for most bus trips during October and some of the unprotected trips that were part of the pairs were actually protected in November, only a portion of the planned pairings could be included for this analysis. Table 2-6 shows the pairings that were valid in each of the three months.

Table 2-6. Pairings of Protected and Unprotected Bus Trips that Form the Matched Analysis Dataset

TRAX Station	Potential “Without” Case		Corresponding CP-Protected Trip(s)		Bus Departure Time	Train Arrival Time
	Bus Route	Bus Direction	Bus Route	Bus Direction		
Millcreek	31	Westbound	37	Westbound	16:40	16:37
	31	Eastbound	37	Westbound	17:40	17:37
Midvale Center	25	Clockwise	88	Westbound	17:08	17:05
	25	Clockwise	88	Westbound	17:38	17:35
	25	Clockwise	88	Westbound	18:08	18:05
Historic Sandy	90	Westbound	94	Eastbound	15:55	15:52
	94	Eastbound	90	Westbound	16:55	16:52
Sandy Civic Center	33	Northbound	811	To Provo	7:44	7:39
	33	Northbound	811	To Provo	8:14	8:09
	33	Northbound	811	To Provo	16:14	16:09
	33	Northbound	345	Outbound	16:42	16:39
	33	Northbound	46	Southbound	17:12	17:09
	33	Northbound	46	Southbound	17:42	17:39
	33	Northbound	46	Southbound	18:12	18:09

CP Assignment information for these pairings was used as input to the CP Assignment merging discussed above in Step #2.

There were a total of 78 observations included in this dataset. Note that at the time of analysis, this dataset was further reduced to account for bus trips without recorded departure times, etc. (see discussion in Section 2.4).

2.3.3 Data Limitations and Assumptions

As described in Section 2.3.2, the system performance data for this evaluation required complex manipulation to be usable for the evaluation. In addition to this manipulation, there were a number of significant limitations that were identified in the data, as well as necessary assumptions that were employed that could have an impact upon the results of the evaluation. The following provides specific details about the more significant of these limitations and necessary assumptions.

As discussed in Section 2.2, it was practically and logistically impossible to measure successful connections through an enumeration of train passengers. Therefore, the evaluation of system performance is based upon a comparison of the bus departure time to the train arrival time, which provides one surrogate for assessing whether a “successful” connection could logically have been made for train passengers. In preliminary investigations by the Evaluation Team, it was determined that train passengers, walking at a normal pace, could depart from the train and reach the farthest bus departure point in roughly 60-120 seconds at every TRAX station considered for this Evaluation. Utilizing this anecdotal information, two alternative definitions of a “successful” connection were developed and used in the statistical analysis: 1) the bus departs 120 seconds (two minutes) after the train arrives (i.e., requiring the bus to hold at the TRAX station for at least 120 seconds after the train arrives), and 2) the bus departs 180 seconds (three minutes) after the train arrives. Generally speaking, one would expect more bus departures to meet the definition of a “successful” connection to be recorded under the 120-second definition than the 180-second definition, because the requirements for how long the bus needs to wait following the train arrival for the departure to be classified as a “success” is less restrictive. That is, the 180-second definition is more conservative in measuring successful connections than the 120-second definition. An alternative measure of success that also was investigated was the amount of time that the bus operator holds the bus after the normally scheduled departure time.

Train arrival times at TRAX stations were automatically recorded as routine operational data by UTA’s computer systems. However, train arrival times were measured only to a minute resolution. In other words, the arrival times were rounded to the nearest minute. Therefore, the train arrival times inherently incorporate variation of up to a minute (plus or minus 30 seconds). This impacts the analysis because the surrogate measures of success were based upon measuring the time between bus departure and train arrivals. For example, the requirement that there be 120 seconds between the train arrival and bus departure for there to be a successful connection is, in actuality, a requirement that the bus departs between 90 and 150 seconds after the train arrives. The requirement that there be 180 seconds between the train arrival and the bus departure for there to be a successful connection is essentially a requirement that the bus departs between 150 and 210 seconds after the train arrives.

Using the data collection method available to this evaluation, train arrival time was not collected by UTA at Sandy Civic Center because this TRAX station is at the end of the north-south line (i.e., train dwell time was the main data being collected and dwell time was not applicable to the last stop on the train trip). However, many of the bus trips where CP was activated and many of the late trains were at Sandy Civic Center, making it an important TRAX station to include in the evaluation. As described in the Evaluation Plan [Ref. 1] for this project, an exploratory analysis was conducted using data collected by UTA during the last two months of 2002. These data included arrival and departure times at all TRAX stations including Sandy Civic Center (a previous version of the train tracking software, which was not in use during the main evaluation, was used to collect these data). Using these data, and average travel time of 166 seconds was calculated for train travel between Historic Sandy (the TRAX station immediately preceding Sandy Civic Center) and Sandy Civic Center. This historical average was applied to the train departure times at Historic Sandy to create estimated arrival times at Sandy Civic Center.

Generally, bus departure times were recorded through the observations of two different field data collectors. There was a very high degree of inter-observer agreement for the bus departure times (see Figure 2-5). Therefore, the departure times for the two different manual observations were averaged into a single departure time. Arrival and particularly departure times measured using Smart-buses are offset from the actual bus arrival and departure times because of how the data were collected. The GPS equipment in the Smart-buses samples GPS positions and GPS time every second, but this information is saved to the log only when a triggering event occurs. The timestamp for a bus departure requires that two conditions be met. First, the GPS equipment must sense that the bus is 650 linear feet from the GPS coordinates associated with the center of the TRAX station. Second, the Smart-bus also must have actually traveled 0.25 miles. Although the Smart-bus-recorded departure times generally agreed with the departure times recorded through manual observers (see Figure 2-6), the median difference between the manual departure times and departure times recorded by Smart-buses was 48 seconds. Therefore, the departure times recorded by Smart-buses were adjusted by subtracting 48 seconds from the recorded Smart-bus departure time. There was insufficient evidence to suggest that the arrival times recorded by manual observers differed from the arrival times recorded by Smart-buses. No adjustments were made to the Smart-bus recorded arrival times.

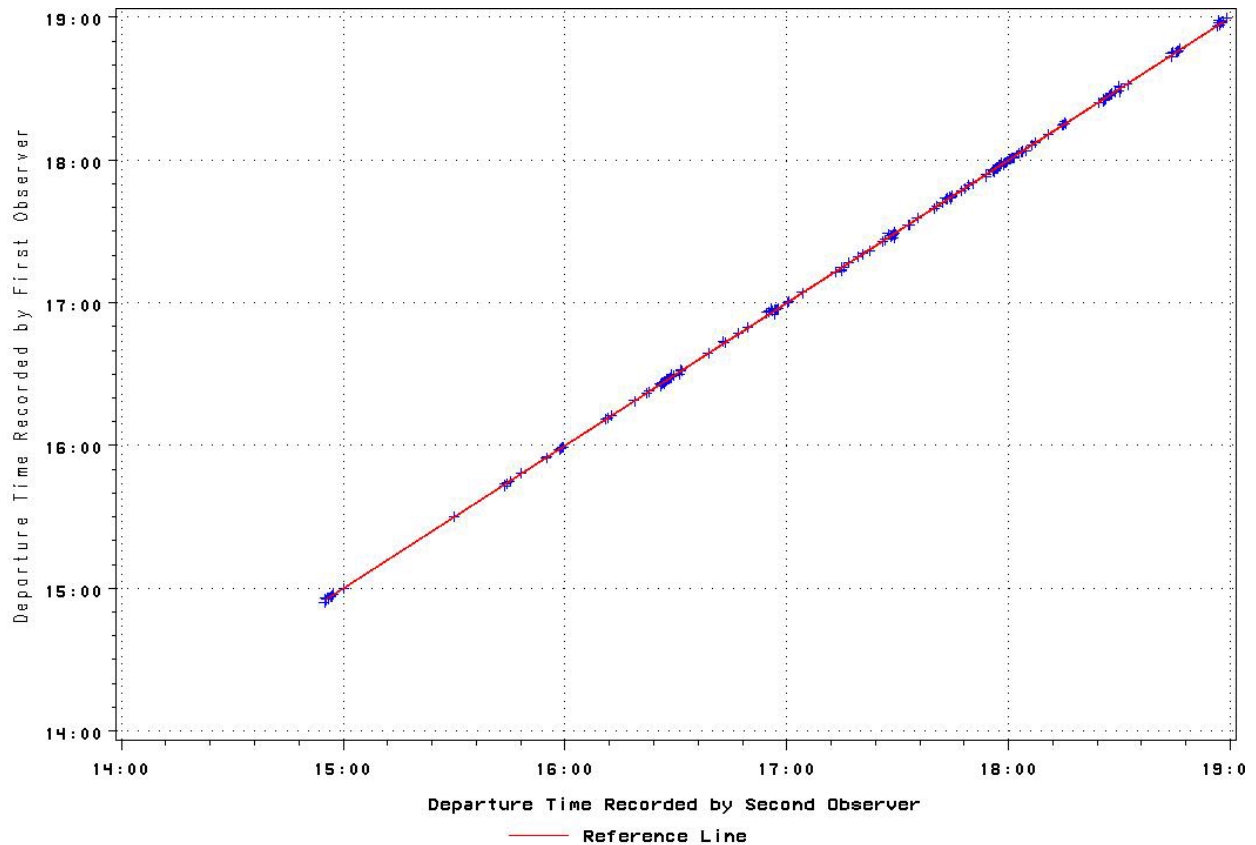


Figure 2-5. Comparison of Bus Departure Times Manually Recorded by Data Collectors

Only a limited number of bus departure times were recorded by bus operators through the MDT equipment. Departure times based upon the MDT data were available for 15 bus trips associated with a late train event and only in three cases were the departure times measured only by MDT. For the analyses, the bus departure times recorded through manual observations were used if available, followed by bus departure times recorded by Smart-buses if manual observations were not available. The MDT departure times were utilized for the three cases where the bus departure was captured only by the MDT method.

The most significant limitation in the data for the evaluation is the relatively small number of bus trips where there was a late train event and the departure time of the bus was recorded. Every attempt was made to collect information on bus departures during late train events, including the use of field data collection teams at three TRAX stations: Millcreek, Historic Sandy, and Sandy Civic Center during the months of October and November. However, due to a failure of UTA’s computer server and difficulties in extracting information from the backup server, data on late trains that occurred for the bulk of October were unavailable. This essentially reduced the number of observed late train events where bus departure times were measured in half from those expected. This affected the analysis by making it more difficult to detect statistically

significant differences. Additionally, it was impossible to investigate interaction terms between significant factors in the statistical models.

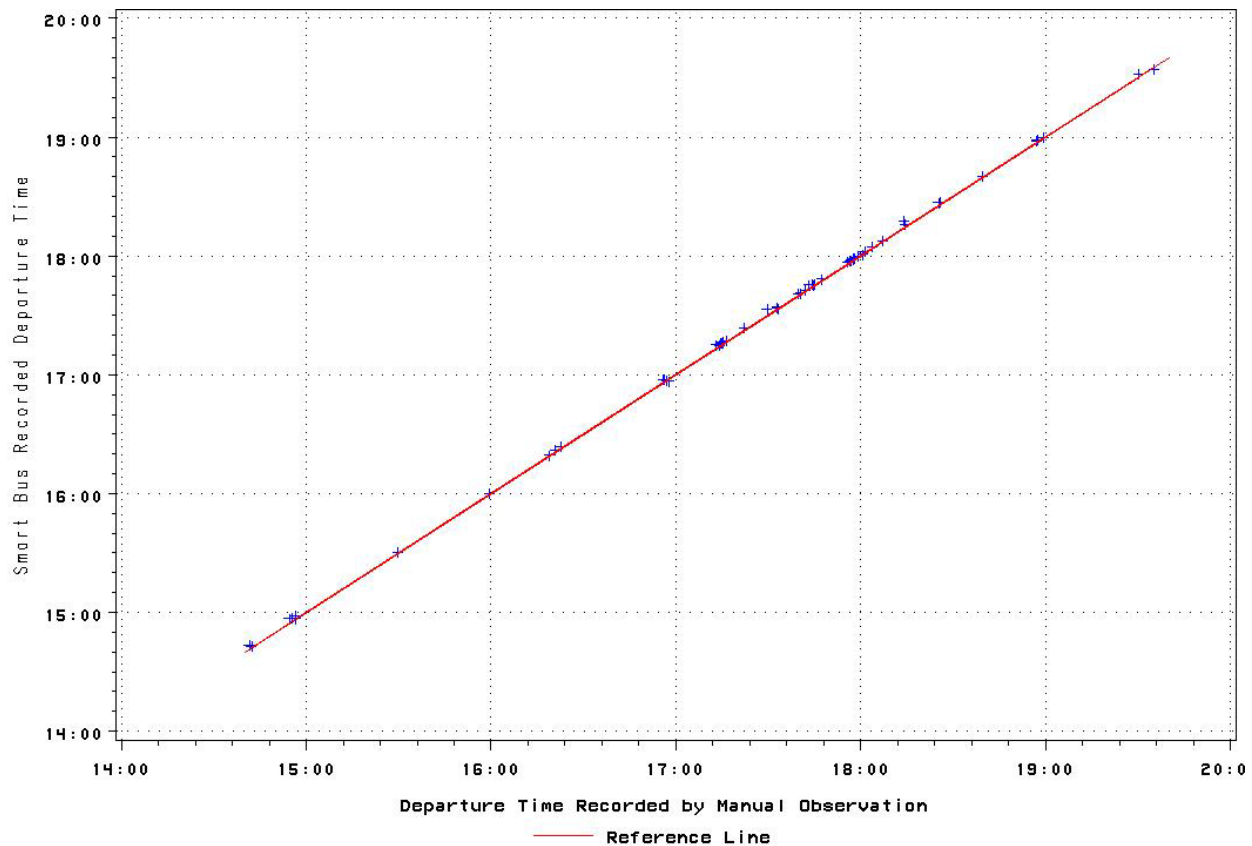


Figure 2-6. Comparison of Bus Departure Times Recorded by Smart-buses to Bus Departure Times Recorded Through Manual Observation

2.4 Effectiveness of Connection Protection

The primary objective of the evaluation of system performance is to evaluate the effectiveness of the CP system. More specifically, the objective is to evaluate the ability of the CP system to prevent missed connections and its ability to improve the number of successful train-to-bus transfers. There are different measures of effectiveness that could be employed. For this evaluation, CP will be deemed to be effective if it increases the likelihood or probability of a successful connection from train to bus.

The basis for the evaluation of system performance is the comparison of bus departure times against train arrival times in situations where the train arrived late at the TRAX station. Train arrival and bus departure times were measured for many different bus trips over the course of three months. There are two different scenarios for evaluating the effectiveness of CP. First,

train arrival and bus departure times were repeatedly measured during late train events, over three months, during which CP was turned on and off for the bus trips. That is, there are multiple measurements for each bus trip over time both with CP active and without CP active where each bus trip can be used as its own baseline. Henceforth, these data will be referred to as the “Unmatched” bus trips.

The second scenario that was used to evaluate the effectiveness of CP was to utilize “matched” bus trips. Under this scenario, data on train arrivals and bus departures during late train events were simultaneously collected for bus trips that were CP protected (i.e., the “with” cases) and for a selected number of trips that were not being CP protected (i.e., the “without” cases). Efforts were made to match each bus trip with CP to a “similar” bus trip that did not have CP. Bus trips were matched by TRAX station, time of day, frequency of bus departures, and an exact bus departure time. Table 2-6 in Section 2.3.2 summarizes the matched bus trips.

Three different statistical analyses were conducted to evaluate the effectiveness of CP using the information collected under both scenarios. Due to the limited number of measurements during late train events among matched bus trips, much of the evaluation is focused upon the Unmatched data.

2.4.1 Active Versus Inactive Connection Protection

Certainly, CP can be effective if “hold until” messages identifying a late train event are issued and followed by bus operators. However, there is the possibility that having a bus trip be actively protected by CP, whether or not a “hold until” message is issued, can raise the awareness or sensitivity of bus operators to late trains, causing improvements in the percentage of successful train-to-bus connections because of this increased awareness. That is, it is possible that simply having CP active may produce improvements successful train-to-bus transfers, even if a specific hold message has not been issued because CP may raise the awareness of bus operators. The specific hypothesis of interest for this evaluation was to determine if having CP being active (whether or not a message is actually issued) significantly increases the probability of a successful connection.

The analysis was conducted using the Unmatched bus trips and was limited to only those bus trips where there was information on the bus departure time in circumstances where CP was both active (“with” events) and where CP was not active (“without” events) at some point during the data collection period. Table 2-7 summarizes the number of bus trips and late train events for each bus trip by TRAX station that were collected during the three-month data collection period by TRAX station, time of day, and day of the week. Not surprisingly, the bulk of the available data is for the three TRAX stations where manual observations of bus departure times were recorded: Millcreek, Historic Sandy, and Sandy Civic Center. Additionally, the manual observations were largely conducted during the PM rush, which also is reflected in the table.

Table 2-7. Number of Unmatched Bus Trips and Late Train Events that had Both CP Active and Inactive During the Data Collection Period

Reference Category	Number of Unique Bus Trips	Total Number of Late Train Events	Number of Late Train Events Where CP Was Active		Number of Late Train Events Where CP Was Not Active
			Hold Issued	Hold Not Issued	
TRAX Station					
Millcreek	11	39	14	5	20
Fashion Place West	1	4	0	2	2
Midvale Center	6	28	9	4	15
Historic Sandy	16	104	38	20	46
Sandy Civic Center	12	77	30	10	37
Time of the Day					
AM Rush	2	14	3	3	8
PM Rush	43	235	87	37	111
Evening	1	3	1	1	1
Day of the Week*					
Monday	38	69	17	9	43
Tuesday	29	48	12	4	32
Wednesday	30	56	26	6	24
Thursday	26	49	21	12	16
Friday	23	30	15	10	5
Total	46	252	91	41	120

* Note that the same bus trips were observed on multiple days of the week.

The first step was to conduct a descriptive exploratory data analysis to investigate the relationship between the probability of a successful connection and the activation of CP. Also investigated were the relationships between other possible factors and successful connections including: lateness of the train, time of day, day of the week, and TRAX station. Figure 2-7 through Figure 2-11 summarize the percentage of successful connections for each of these potential factors. All 252 of the late train events included in Table 2-7 are also included in these figures, with 91 late train events where a “hold until” message was issued; 41 where CP was active, but a “hold until” message was not issued; and 120 late train events where CP was inactive. Although these percentages do not account for clustering introduced because of multiple measurements for the same bus trips over time (i.e., repeated measures), they do provide information that suggests that the probability of a successful connection might be related to the status of CP (active or inactive), TRAX station, and lateness of the train. More specifically:

- A higher percentage of successful connections was observed, regardless of the bus departure requirements, when CP was active, than when CP was inactive, with the

highest percentage of successful connections occurring when CP “hold until” messages were issued.

- The percentage of connections that were successful decreased as the trains became later.
- The percentage of successful connections varied somewhat by TRAX station, with Midvale Center having a lower percentage of successful connections than any other TRAX station.
- Time of the day may be related to the percentage of connections that were successful, but there were so few observations during Evening and AM Rush, that meaningful comparisons by time of day could not be performed. These percentages are shown for completeness, though.
- There was variation in the percentage of connections that were successful by day of the week, with Monday and Tuesday having lower success rates than Wednesday, Thursday, or Friday.

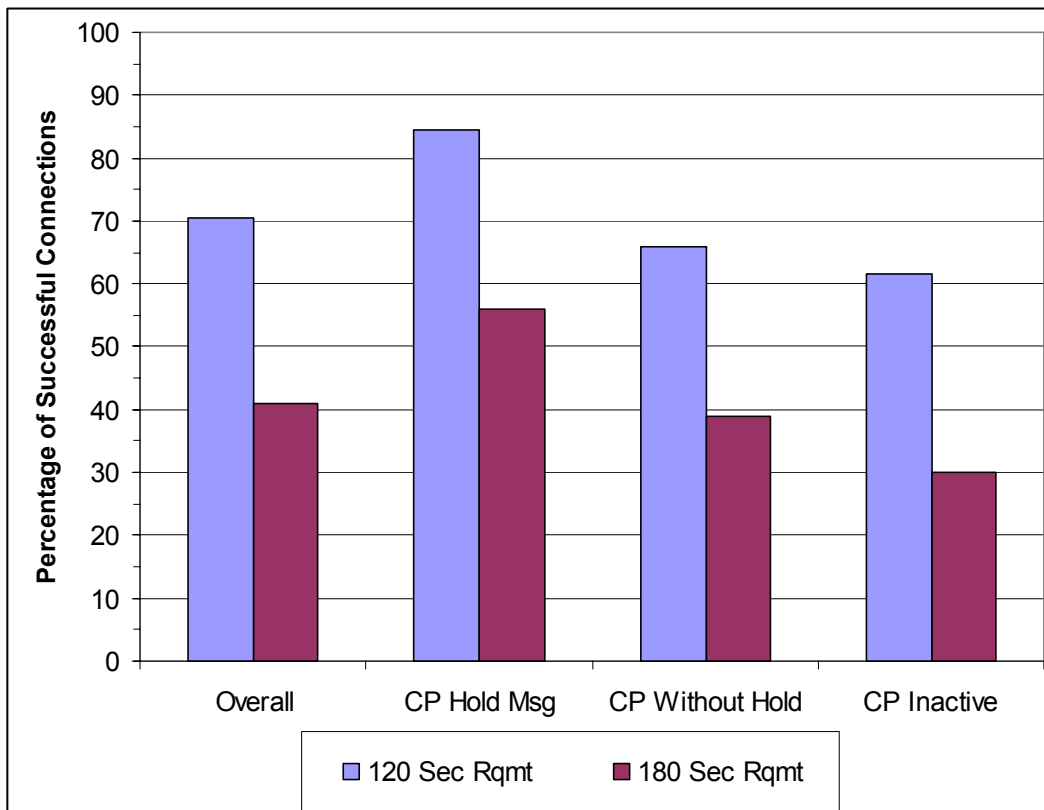


Figure 2-7. Percentage of Connections that were Successful by Status of CP

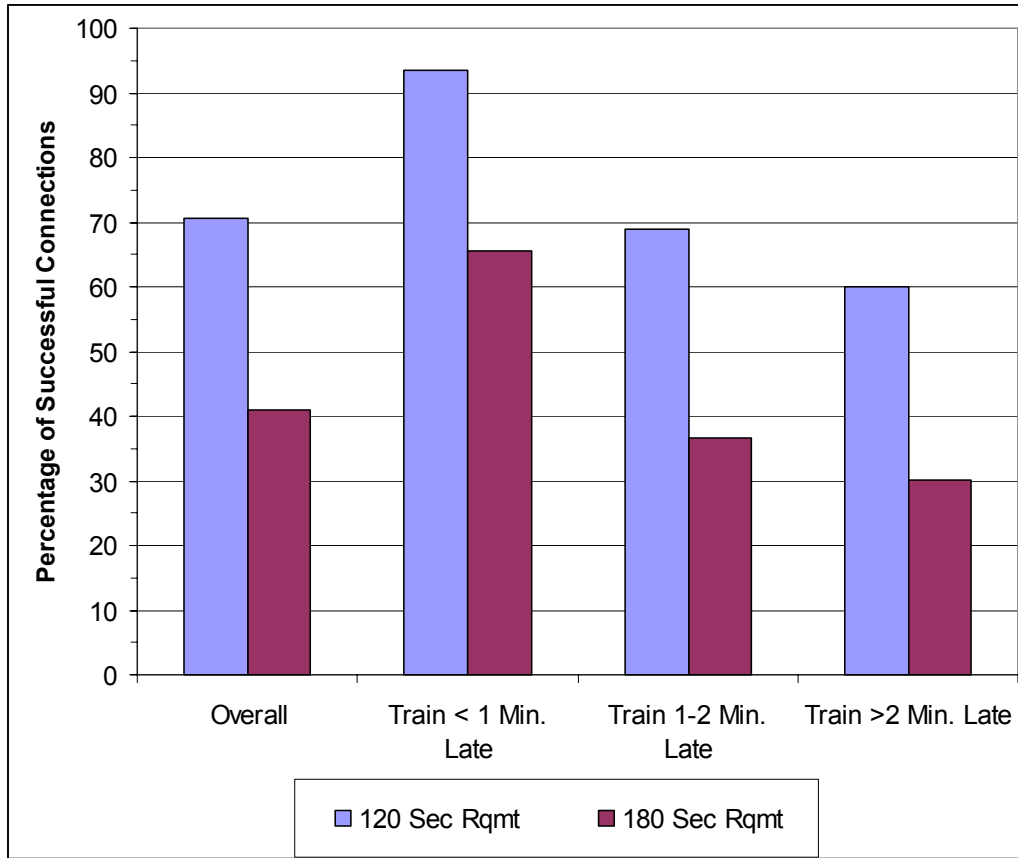


Figure 2-8. Percentage of Connections that were Successful by Lateness of the Train



Figure 2-9. Percentage of Connections that were Successful by TRAX Station

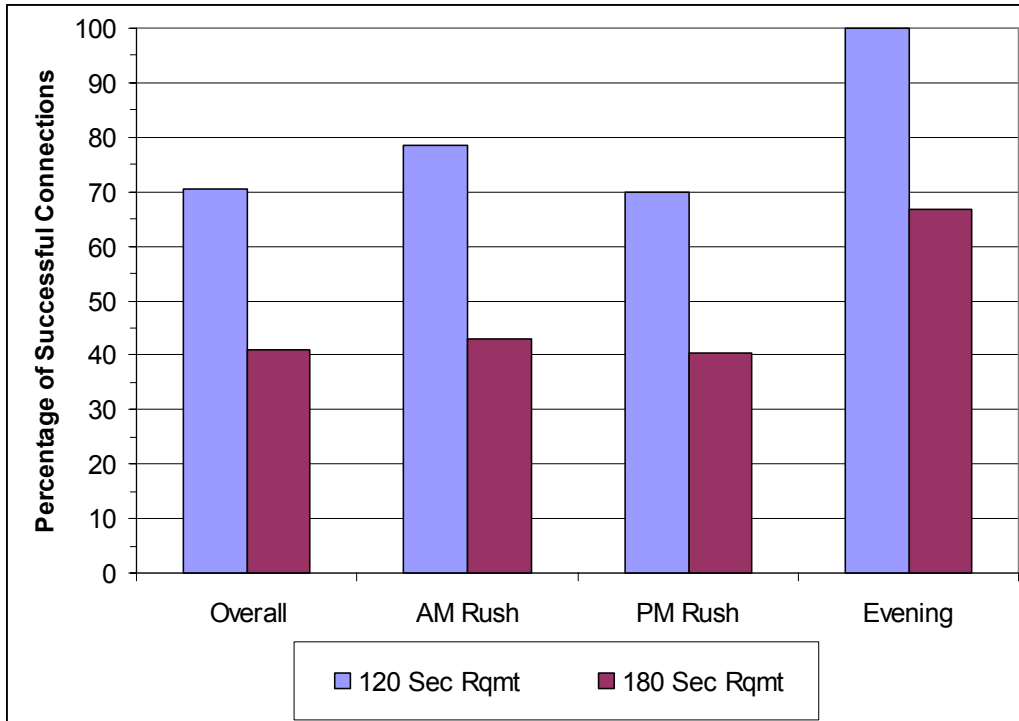


Figure 2-10. Percentage of Connections that were Successful by Time of Day

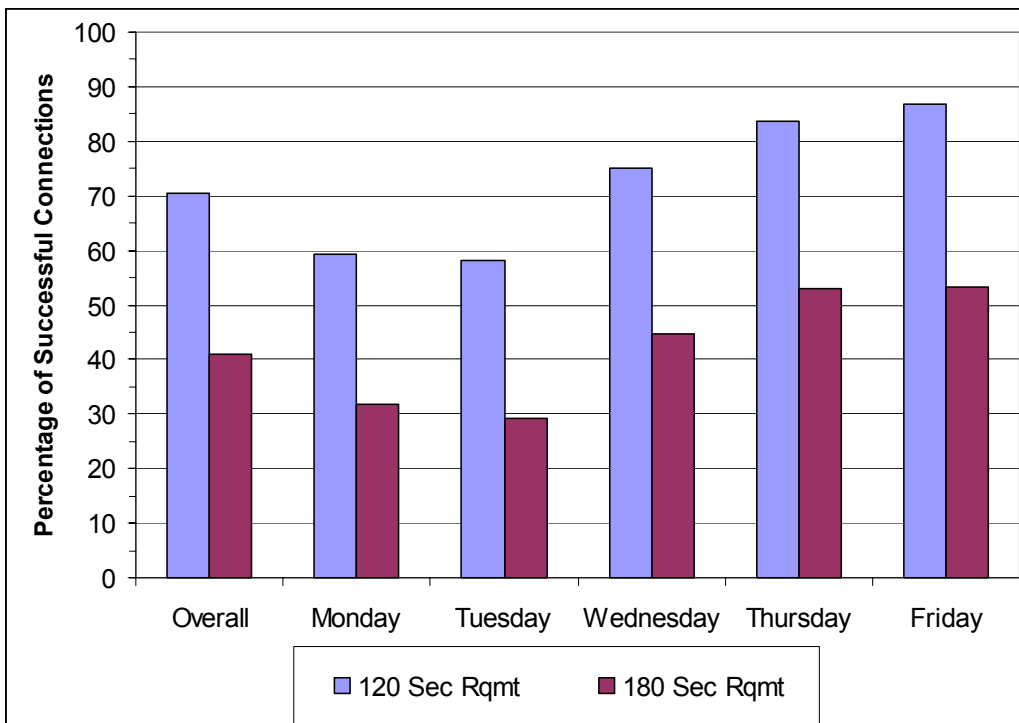


Figure 2-11. Percentage of Connections that were Successful by Day of the Week

The second step of the analysis was to fit logistic regression models that were used to identify factors that were statistically significantly related to the probability of a successful connection, including whether or not CP was active for the bus trip. These models account for the inherent clustering in the data that resulted from repeated measurements of the same bus trip over the three-month data collection period, and each bus trip essentially serves as its own reference baseline. A separate model was fit for each definition of a successful connection. The models were first fit including only the main effect of CP activation (CP inactive, CP active and “hold until” message issued, and CP active but no “hold until” message issued), and subsequent terms were added one at a time and tested for statistical significance. Terms found to be significant included the lateness of the train and the TRAX station. Weekday was suspected of being a significant factor, but could not be reliability included in the model due to data limitations. Interaction terms between CP activation and other covariates were investigated but also could not be fit because of the limited sample sizes.

Table 2-8 presents odds ratios estimated from the logistic regression models for the status of CP and lateness of the train. The odds ratios provide a summary of the likelihood of a successful connection for different levels of the factors of interest. As observed in Table 2-8, there is a significant amount of variability in the data, part of which is a function of the relatively small sample size. This results in large confidence intervals and makes it difficult to identify with statistical significance the factors that are related to a successful connection. Some care needs to be taken when interpreting the odds-ratios and estimates of probability because of the broad confidence intervals. Nevertheless, the results of the logistic regression models suggest that there is a significant impact of activating CP, after adjusting for the impacts of TRAX station and lateness of the train.

Train riders meeting a bus trip when CP was active and a “hold until” message was issued to the bus operator were 3.1 to 3.9 times (depending upon the definition of a successful connection) more likely to have a successful connection than were train riders meeting the same bus trips when CP was inactive, which was statistically significant. Additionally, train riders meeting a bus when CP was active and a “hold until” message was issued were 2.5 to 3.3 times more likely to have had a successful connection than train riders meeting a bus when CP was active but a “hold until” message was not issued, which also is statistically significant. Finally, train riders meeting a bus trip when CP was active, but no “hold until” message was issued are 1.0 to 1.2 times more likely to have had a successful connection than train riders meeting a bus trip when CP was inactive. This does not represent a significant improvement in the likelihood of having a successful connection.

The estimated probability of a successful connection, based upon the estimated model parameters, was significantly different when CP was active and a “hold until” message was issued versus when CP was inactive or when CP was active but a “hold until” message was not issued. The adjusted probability of a successful connection when CP was active and a “hold until” message was issued was 87.4% (120-second definition) and 50.9% (180-second definition) compared to 64.0% and 25.1% when CP was inactive, and 64.9% and 29.3% when CP was active but a “hold until” message was not issued, respectively. Figure 2-12 summarizes the adjusted estimates with associated 95% confidence intervals of the probability of a successful connection based upon the estimated model parameters.

Table 2-8. Adjusted Odds Ratios Comparing the Odds of a Successful Connection for Status of CP, Lateness of the Train, and TRAX Station

Comparison	Definition of a Successful Connection	
	Bus Departure \geq 120 Seconds After Train Arrival	Bus Departure \geq 180 Seconds After Train Arrival
	Odds Ratio (95% Confidence Interval)	Odds Ratio (95% Confidence Interval)
Status of CP		
CP Active and Hold Issued vs. CP Inactive	3.9 (1.6 – 9.5)*	3.1 (1.6 – 6.1)*
CP Active and Hold Issued vs. CP Active but no Hold	3.3 (1.25 – 10.0)*	2.5 (1.0 – 5.0)*
CP Active, but No Hold Issued vs. CP Inactive	1.0 (0.4 – 2.9)	1.2 (0.5 – 3.1)
Lateness of the Train		
Train Late \leq 1 Minute vs. Train Late 1-2 Minutes	8.7 (2.6 – 28.9)*	3.3 (1.5 – 7.2)*
Train Late \leq 1 Minute vs. Train Late \geq 2 Minutes	15.5 (4.3 – 55.5)*	5.9 (2.4 – 14.4)*
Train Late 1-2 Minutes vs. Train Late \geq 2 Minutes	1.8 (0.8 – 3.9)	1.8 (0.9 – 3.7)
TRAX Station		
Historic Sandy vs. Midvale Center	27.3 (8.0 – 92.9)*	12.4 (2.4 – 62.3)*
Historic Sandy vs. Millcreek	1.9 (0.6 – 6.2)	1.5 (0.6 – 3.7)
Historic Sandy vs. Sandy Civic Center	1.9 (0.8 – 4.6)	1.2 (0.5 – 3.0)
Midvale Center vs. Millcreek	0.1 (0.0 – 0.3)*	0.1 (0.0 – 0.7)*
Midvale Center vs. Sandy Civic Center	0.1 (0.0 – 0.3)*	0.1 (0.0 – 0.7)*
Millcreek vs. Sandy Civic Center	1.0 (0.3 – 4.1)	0.8 (0.2 – 2.6)

* Statistically significant

As illustrated in Table 2-8 and Figure 2-12, the probability of a successful connection was also related to TRAX station and the lateness of the train. Passengers meeting buses at Midvale Center were significantly less likely to have a successful connection than were passengers meeting buses at any other TRAX station. There were no other statistically significant differences between the TRAX stations. One possibility for this result is that it may require less time at Midvale Center for passengers to disembark and proceed to the bus pickup point than at other TRAX stations investigated. Thus, the requirements that the bus departs more than 120 or 180 seconds after the train arrives for a successful connection may be overly strict at Midvale Center in relation to the actual successful connection rate (i.e., a requirement that the bus departs at least 60 seconds after the train arrives may be a more appropriate definition of a successful connection at Midvale Center). This hypothesis is impossible to examine with the data collected for this evaluation, but is a finding that UTA may want to investigate further.

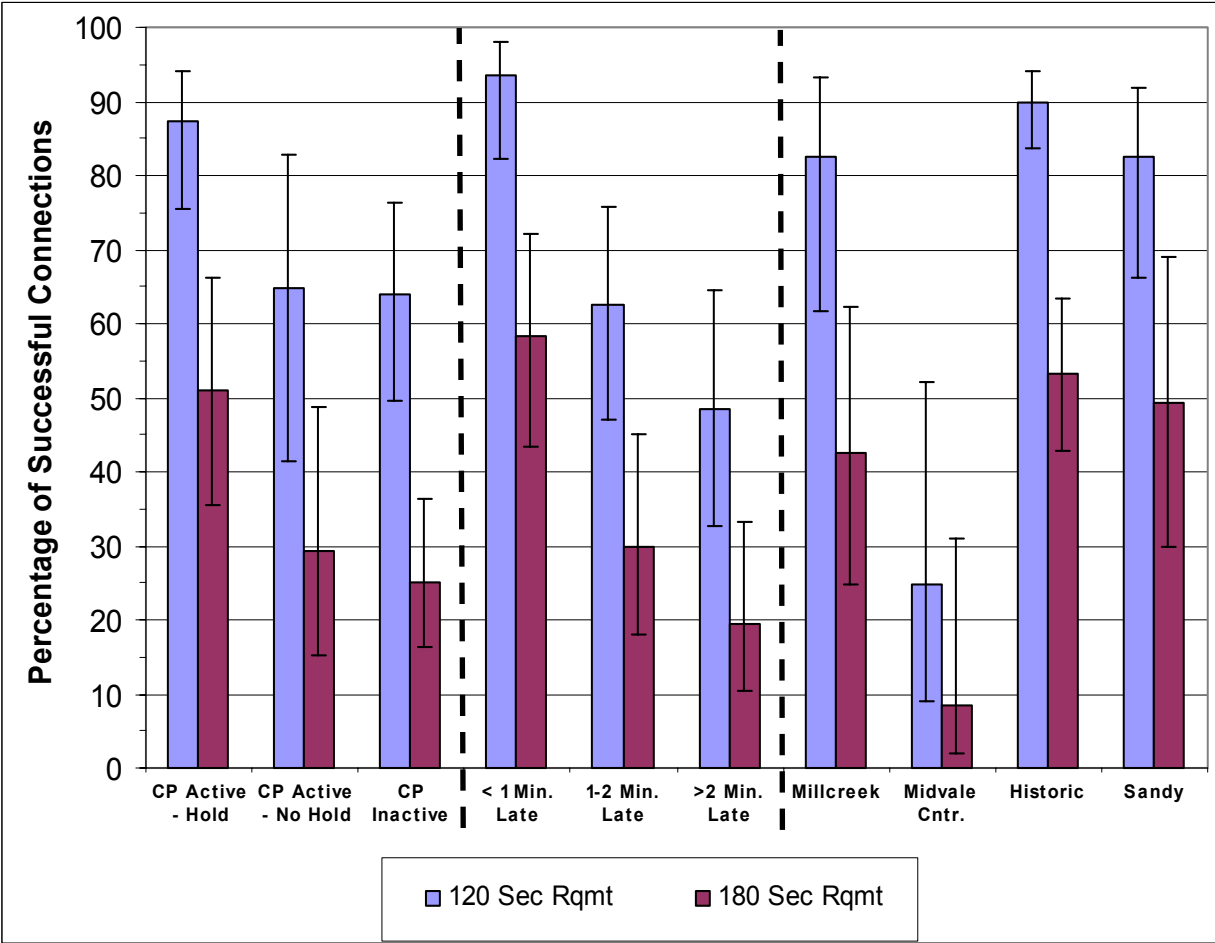


Figure 2-12. Adjusted Estimates and 95% Confidence Intervals of the Probability of a Successful Connection

Train riders were more likely to have a successful connection if the train was less than one minute late than if the train was 1-2 minutes late or more than two minutes late. There was a significant difference in the likelihood of train riders having a successful connection at the different TRAX stations. These results are not altogether unexpected because there is a natural lag of approximately three minutes built into the train arrival/bus departure schedule. Because of this lag, trains that are less than one minute late are more likely to have a successful connection than are later trains, even if the bus departs as scheduled. What is interesting is that the effect of the lateness of the train was still significant, even after accounting for the effects of CP. This suggests that CP did not “equalize” the probability of a successful connection between slightly late trains and trains that were more than one minute late.

In summary, this analysis was conducted to investigate the impact of activating CP for bus trips. Data on the bus departure times were measured for 46 bus routes and 252 bus trips meeting a late train. Roughly half of the late train events occurred when CP was inactive for these bus trips and half occurred when CP was activated for these same bus trips. Therefore, each bus trip serves as its own reference level for comparison. Based upon the results of the descriptive statistics and

logistic regression models, the results suggest that when active and when a “hold until” message is issued to the bus operator, CP does significantly improve the probability of a successful connection over when CP was inactive or when CP is active but a “hold until” message has not been issued.

The lack of significance between the estimated odds ratios and associated probabilities of a successful connection between late train events where CP was active but a “hold until” message was not sent and late train events where CP was inactive may be a result of several different factors including limited sample sizes. However, this may also suggest that CP does not have an overall effect on operator behavior (and subsequently on the probability of a successful connection) simply because CP is active. That is, CP may not be training, conditioning, or sensitizing operators to wait for passengers on late trains in situations where a CP “hold until” message has not been issued. Alternatively, this could suggest that operators rely on CP to inform them of a late train event. The absence of a “hold until” message may be interpreted by operators as an indication that the train is running on-time and they do not need to be proactive in waiting for train passengers. In either case, it would be important that CP “hold until” messages are accurately issued to bus operators in the case of a late train event.

2.4.2 Effect of CP “Hold Until” Messages

The results of Section 2.4.1 suggest that there is a significant difference between the odds of a successful connection when a CP “hold until” message is issued and the corresponding odds when CP is active but a “hold until” message is not issued. However, because the focus of Section 2.4.1 was to examine the effectiveness of CP when active during late trains events compared to events where CP was not active, the data were limited to only those bus trips that experienced late trains events both when CP was active and when CP was inactive over the course of the data collection period. This section is focused on evaluating the effect of issuing a CP “hold until” message compared to not issuing a message under the condition that CP is active. For this analysis, only bus trips where CP was active are included (including, however, bus trips that were protected for the entire three-month data collection period – which were excluded from the analysis in Section 2.4.1). Further, each bus trip needed to have at least one late train event where a CP “hold until” message was not issued and at least one other late train event where a CP “hold until” message was issued. Thus, as before, each bus trip will serve as its own baseline reference for the analysis. Table 2-9 summarizes the number of bus trips and late train events that were included in this analysis. Bus trips at Ballpark and Murray Central were not included in the analysis because there were no late train events where a CP “hold until” message was issued and the bus departure times were measured.

Figures 2-13 through Figure 2-17 present summary statistics for the percentage of successful train-to-bus connections observed among bus trips where CP was active. As expected, the percentages in these figures are generally higher than those presented in Section 2.4.1 because they include a higher percentage of bus trips where a CP “hold until” message was issued to bus operators than do the percentages calculated in Section 2.4.1. Again, this is an indication that CP is effective in increasing the probability of a successful connection. However, unlike the figures in Section 2.4.1, the difference between the unadjusted percentage of successful connections when a CP “hold until” message is issued and when a “hold until” message is not issued is much

smaller. Additionally, it appears that the probability of a successful connection, given that CP is active, also is related to the TRAX station, lateness of the train, time of day, and day of the week, though the relationships are not as clearly defined as in the previous analysis.

Table 2-9. Number of Unmatched Bus Trips and Late Train Events with CP Active that Both Received and did not Receive a “Hold Until” Message During the Data Collection Period

Reference Category	Number of Unique Bus Trips	Number of Late Train Events Where CP Was Active		Total Number of Late Train Events Where CP Was Active
		Hold Issued	Hold Not Issued	
TRAX Station				
Ballpark	1	0	1	1
Murray Central	1	0	1	1
Millcreek	15	17	6	23
Fashion Place West	4	4	3	7
Midvale Center	7	9	2	11
Historic Sandy	23	45	14	59
Sandy Civic Center	28	75	38	113
Time of the Day				
AM Rush	9	7	7	14
Mid-Day	2	1	1	1
PM Rush	65	132	61	193
Evening	3	10	5	15
Day of the Week				
Monday	32*	31	13	44
Tuesday	24*	23	6	29
Wednesday	34*	38	8	46
Thursday	33*	33	24	57
Friday	34*	25	14	39
Total	79	150	65	215

* The same bus trip could contribute to multiple days.

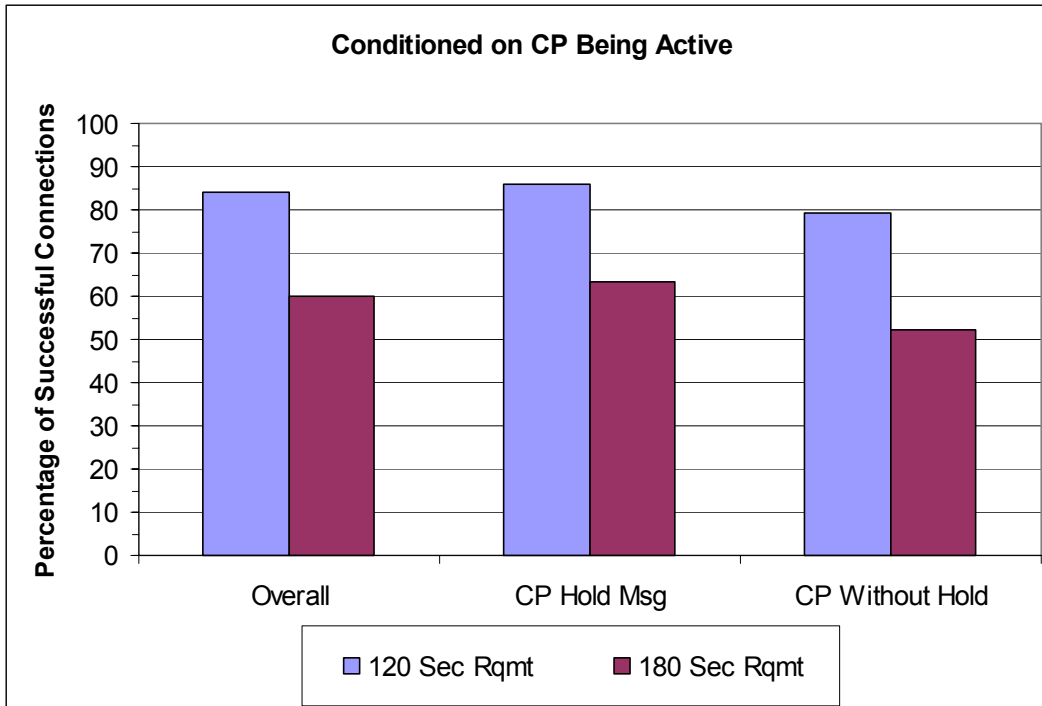


Figure 2-13. Unadjusted Percentage of Successful Connections by Whether a “Hold Until” Message was Issued, Conditional Upon CP Being Active

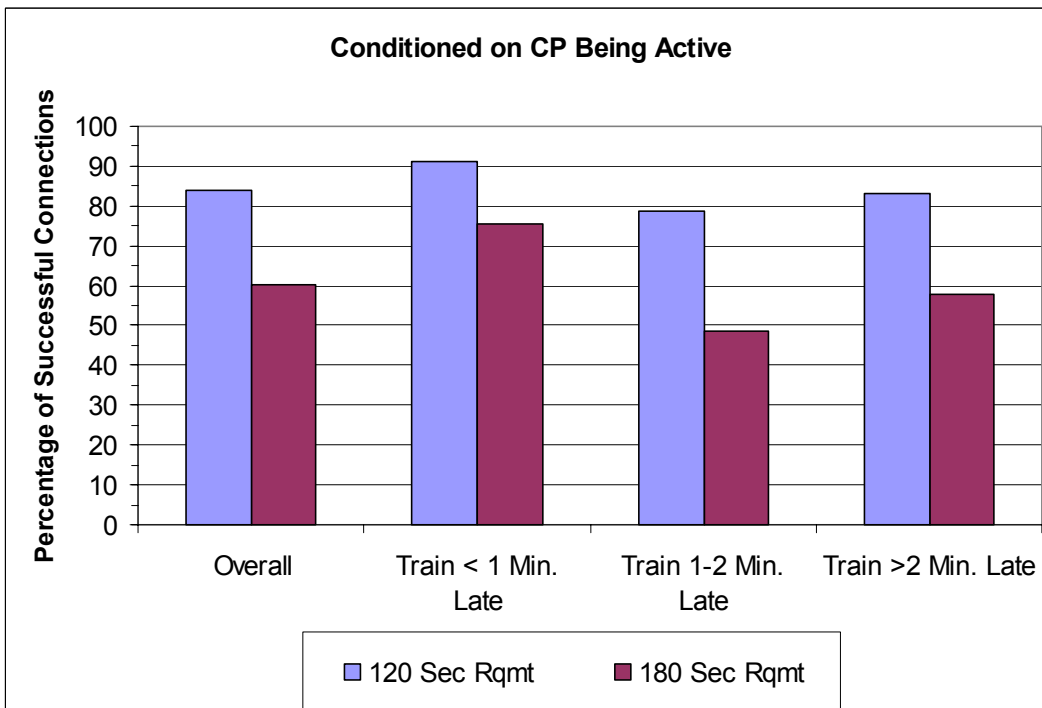


Figure 2-14. Unadjusted Percentage of Successful Connections by Lateness of the Train, Conditional Upon CP Being Active

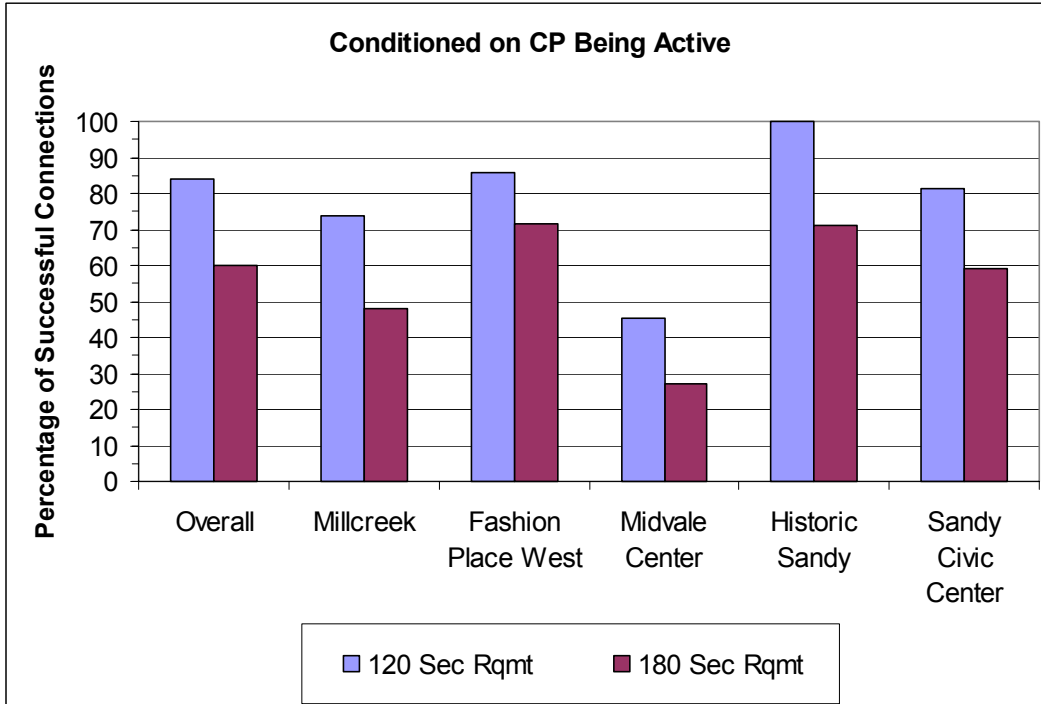


Figure 2-15. Unadjusted Percentage of Successful Connections by TRAX Station, Conditional Upon CP Being Active

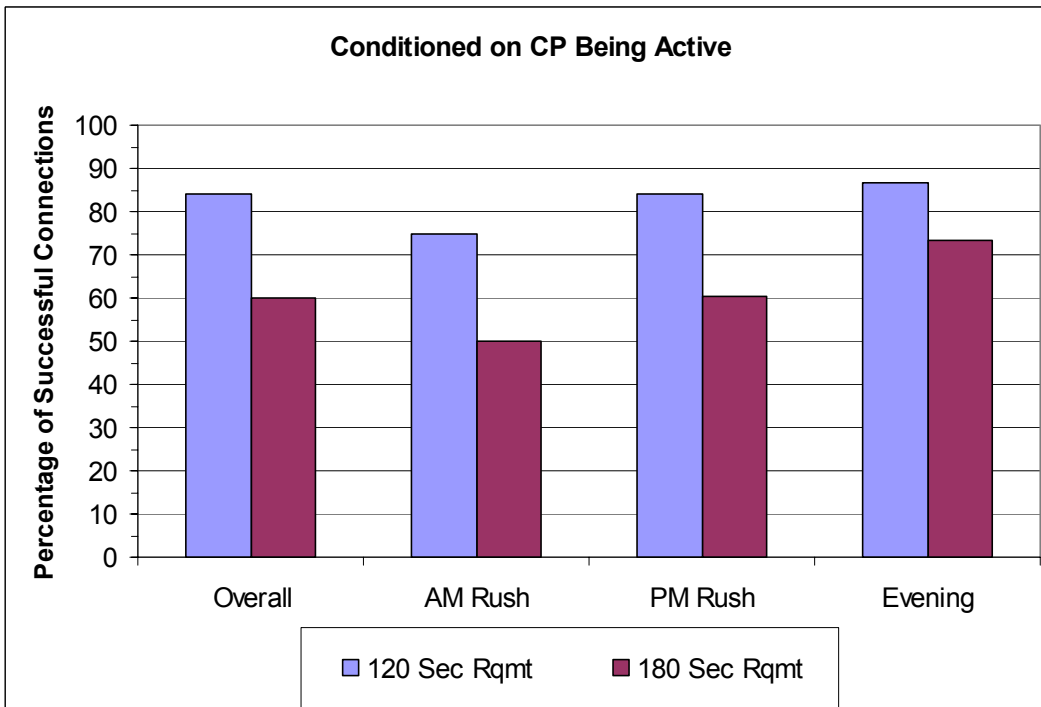


Figure 2-16. Unadjusted Percentage of Successful Connections by Time of Day, Conditional Upon CP Being Active

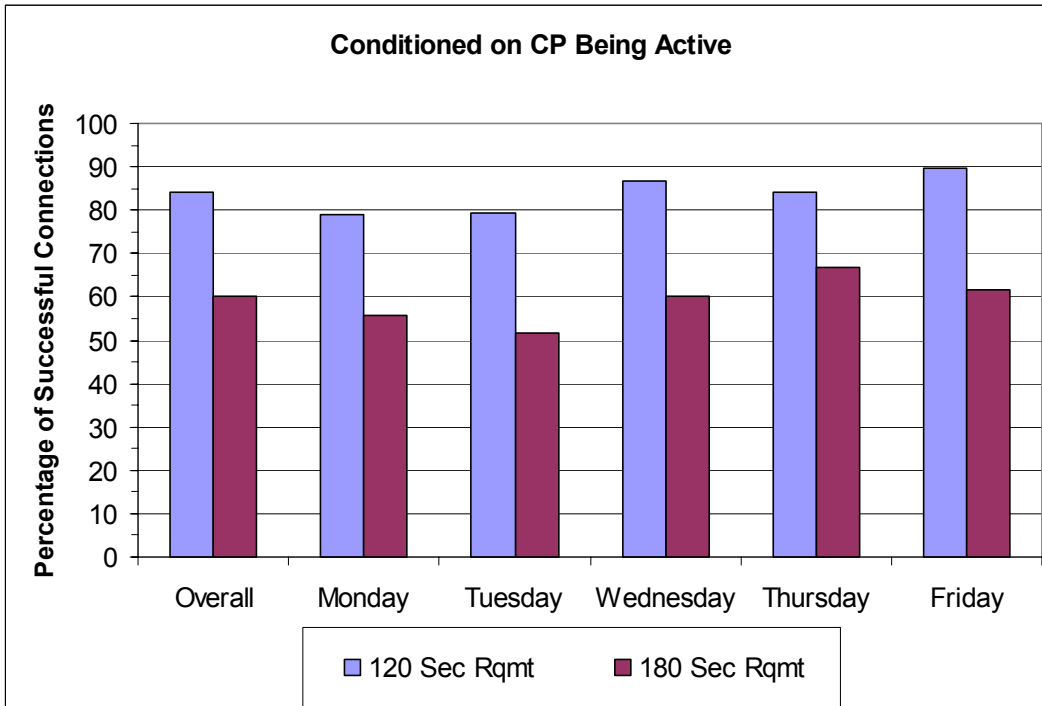


Figure 2-17. Unadjusted Percentage of Successful Connections by Day of the Week, Conditional Upon CP being Active

Following the methodology employed in Section 2.4.1, separate logistic regression models were fit for each definition of a successful connection to assess the impact of issuing a CP “hold until” message, given CP is active. Again, the model building began by including a main effect term for whether or not a CP “hold until” message was issued. Other factors were entered into the model one at a time and tested for significance. Once all significant factors were identified, factors not included in the model were re-introduced to verify that they remained insignificant. The models for the two definitions of a successful connection both identified the issuance of a CP “hold until” message as either significant or marginally significant. Under the 180-second definition, lateness of the train and TRAX station were identified as additional significant factors. Under the 120-second definition, weekday and lateness of the train were not identified as significant factors but were included in the model as adjustment factors. The effect of TRAX station could not be tested in the model because of the small sample sizes. Table 2-10 summarizes the estimated odds ratios based upon the model parameters. Figure 2-18 through Figure 2-21 summarize the associated adjusted estimates for the probability of a successful connection for each level of the factors included in the models.

Table 2-10. Adjusted Odds Ratios Comparing the Odds of a Successful Connection for Status of CP, Lateness of the Train, and TRAX Station

Comparison	Definition of a Successful Connection	
	Bus Departure \geq 120 Seconds After Train Arrival	Bus Departure \geq 180 Seconds After Train Arrival
	Odds Ratio (95% Confidence Interval)	Odds Ratio (95% Confidence Interval)
Status of CP		
CP Active and Hold Issued vs. CP Active but no Hold	1.9 (1.0 – 3.8)**	2.4 (1.1 – 5.3)*
Lateness of the Train		
Train Late \leq 1 Minute vs. Train Late 1-2 Minutes	2.6 (0.8 – 7.8)	4.0 (1.5 – 10.7)*
Train Late \leq 1 Minute vs. Train Late \geq 2 Minutes	1.9 (0.6 – 5.9)	7.0 (2.1 – 23.4)*
Train Late 1-2 Minutes vs. Train Late \geq 2 Minutes	0.7 (0.3 – 1.6)	1.8 (0.6 – 5.1)
Weekday		
Monday vs. Tuesday	1.0 (0.3 – 1.6)	1.3 (0.4 – 3.6)
Monday vs. Wednesday	0.7 (0.2 – 1.8)	1.0 (0.4 – 2.5)
Monday vs. Thursday	0.7 (0.3 – 1.8)	0.6 (0.3 – 1.4)
Monday vs. Friday	0.4 (0.1 – 1.2)	0.6 (0.2 – 1.5)
Tuesday vs. Wednesday	0.7 (0.2 – 2.1)	0.8 (0.3 – 2.1)
Tuesday vs. Thursday	0.7 (0.3 – 1.6)	0.5 (0.2 – 1.3)
Tuesday vs. Friday	0.4 (0.1 – 1.5)	0.5 (0.2 – 1.3)
Wednesday vs. Thursday	1.1 (0.4 – 3.0)	0.6 (0.2 – 1.8)
Wednesday vs. Friday	0.5 (0.1 – 2.1)	0.6 (0.2 – 1.6)
Thursday vs. Friday	0.5 (0.1 – 1.7)	0.9 (0.4 – 2.3)
TRAX Station		
Fashion Place vs. Historic Sandy	--	1.2 (0.2 – 9.6)
Fashion Place vs. Midvale Center	--	14.5 (0.9 – 227.6)
Fashion Place vs. Millcreek	--	4.6 (0.6 – 35.7)
Fashion Place vs. Sandy Civic Center	--	1.2 (0.1 – 10.5)
Historic Sandy vs. Midvale Center	--	12.0 (1.3 – 110.7)*
Historic Sandy vs. Millcreek	--	3.8 (1.3 – 11.0)*
Historic Sandy vs. Sandy Civic Center	--	1.0 (0.3 – 2.9)
Midvale Center vs. Millcreek	--	0.3 (0.0 – 2.5)
Midvale Center vs. Sandy Civic Center	--	0.1 (0.0 – 0.9)*
Millcreek vs. Sandy Civic Center	--	0.3 (0.1 – 1.0)**

* Statistically significant

** Marginally statistically significant

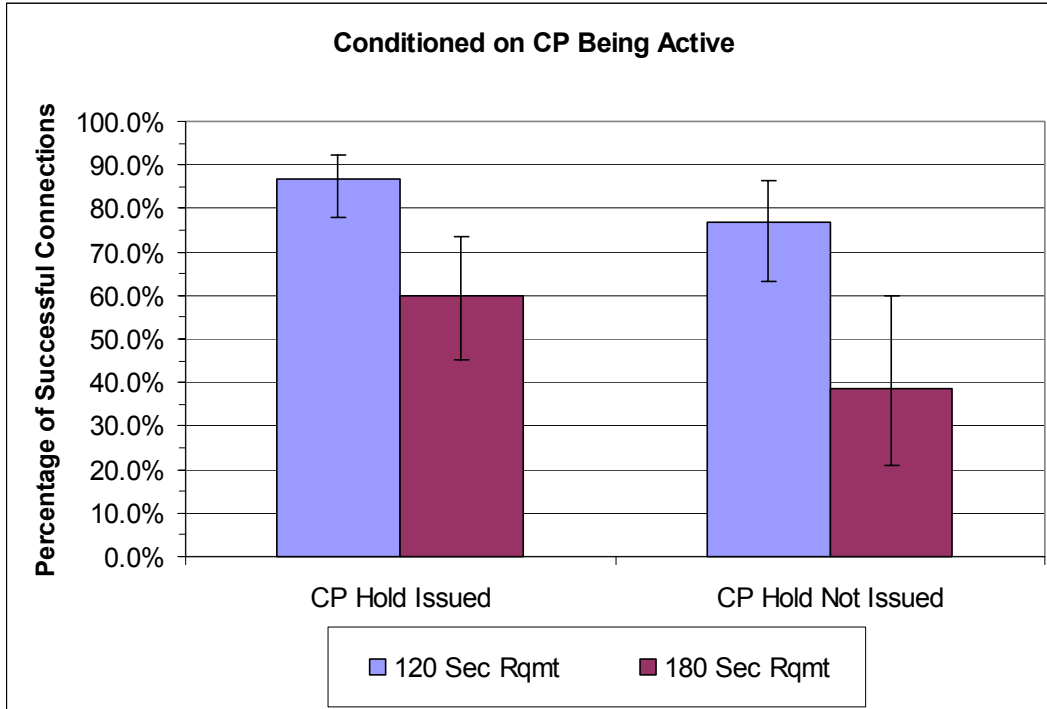


Figure 2-18. Adjusted Estimates of the Probability of a Successful Connection by Whether a CP “Hold Until” Was Issued

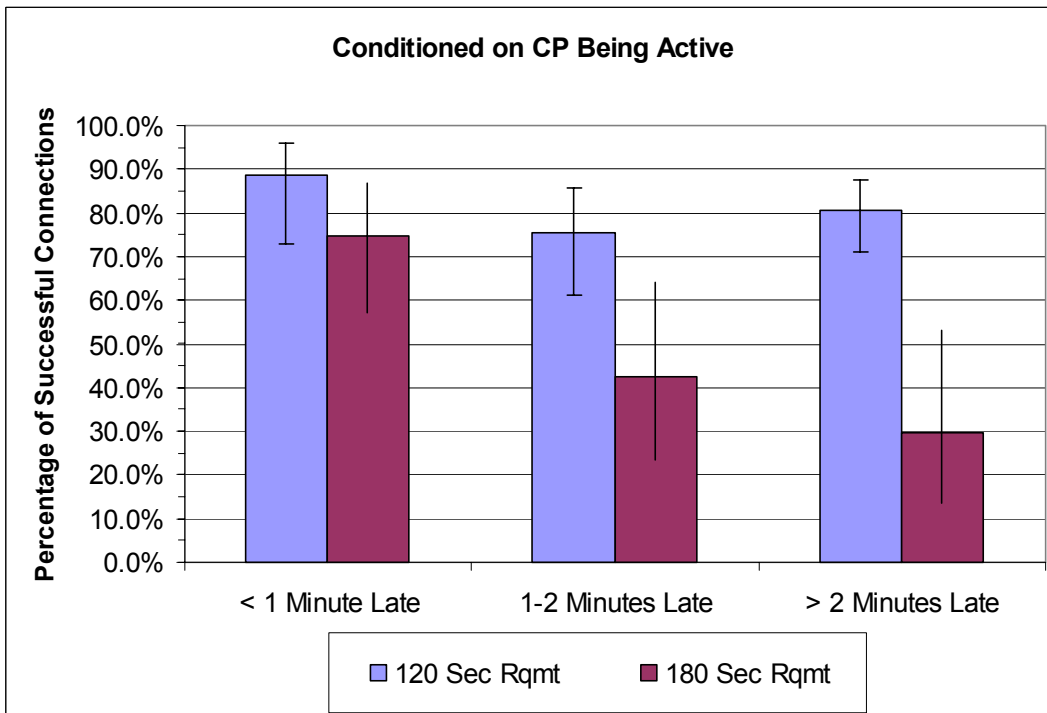


Figure 2-19. Adjusted Estimates of the Probability of a Successful Connection by Lateness of the Train

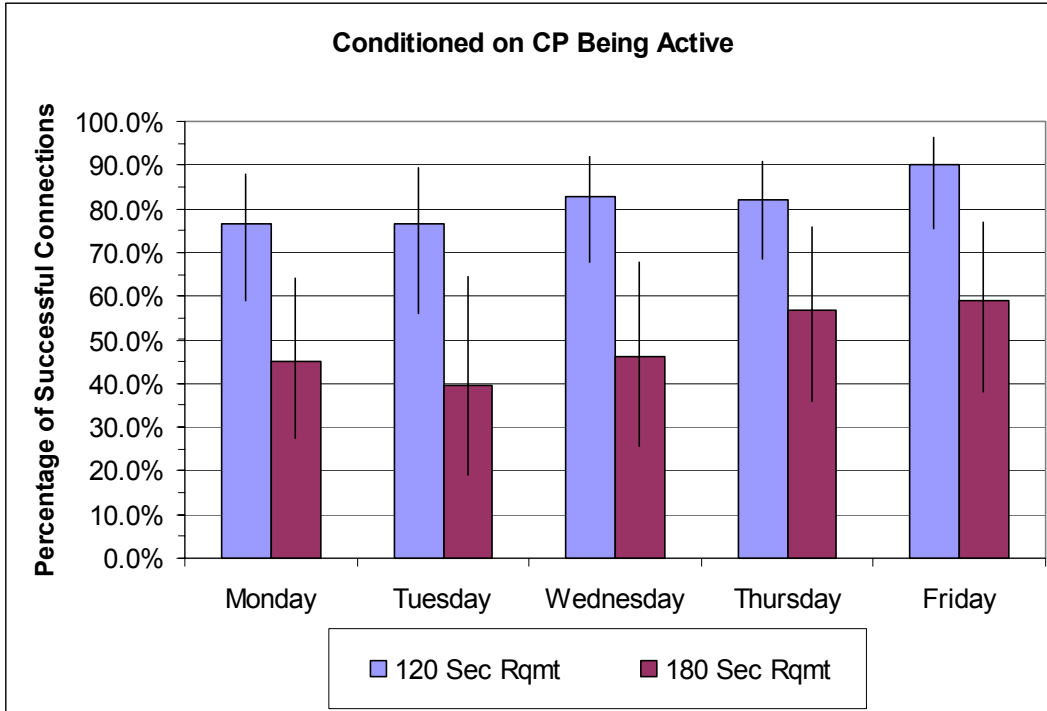


Figure 2-20. Adjusted Estimates of the Probability of a Successful Connection by Day of the Week

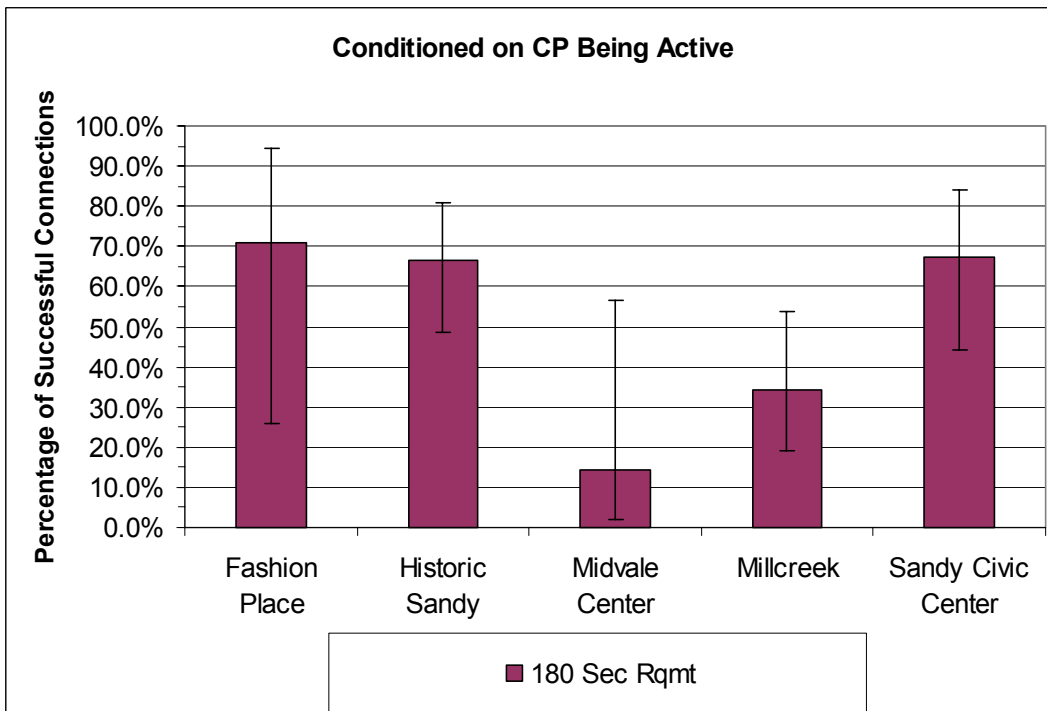


Figure 2-21. Adjusted Estimates of the Probability of a Successful Connection by TRAX Station

The results observed in this analysis confirm those observed in the analysis presented in Section 2.4.1. That is, when the train arrives late at the TRAX station, train riders meeting a bus that has been issued a CP “hold until” message are roughly two times more likely to have a successful connection than are train riders who are meeting a bus that has not received a CP “hold until” message. This represents a statistically significant (though marginally significant with p-values of 0.0305 and 0.0929 for the 180- and 120-second bus departure requirement, respectively) improvement in the probability of a successful connection. The relatively small sample size of 215 late train events combined with significant variability in the data result in fairly large estimates of the variance in the estimated parameters, which made it difficult to statistically identify differences in the probability of a successful connection.

2.4.3 Analysis of Matched Bus Trips

As discussed previously, the data collection effort included plans to collect data from selected bus trips that were CP protected that could be matched to similar bus trips that were not CP protected. Thus, unlike the analysis of data from unmatched bus trips, each bus trip with CP active has a corresponding bus trip where CP was inactive to serve as a baseline reference level.

Every effort was made to collect train arrival and bus departure times for these 14 matched (see Table 2-6) bus trips during the three-month data collection period. Unfortunately, bus departure times were recorded for only 14 late train events with these bus trips, which greatly limits the utility of this information for drawing statistically-based inferences. Table 2-11 summarizes the data collected for the matched bus trips.

Among these 28 bus trips for the 14 late train events, there were 11 successful connections (39.3%) under the 180-second requirement and 16 successful connections (57.1%) under the 120-second bus departure requirement. Table 2-12 summarizes the number and percentage of bus trips where a successful connection occurred, cross-referenced by the status of CP. Due to the small sample sizes, the percentages in Table 2-12 differ somewhat from those obtained using the unmatched data (see Section 2.4.1 and 2.4.2). However, the general pattern remains very similar; bus trips where a CP “hold until” message is issued have a higher percentage of successful connections than do bus trips where a CP “hold until” message is not issued (either because CP is inactive or for some other reason). The percentage of successful connections for bus trips where CP is inactive is similar to the percentages among bus trips where CP is active but no “hold until” message is issued, which does not support the hypothesis that CP raises the awareness or sensitivities of bus drivers by simply being active.

While the sample sizes prohibit more sophisticated statistical analysis, the results for the matched bus trips generally support the hypothesis that, when a CP “hold until” message is issued, CP is effective in increasing the percentage of successful connections.

Table 2-11. Summary of Late Train Events for Matched Bus Trips

TRAX Station	Potential "Without" Case		Corresponding CP-Protected Trip(s)		Bus Departure Time	Train Arrival Time	Number of Late Train Events	Number of CP "Hold Until" Messages Issued on CP Protected Trips
	Bus Route	Bus Direction	Bus Route	Bus Direction				
Millcreek	31	Westbound	37	Westbound	16:40	16:37	2	0
	31	Eastbound	37	Westbound	17:40	17:37	1	0
Midvale Center	25	Clockwise	88	Westbound	17:08	17:05	2	1
	25	Clockwise	88	Westbound	17:38	17:35	0	0
	25	Clockwise	88	Westbound	18:08	18:05	0	0
Historic Sandy	90	Westbound	94	Eastbound	15:55	15:52	0	0
	94	Eastbound	90	Westbound	16:55	16:52	0	0
Sandy Civic Center	33	Northbound	811	To Provo	7:44	7:39	2	0
	33	Northbound	811	To Provo	8:14	8:09	0	0
	33	Northbound	811	To Provo	16:14	16:09	5	4
	33	Northbound	345	Outbound	16:42	16:39	0	0
	33	Northbound	46	Southbound	17:12	17:09	1	1
	33	Northbound	46	Southbound	17:42	17:39	1	1
	33	Northbound	46	Southbound	18:12	18:09	0	0
Total							14	7

Table 2-12. Number and Percentage of Successful Connections Among Matched Bus Trips

Status of CP	Number (Percentage) of Successful Connections		Total Number of Bus Trips
	120-Second Departure Requirement	180-Second Departure Requirement	
CP Active and "Hold Until" Message Issued	6 (85.7%)	6 (85.7%)	7
CP Active but No "Hold Until" Message Issued	4 (57.1%)	2 (28.6%)	7
CP Inactive (Matched Unprotected Bus Trips)	6 (42.9%)	3 (27.3%)	14

2.4.4 Analysis of Minutes Held Past Scheduled Departure Time

For a train-to-bus connection to be successful there has to be enough time for a train passenger to disembark from the train and maneuver to the bus departure point. Presumably, the longer the train passengers have to move from the train to the bus, the higher the probability of a successful connection. Again, it was impossible to measure actual instances of a successful connection. In

the previous sections, analysis has been conducted to assess the effect of CP using two different requirements on the length of time following the train arrival that the bus departs as surrogate measures for successful connections. An alternative surrogate measure is the length of time that the bus operator waits for train passengers past the scheduled bus departure time. If CP is having an effect on the behavior of bus operators, the average length of time that the bus operators hold past their scheduled departure time should be significantly greater than the corresponding averages when CP is inactive.

There were 252 late train events measured on unmatched bus trips where CP was both active and inactive at some point during the data collection period (i.e., as in Section 2.4.1). On average, bus operators departed 2.3 minutes past the scheduled bus departure time. Figure 2-22 through Figure 2-26 summarize the average delay in departure past the scheduled departure time by lateness of the train, TRAX station, weekday, and day of the week, respectively. Highlights from the figures include:

- Bus operators held the buses 2.8 minutes past the scheduled departure time on average when a CP “hold until” message is issued. On average, they held the buses for less time in the absence of a CP “hold until” message with 1.96 minutes past the scheduled departure time when CP was active, but a “hold until” message was not issued and 2.08 minutes past the scheduled departure time when CP was inactive.
- As expected, bus operators hold the buses longer for later trains than for trains that are less than one minute late although this was not uniform across the three types of bus trips. Bus operators that received a “hold until” message held the bus, on average, 1.8 minutes, 2.4 minutes, and 3.4 minutes in situations where the train was <1 minute late, 1-2 minutes late, and >2 minutes late, respectively. Bus operators where CP was inactive held the bus, on average, for 1.2 minutes, 2.4 minutes, and 2.2 minutes, respectively.
- There is some variability in the length of time past the scheduled departure time that the buses were held at the different TRAX stations. In particular, the bus operators were much closer to the scheduled departure times for Fashion Place West and Midvale Center than for any of the other TRAX stations.
- Bus operators held the buses longer in the latter part of the week (Wednesday – Friday) than in the earlier part of the week (Monday – Tuesday).

A repeated measures ANOVA model was fit using the number of minutes that the bus was held past the scheduled departure time as an outcome variable. Status of CP, lateness of the train, TRAX station, time of the day, and day of the week were all included in the model as explanatory variables. This model accounts for the repeated observations made on the same bus trip over the three-month data collection window. Again, because each bus trip was required to have instances where CP was active and late train events where CP was inactive, each bus trip effectively serves as its own baseline reference level. Status of CP, lateness of the train, TRAX station, and day of the week were all significant predictors of the hold past the scheduled departure time (hold time). Time of the day was not a significant predictor and was removed from the model.

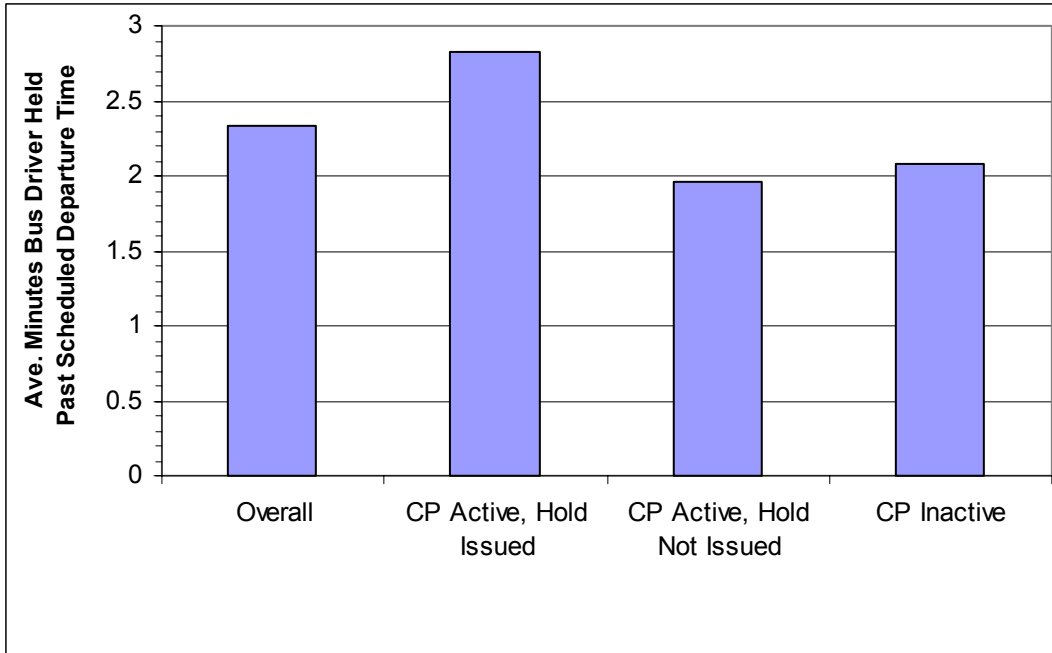


Figure 2-22. Average Number of Minutes Bus Operators Held Buses Past the Scheduled Departure Time by Status of CP

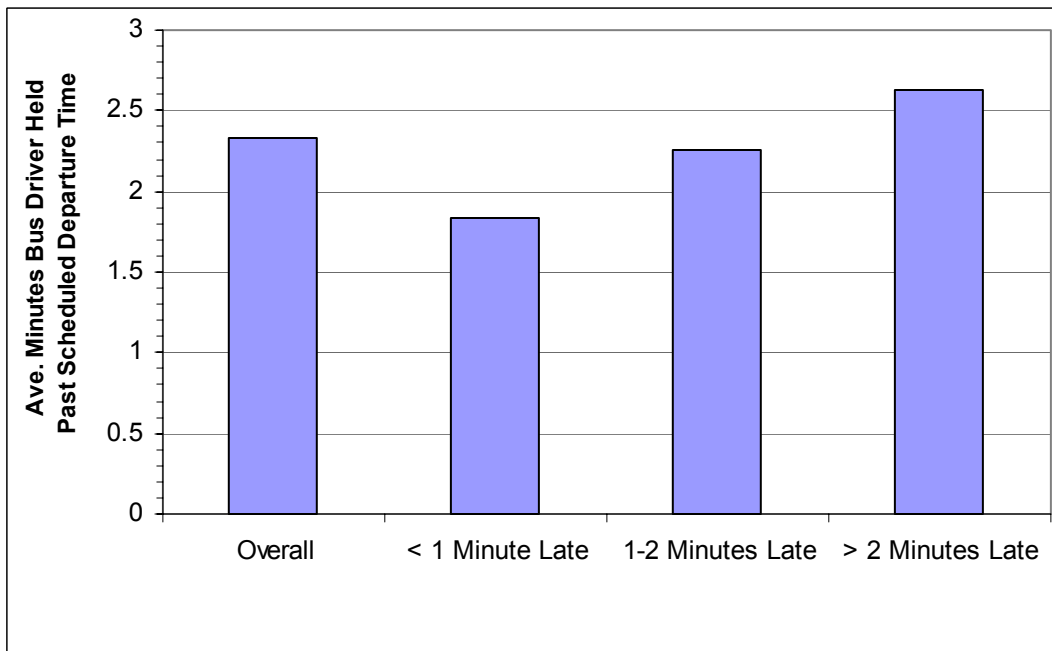


Figure 2-23. Average Number of Minutes Bus Operators Held Buses Past the Scheduled Departure Time by Lateness of the Train

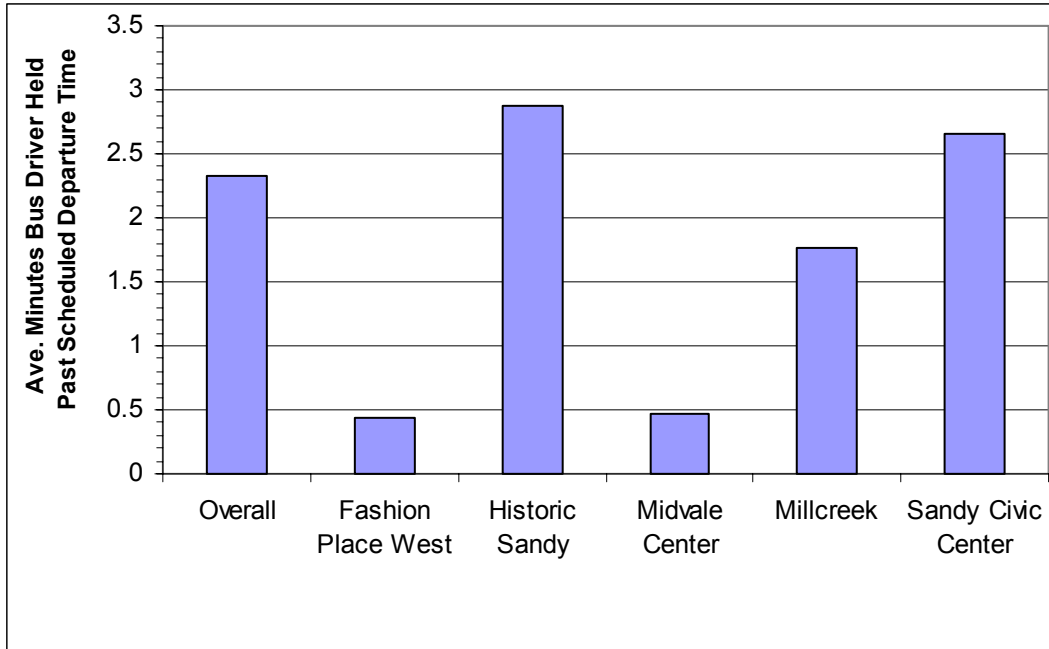


Figure 2-24. Average Number of Minutes Bus Operators Held Buses Past the Scheduled Departure Time by TRAX Station

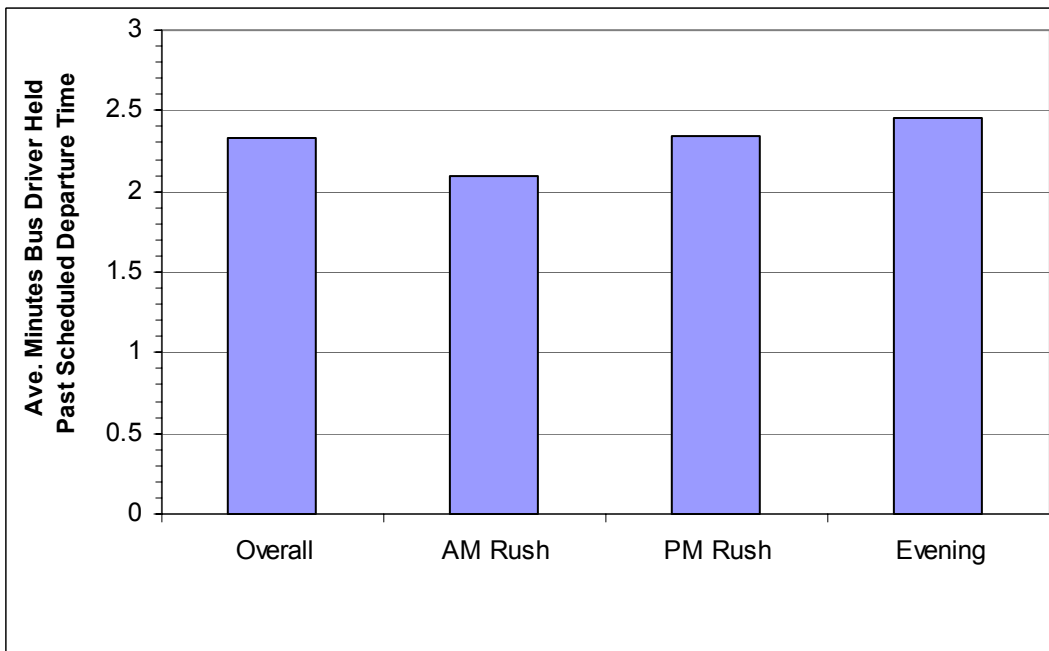


Figure 2-25. Average Number of Minutes Bus Operators Held Buses Past the Scheduled Departure Time by Time of Day

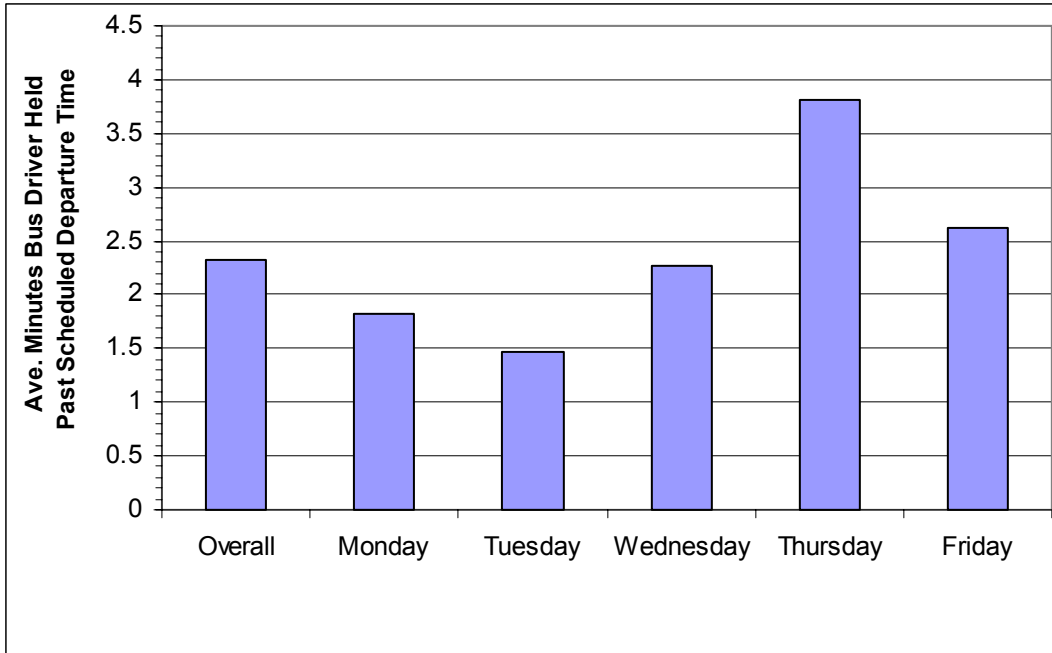


Figure 2-26. Average Number of Minutes Bus Operators Held Buses Past the Scheduled Departure Time by Day of the Week

Although Figure 2-22 seems to indicate a significant difference between the average hold time when a CP “hold until” message is issued and when a CP “hold until” message was not issued, the model-based results, which are adjusted for other factors such as lateness of the train, indicate smaller differences. Table 2-13 summarizes the adjusted average hold time in minutes past the scheduled departure time, based upon the estimated model parameters. Table 2-14 summarizes the pairwise comparisons between levels of the significant explanatory factors. As observed in the tables, there was not enough evidence to statistically determine that the difference in the average hold time when a CP “hold until” message was issued (2.14 minutes) was significantly different from the average hold time when CP was inactive (1.81 minutes). Similarly, there was insufficient evidence to detect a significant difference in the average hold time when CP was inactive and when CP was active but a “hold until” message was not issued (estimated difference of 41 seconds). There was enough evidence to determine that the average hold time when a CP “hold until” message was issued was significantly higher than the average hold time when CP was active but a “hold until” message was not issued (estimated difference of approximately one minute).

Table 2-13. Adjusted Averages of the Hold Time in Minutes Past the Scheduled Departure Time Based Upon Estimated Model Parameters

Explanatory Factor	Adjusted Estimate of Average Hold Time in Minutes Past the Scheduled Departure Time (95% Confidence Interval)
Status of CP	
CP Active, "Hold Until" Message Issued	2.14 (1.51 - 2.77)
CP Active, "Hold Until" Message Not Issued	1.12 (0.37 - 1.87)
CP Inactive	1.81 (1.20 - 2.41)
Lateness of the Train	
Train < 1 Minute Late	1.05 (0.34 - 1.76)
Train 1-2 Minutes Late	2.02 (1.35 - 2.68)
Train >2 Minutes Late	2.00 (1.28 - 2.72)
TRAX Station	
Fashion Place West	1.44 (-0.75 - 3.62)
Historic Sandy	2.87 (2.44 - 3.31)
Midvale Center	0.16 (-0.67 - 1.00)
Millcreek	1.78 (1.05 - 2.52)
Sandy Civic Center	2.18 (1.46 - 2.91)
Day of the Week	
Monday	1.11 (0.45 - 1.77)
Tuesday	0.54 (-0.21 - 1.29)
Wednesday	1.73 (1.01 - 2.44)
Thursday	3.26 (2.51 - 4.00)
Friday	1.82 (0.92 - 2.72)

The results associated with the average hold time are consistent with the finding that CP has an effect on improving successful train to bus connections. That is, on average, bus operators that received a "hold until" message held the bus longer at the TRAX station than did bus operators that did not receive a "hold until" message. Though some of the comparisons do not reach statistical significance, it should be noted that the standard errors and corresponding confidence intervals for the model-based estimates indicate significant variability in the data, which is a function of the relatively small samples sizes. It is entirely possible that estimates that were found to be insignificant may, in fact, be found to be significant if larger sample sizes were available.

Table 2-14. Pairwise Differences in the Average Hold Time in Minutes Past the Scheduled Departure Time Based Upon Estimated Model Parameters

Comparison	Estimated Difference in Minutes (95% Confidence Interval)	P-value
Status of CP		
CP Active and Hold Issued vs. CP Inactive	0.33 (-0.29 to 0.95)	0.2872
CP Active and Hold Issued vs. CP Active but no Hold	1.02 (0.21 to 1.83)	0.0140*
CP Active, but No Hold Issued vs. CP Inactive	-0.69 (-1.50 to 0.12)	0.0932
Lateness of the Train		
Train Late ≤ 1 Minute vs. Train Late 1-2 Minutes	-0.96 (-1.73 to -0.20)	0.0142*
Train Late ≤ 1 Minute vs. Train Late ≥ 2 Minutes	-0.95 (-1.82 to -0.07)	0.0344**
Train Late 1-2 Minutes vs. Train Late ≥ 2 Minutes	0.02 (-0.83 to 0.87)	0.9681
TRAX Station		
Fashion Place West vs. Historic Sandy	-1.43 (-3.66 to 0.79)	0.2002
Fashion Place West vs. Midvale Center	1.27 (-1.08 to 3.63)	0.2803
Fashion Place West vs. Millcreek	-0.35 (-2.63 to 1.94)	0.7608
Fashion Place West vs. Sandy Civic Center	-0.75 (-3.12 to 1.62)	0.5287
Historic Sandy vs. Midvale Center	2.71 (1.78 to 3.63)	<.0001*
Historic Sandy vs. Millcreek	1.09 (0.27 to 1.91)	0.0108**
Historic Sandy vs. Sandy Civic Center	0.69 (-0.16 to 1.54)	0.1109
Midvale Center vs. Millcreek	-1.62 (-2.70 to -0.54)	0.0043*
Midvale Center vs. Sandy Civic Center	-2.02 (-3.10 to -0.94)	0.0005*
Millcreek vs. Sandy Civic Center	-0.40 (-1.51 to 0.71)	0.4722
Day of the Week		
Monday vs. Tuesday	0.57 (-0.24 to 1.37)	0.1638
Monday vs. Wednesday	-0.62 (-1.40 to 0.16)	0.1182
Monday vs. Thursday	-2.15 (-2.97 to -1.33)	<.0001*
Monday vs. Friday	-0.71 (-1.67 to 0.25)	0.1474
Tuesday vs. Wednesday	-1.19 (-2.04 to -0.33)	0.0071*
Tuesday vs. Thursday	-2.72 (-3.61 to -1.83)	<.0001*
Tuesday vs. Friday	-1.28 (-2.30 to -0.25)	0.0153**
Wednesday vs. Thursday	-1.53 (-2.36 to -0.70)	0.0004*
Wednesday vs. Friday	-0.09 (-1.07 to 0.88)	0.8544
Thursday vs. Friday	1.44 (0.46 to 2.42)	0.0044*

* Statistically significant

** Marginally statistically significant

Other findings associated with the estimated average hold times also are consistent with earlier findings. These include:

- The average hold time is related to the lateness of the train. Bus operators hold the bus, on average, roughly one minute longer if the train is more than one minute late than if the train is less than one minute late. There was no significant difference between the average hold time between moderately late trains (1-2 minutes) and later trains (> 2 minutes late). This may suggest a one-minute threshold where the bus operators, on average, cease to wait for a late train and depart.
- Bus operators at Midvale Center tended to hold the bus for shorter lengths of time past their scheduled departure times than did bus operators at Historic Sandy, Sandy Civic Center, and Millcreek. Differences in the average hold times were 2.7 minutes, 2.0 minutes, and 1.6 minutes, respectively. This indicates that train passengers meeting buses at Midvale Center when the train is late may be more at risk for missing a connection than are train passengers meeting buses at Historic Sandy, Sandy Civic Center, and Millcreek.
- Bus operators tended to hold the buses longer in the latter part of the week (Wednesday – Friday) than in the earlier part of the week (Monday – Tuesday) with differences ranging from 37 seconds to 2.7 minutes.

2.5 Operational Aspects of System Performance

A second objective of the evaluation of system performance data was to evaluate operational aspects of the system performance. However, this did not include an evaluation of the specific hardware and software that comprise the CP system. Rather, particular emphasis was on evaluating the extent to which the CP system consistently operates the way that it was conceptually designed from an overall perspective.

2.5.1 Compliance with CP “Hold Until” Messages

A necessary condition for CP to be effective in improving the number of successful train-to-bus connections is that the bus operators’ behavior is affected by a CP “hold until” message. Operator behavior could be affected in different ways. First, a CP “hold until” message could sensitize operators that the train is late and influence them to hold their bus departure longer than normal. Alternatively, bus operators could strictly follow the suggestions of CP and delay the bus departure until after the CP suggested departure time. Finally, CP “hold until” message could be ignored by operators. Reality of the operator reaction to a CP “hold until” message probably is a mixture of all three possibilities. This analysis is focused on examining the “hold until” messages to determine the percentage of operators that depart some time after the CP suggested time.

During the three-month data collection period, CP “hold until” messages were issued to 150 bus trips for late trains. Overall, only 51.3% of the bus operators departed after the CP suggested

departure time. Figure 2-27 summarizes the conditional distributions of departure times relative to the CP suggested departure time for the 150 bus trips. Generally, bus operators who left before the CP suggested departure time left approximately one minute (average of 75 seconds, median of 48 seconds) before the suggested hold time. Bus operators who left after the CP suggested hold time left 1-2 minutes (average of 135 seconds, median of 59 seconds) after the suggested CP departure time.

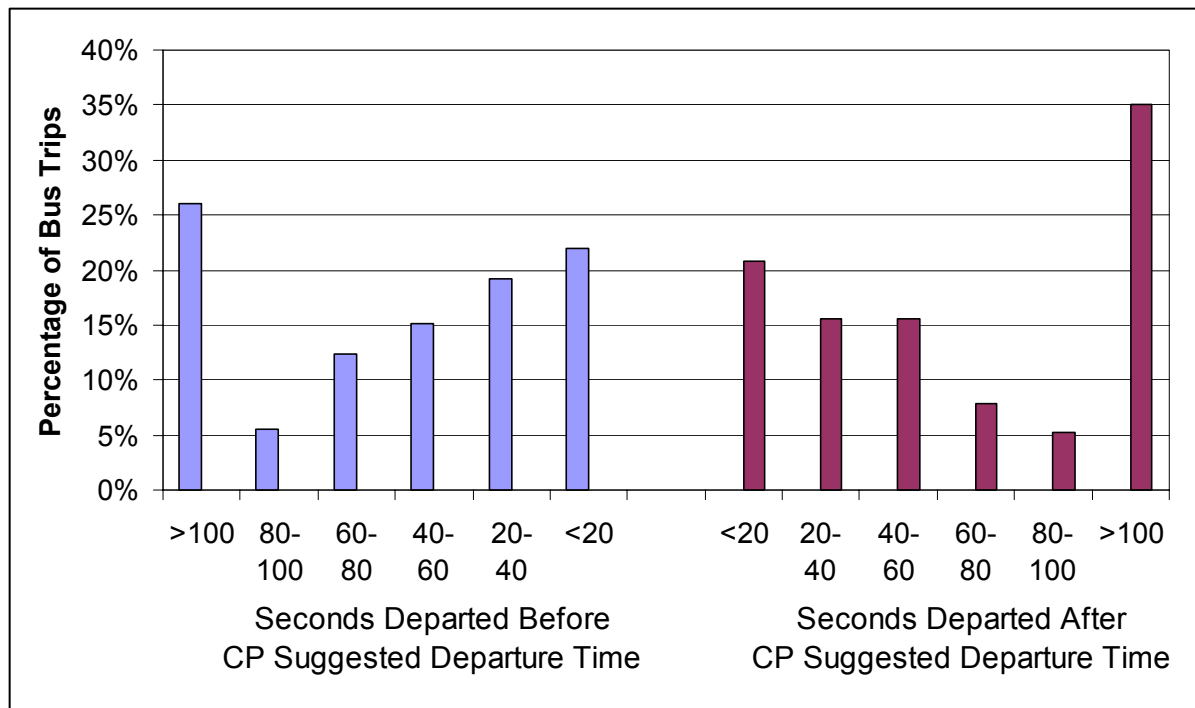


Figure 2-27. Conditional Distribution of Departures Before and After CP Suggested Departure Time

Figure 2-28 summarizes the percentage of successful connections under both definitions of a successful connection (see Section 2.4.1). As observed in the figure, there is a strong association between compliance with the CP suggested departure time and successful connections. Bus operators who departed after the CP suggested departure time almost uniformly had a successful connection while bus operators who departed before the CP suggested departure time had successful connections of 71.2% under the 120-second departure requirement and 28.8% under the 180-second departure requirement. If all of the bus operators who departed prior to the CP suggested departure time followed the suggestions of CP, an additional 20 bus trips (13%) under the 120-second departure requirement and 33 bus trips (22%) under the 180-second departure requirement would have had successful connections raising the overall percentages of successful connections to 99.3% and 85.3%, respectively. Therefore, it seems likely that increasing bus operator compliance with CP “hold until” messages would increase the effectiveness of CP in improving successful train-to-bus connections. It also suggests that CP “hold until” messages

alone are generally not raising the sensitivity of operators to a late train resulting in improved connections; rather improvements stem from following CP suggested departure times.

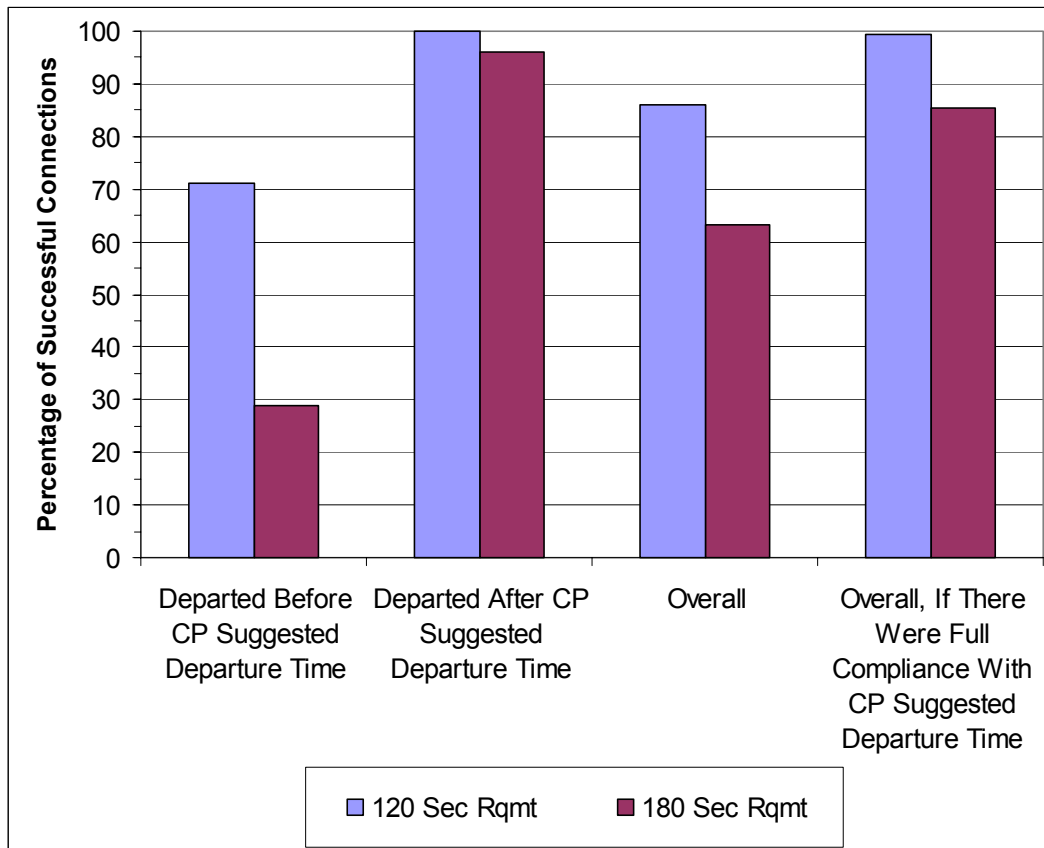


Figure 2-28. Percentage of Successful Connections by Compliance with CP Suggested Departure Times

2.5.2 Relationship Between CP “Hold Until” Messages and Actual Lateness of the Train

The CP system utilizes a prediction algorithm to predict whether trains will arrive late at a TRAX station and whether a CP “hold until” message should be issued. Essentially, the system monitors train arrival times at points along the TRAX line, determines if the train is running late, assesses how late the train is expected to be, compares this projection against the scheduled bus departure times, and issues a CP “hold until” message to the appropriate bus trips, at up to three downstream TRAX stations. This analysis was conducted with the objective of assessing the relationship between issuance of a CP “hold until” message and the actual lateness of the train at the TRAX station. In other words, this analysis examines the ability of the CP system to accurately project late trains and issue CP “hold until” messages appropriately. This is important because erroneous CP “hold until” message could have a detrimental impact on bus operators’ willingness to follow or have confidence in CP suggested departure times. On the other hand, if

CP “hold until” messages are not issued when they should be, it will be less effective than it could be because bus operators will not receive guidance from the CP system.

Among the 245 bus trips where CP was active, only 150 received a CP “hold until” message (61.2%). Although the bulk of CP “hold until” messages were issued to bus trips where the train was actually more than two minutes late (62.0%), there were a significant number of CP “hold until” messages issued to bus operators where the train was less than two minutes late (38.0%). This suggests that trains have the ability to make up time after the point from which the initial projection was made – resulting in inaccurate issuance of CP “hold until” messages. However, comparing the distribution of train arrival times between bus trips when a CP “hold until” message was issued to bus trips where a message was not issued (Figure 2-29) suggests that trains can also be delayed more than projected, resulting in a failure to issue a CP “hold until” message when appropriate. Generally, the distribution of train arrival times between bus trips that received a CP “hold until” message and bus trips that did not are very similar (Figure 2-29). There were no statistically significant differences between these two distributions.

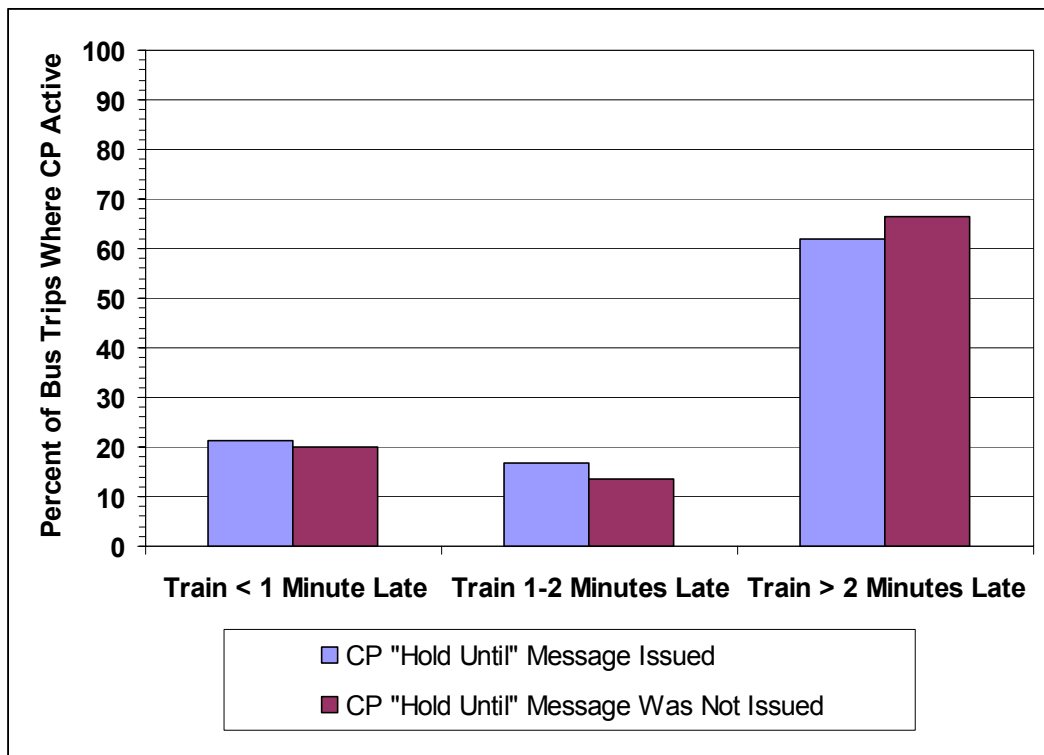


Figure 2-29. Comparison of the Distribution of Train Arrival Times by Whether a CP “Hold Until” Message is Issued

In summary, these results indicate that there are some inaccuracies resulting from the decision process of whether or not to issue a CP message. The effectiveness of CP could be improved by revising the algorithms employed for deciding whether to issue a CP message.

2.5.3 Late Bus Arrivals

One factor that may be related to the behavior of bus operators, including their willingness to wait at the TRAX station, is the degree to which they arrive at the TRAX station “on-time.” Bus operators who are running behind schedule may be less willing to wait at the TRAX station than are bus operators who are not running behind schedule. This could lead to missed connections on the part of train passengers. However, arriving late at the TRAX station also could have a positive impact on successful connections because the bus departure from the TRAX station is delayed. For example, consider two bus operators, one of whom is running on time and the other is running four minutes behind schedule. Further assume that the first bus operator waits for three minutes at the TRAX station past his/her scheduled departure time, but the second bus operator only waits for one minute. If the train arrives on time or is less than two minutes late then both buses would have successful connections. If the train is 2-3 minutes late, the first operator would have missed connections, but the second operator would not (even though the second operator waited for less time at the TRAX station). In short, the impact of the bus arriving late at the TRAX station is dependent upon the lateness of the train. Figure 2-30 and Figure 2-31 summarize the conditional distributions of bus trips by arrival time relative to the scheduled bus departure time for late trains and on-time trains, respectively.

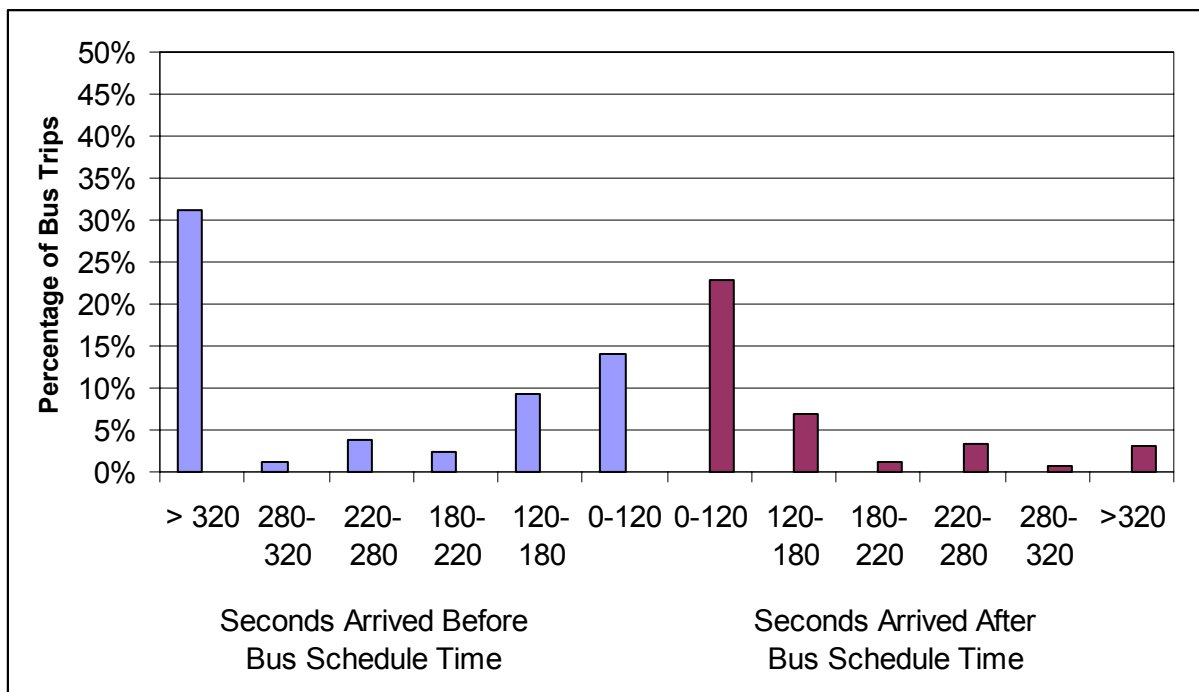


Figure 2-30. Distribution of Bus Arrivals Relative to Scheduled Bus Departure Time During Late Train Events

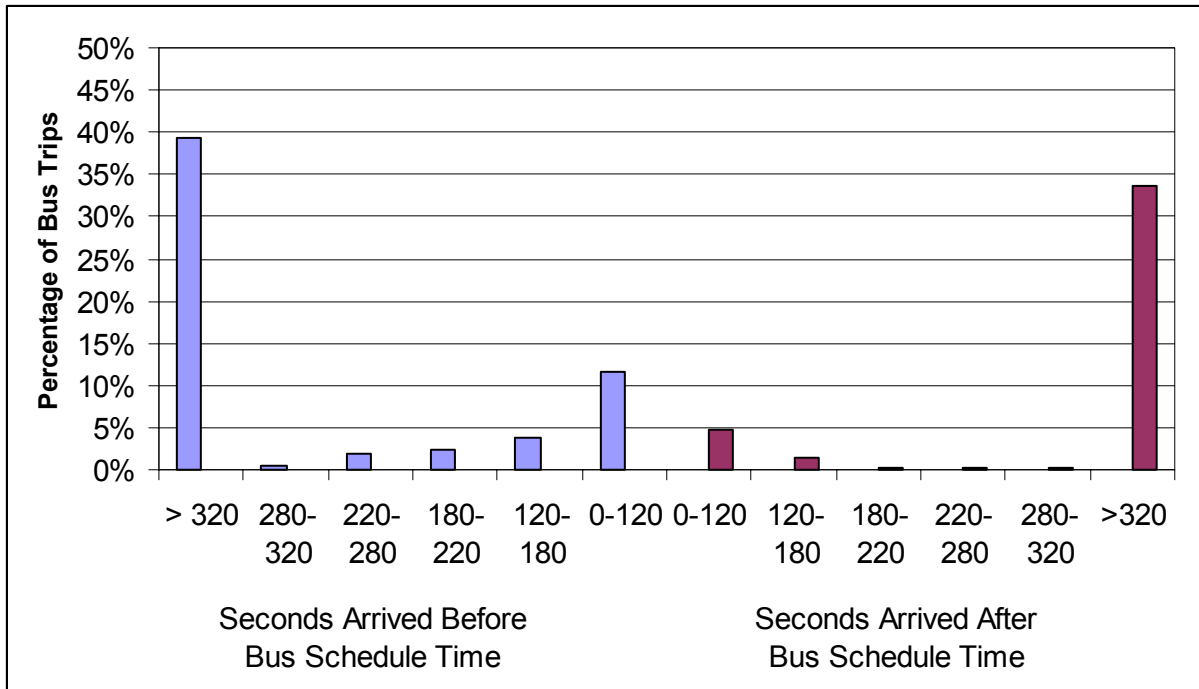


Figure 2-31. Distribution of Bus Arrivals Relative to Scheduled Bus Departure Time During On-Time Train Events

The distributions presented in Figure 2-30 and Figure 2-31 are quite different. For late train events, the majority of bus operators were either on-time or were late by less than two minutes (84.7%). Conversely, for on-time train events, there were a much larger percentage of bus operators who arrived at the TRAX station more than five minutes after the scheduled bus departure time (33.6%). These conflicting distributions may be an artifact of the data, because relatively few bus trips with measured arrival times were associated with a late train event (321) versus a large number of bus trips with measured arrival times where trains arrived on-time at the TRAX station (1,854).

Repeated measures ANOVA models were used to assess the impact of the bus arriving late at the TRAX station on the total length of time that the bus operator waited at the TRAX station (Dwelltime) and the length of time that the bus operator waited past the scheduled departure time (Holdtime) adjusted for the presence or absence of a late train, and the correlation in the repeated observations for the same bus trip. Bus trips where a CP “hold until” message was issued were excluded from the models. The results of these models include:

- Bus operators who arrived late at the TRAX station have an estimated average departure of 233 seconds past the scheduled departure time with a 95% confidence interval of 195 seconds to 271 seconds. Conversely, bus operators who arrived early or on-time were estimated to depart 79 seconds (56 seconds to 102 seconds) after the scheduled departure time.

- Bus operators who arrived late at the TRAX station waited 51 seconds with a 95% confidence interval of 0 seconds to 108 seconds. Bus operators that arrived early or on-time waited 591 seconds (550 seconds to 633 seconds).

The effect of late buses on the probability of a successful are mixed and difficult to accurately assess without the use of sophisticated statistical analysis that cannot be supported with the data collected. However, using the models and data described in Section 2.4.1, and after adjusting for the impacts of TRAX station, lateness of the train, and the status of CP, the effect of the bus arriving late was not a significant predictor for the probability of a successful connection under the requirement that buses depart at least 120 seconds after the train arrives. It was a significant predictor under the requirement that the buses depart at least 180 seconds after the train arrives (p-value = 0.0185). Train passengers who met a bus that arrived late were 2.4 times (1.2 to 5.0) more likely to have a successful connection than were train passengers who that did not meet a late bus. Investigating interaction terms between terms associated with late buses and lateness of the train, as well as TRAX station, is important to fully understand the impact of late buses on the probability of a successful connection but could not be completed under the limited sample sizes.

2.6 Summary of Findings

System performance data that could be used to evaluate the effectiveness of CP in improving train-to-bus connections were collected during a three-month period beginning in September 2003 and continuing through November 2003. These data include information on bus departure times, train arrival times (for instances when the train arrived late at a TRAX station), CP message logs, bus schedules, and CP assignments. Although logistical and other unexpected barriers prevented the full implementation of the planned data collection protocol, sufficient data were collected so that the effectiveness of CP could be evaluated.

It was not practically possible to actually measure “successful” train-to-bus connections of individual passengers. Therefore, three surrogate measures for a successful connection were employed: 1) requiring a bus departure more than 120 seconds after the train arrival, 2) requiring a bus departure of more than 180 seconds after the train arrival, and 3) time that the bus was held past the normal scheduled departure time. Four different analyses were conducted to investigate the effectiveness of CP. The first two analyses modeled the probability of a successful connection as a function of CP and other factors using the first two surrogate measures and unmatched bus trips where repeated observations were collected over time. The third analysis was similar, but was conducted using matched bus trips. Finally, the fourth analysis was conducted using the hold times.

The results were fairly consistent across the four different analyses. Based upon the system performance data, CP does significantly increase the percentage of successful train-to-bus connections. Train riders meeting a bus trip when CP was active and a “hold until” message was issued to the bus operator were 3.1 to 3.9 times (depending upon the definition of a successful connection) more likely to have a successful connection than were train riders meeting the same bus trips when CP was inactive, which was statistically significant. Additionally, train riders meeting a bus when CP was active and a “hold until” message was issued were two to three

times more likely to have had a successful connection than train riders meeting a bus when CP was active but a “hold until” message was not issued. Finally, train riders meeting a bus trip when CP was active but no “hold until” message was issued are 1.0 to 1.2 times more likely to have had a successful connection than train riders meeting a bus trip when CP was inactive.

Bus operators tended to hold the buses longer past their normal scheduled departure time when a CP “hold until” message was issued than when a “hold until” message was not issued. This result was significant for comparisons where CP was active (roughly one minute longer on average), but not significant when compared to late train events where CP was inactive (41 seconds longer on average).

Other findings based upon the system performance data include:

- Successful connections were also significantly related to the lateness of the train, with lower percentages of successful connection with later trains.
- There is some variation in the degree of successful connections by TRAX station, with Midvale Center having a lower percentage of successful connections than any other TRAX station.
- Day of the week was a significant predictor of the average length of time that the bus operators held the buses past their scheduled departure times for a late train event. Bus operators tended to hold the buses longer in the latter part of the week (Wednesday – Friday) than in the earlier part of the week (Monday – Tuesday), with differences ranging from 37 seconds to 2.7 minutes.

Operationally, CP has successfully identified and correctly issued suggested departure times to operators in the event of a late train. However, CP is not operating to the fullest extent possible and could be adjusted to increase effectiveness of CP in preventing missed train-to-bus connections. More specifically, there are operational issues that, if addressed, would likely increase the effectiveness of CP beyond the levels identified in this analysis.

During the course of the evaluation, there were several instances where CP was not operational. Certainly, there are going to be times when any computer system will experience a malfunction, or when UTA may want to turn CP off for selected bus trips. However, there were at least two periods (late Summer and in October) where CP was not activated for all but a few routes due to an oversight in CP assignments. Increasing the reliability of the system, including establishing a protocol for review of CP assignments, would increase the effectiveness of CP. It is important to note that UTA staff were intensely focused on the opening of a new rail extension, hosting the APTA Annual meeting immediately prior to the data collection period, and in process of reconfiguring management and functional responsibilities of UTA staff. Therefore, these events may be anomalies and may not reflect normal UTA operations.

Compliance or accepting the recommendation for alternative departure times issued by CP is an important component of the success of CP in increasing successful bus-to-train connections. Simply put, if operators routinely ignore suggestions from CP, then the only effect that CP could

have would be to “sensitize” operators to a late train, with the hope that with this sensitivity comes a change in behavior. This hypothesis can be examined through a comparison of the percentage of successful connections during late train events where CP was active but a “hold until” message was not generated and late trains events where CP was inactive. Train riders meeting a bus trip when CP was active but no “hold until” message was issued were 1.0 to 1.2 times more likely to have had a successful connection than train riders meeting a bus trip when CP was inactive, which does not represent a significant improvement in the likelihood of having a successful connection. Only 51.3% of bus operators that were sent a suggested departure time by CP departed after the suggested departure time. However, if 100% of the operators followed the suggestions of CP, then the percentage of successful connections would be increased by 28% and 57% for the 120- and 180-second requirement, respectively. These results indicate that increasing compliance may increase the impact of CP on successful connections. One important caveat to this finding is that it does not take into consideration the number of passengers who are trying to make the train-to-bus connection or who have already boarded the bus and will be delayed if the bus holds at the TRAX station. Thus, improvements could be made to increase the percentage of successful connections, but these improvements may come at a cost to other bus passengers who are not trying to make a train-to-bus connection.

The mechanism for determining when to send a suggested departure time (“hold until”) message to bus operators was not associated with the actual lateness of the train at the TRAX station. This results in issuing “hold until” messages when the trains are less than a minute late and failure to issue “hold until” messages when trains are more than two minutes late. The effectiveness of CP in reducing the number of missed train-to-bus connections could be improved if a more accurate decision process was employed.

3.0 User Perceptions: Evaluation Findings

3.1 Introduction

The qualitative component of the CP program evaluation primarily used surveys and interviews to assess traveler and bus operator satisfaction with the CP system. The objectives, as presented in the Evaluation Plan [Ref. 1], include the following:

- The evaluation will assess passengers' perceptions of improved connections where CP is implemented;
- The evaluation will assess the effectiveness of the CP system based on feedback from bus operators, dispatchers, and supervisors;
- The evaluation will analyze and compare customer comments from the surveys and the UTA comment/complaint logs with regard to connection reliability with and without CP.

This section presents the findings from this component of the evaluation based on survey data collected from a sample of bus riders, a survey of bus operators, interviews with bus operators, their supervisors and dispatchers, and an analysis of comments and complaints offered by bus riders relevant to the CP program. The qualitative evaluation sought to examine the perceptions of a selection of different UTA users, and derive an integrated perspective on the benefits and effectiveness of the CP program from multiple points of view.

3.2 Overview of Approach



Figure 3-1. BYU Student Interviewer Conducting Survey on UTA Bus

The approach to the qualitative component of this evaluation is presented in detail in the Evaluation Test Plan report [Ref. 2], and is briefly summarized here. For the bus rider survey, the evaluation team designed and tested the survey questionnaires, and Brigham Young University (BYU) provided student interviewers who were assigned to three TRAX stations to cover a mix of CP protected and unprotected bus trips during the afternoon and evening over three days from October 21 to 23, 2003. The three TRAX stations included Millcreek, Historic Sandy, and Sandy Civic Center, and they were selected on the basis of the pilot data collection and analysis that showed they had the highest number of late train events. The BYU students

boarded the selected buses at these TRAX stations and distributed paper questionnaires to the rail-to-bus transfer riders and a different questionnaire for the on-board passengers (Figure 3-1). Although the target sample size was 400 completed survey questionnaires, the evaluation

actually resulted in 522 completed questionnaires, including 433 riders transferring from rail to bus and 89 on-board passengers. Among all the completed survey forms, 53% were on bus trips designated for CP protection. As has been noted previously, however, the CP system was not always functioning properly during the evaluation period, and therefore it is likely that some of the rider respondents were exposed to bus trips for which CP protection was designated but not always functional.

A survey was distributed to all current UTA bus operators, including both regular and extra board operators, along with their pay check distribution on November 13, 2003. The survey could be filled out by hand and returned to the office or could be completed on-line over the Internet. An incentive drawing for a dinner for two was offered, and 251 completed surveys were returned, for an overall estimated response rate of 28%. This survey sought to understand bus operators' experiences with CP, their responses to late train events either with or without CP "hold until" messages being issued, and their perceptions of the CP program and suggestions for improvement.

Members of the evaluation team conducted interviews on November 11, 2003 with the UTA radio controllers who are in constant contact with the UTA bus operators, the operations supervisors and work dispatchers, bus operators who were available in their dispatch waiting room, and other UTA staff responsible for the CP program and management of customer complaints.

Sample sizes for the bus rider and operator surveys were designed to provide a sufficient number of completed surveys to allow for the identification of statistically significant relationships in the data at or above a 95% confidence level. As noted, the actual sample sizes exceeded the target. The analyses of the survey data are based on Chi Square tests of differences in percentages and difference of means tests for the strength of relationships and tests of statistical significance.

3.3 Bus Rider Surveys

Two separate surveys were conducted for the bus riders: one for riders who were transferring to bus from a TRAX train and another for riders who were on the bus but had not transferred at the TRAX station where the survey was conducted. A comprehensive schedule was prepared that showed all TRAX trains and all buses connecting at the three TRAX stations from 4:00 p.m. to the last bus trips of the day. Appendix A shows all of these trips and highlights those that were presumed to be protected by CP and those that were not. Unfortunately, it turned out that many of the trips that were supposed to be protected during the survey period and the month preceding the survey were actually not protected during this period due to system problems. It is not possible to determine how this may have affected responses to the surveys, though from a bus rider's perspective, the presence or absence of CP is essentially invisible. In addition, it is not possible to determine the number of missed connections a rider may have experienced that would have been successfully made if CP had been properly running at this time.

The survey for the rail-to-bus transfer riders is shown in Appendix B and the survey for the on-board passengers is shown in Appendix C. Furthermore, Appendix D provides a table with details on which of the available trips were covered by the survey, which were not, and how

many riders and actual respondents were on each of these trips. Appendix E shows the complete results for the two bus rider surveys, including frequency distributions and percentages. These results are analyzed and presented in this section of the report.

3.3.1 Background

The bus rider surveys were conducted over a three-day period from October 21, 2003, to October 23, 2003. Table 3-1 shows the distribution of responses for the train-to-bus transfer riders and the on-board passengers at the three TRAX stations where the surveys were conducted.

Table 3-1. Distribution of Survey Respondents by TRAX Station and Rider Type

TRAX Station	Train-to-Bus Riders		On-Board Passengers	
	Number	Percent	Number	Percent
Millcreek	176	41%	57	64%
Historic Sandy	74	17%	12	14%
Sandy Civic Center	183	42%	20	22%
Totals:	433	100%	89	100%

A total of 522 valid questionnaires were completed and included in the analysis of results, substantially exceeding the target sample size of 400.

Figures 3-2 and 3-3 show the demographic characteristics of the respondents, in terms of gender and age category. Overall, there are more males than females in the survey, and the riders are predominantly in the working ages of 21 to 64 years old. About 18% of the respondents are less than 21 years old and most of them are likely students. There are very few persons of retirement age or older (only 10, or about 2% of the total sample). Because the overall response rate to the

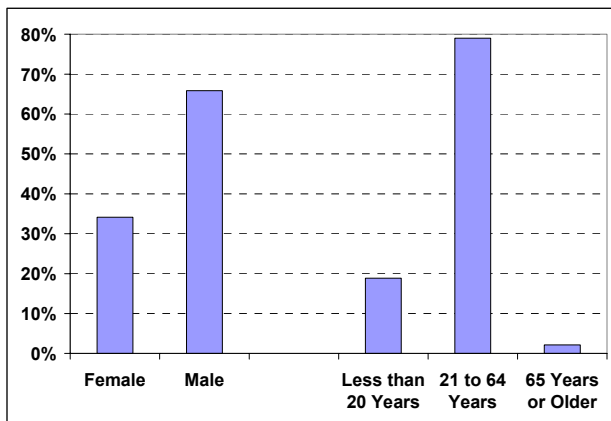


Figure 3-2. Train-to-Bus: Gender and Age

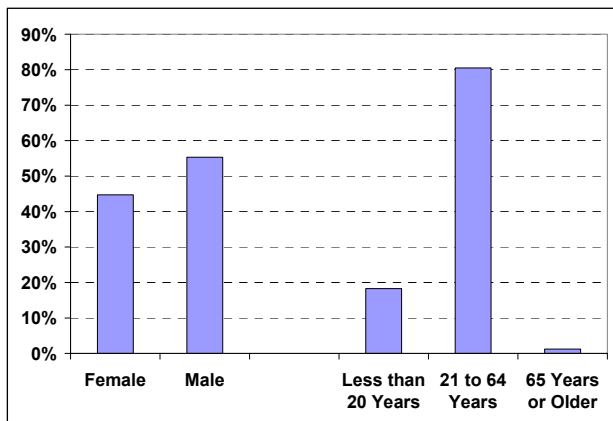


Figure 3-3. On-Board: Gender and Age

surveys conducted on the buses was estimated to be about 77% of all the riders on the buses surveyed, this distribution is assumed to closely approximate the demographics of the bus riders on these routes at these times of day and days of week.

Frequency of riding the buses is shown for the train-to-bus transfer respondents in Figure 3-4 and for the on-board passengers in Figure 3-5. The distribution of riding frequency is very similar for both samples of respondents. Over the entire survey sample, 38% said that they ride the bus 10 or more times during a typical work week, or at least one round trip a day between Monday and Friday. Many of these are likely commute trips. About one-quarter of the sample rides the bus 4 or 5 one-way trips a week. Overall, only 7% are infrequent riders, reporting one or fewer times a week.

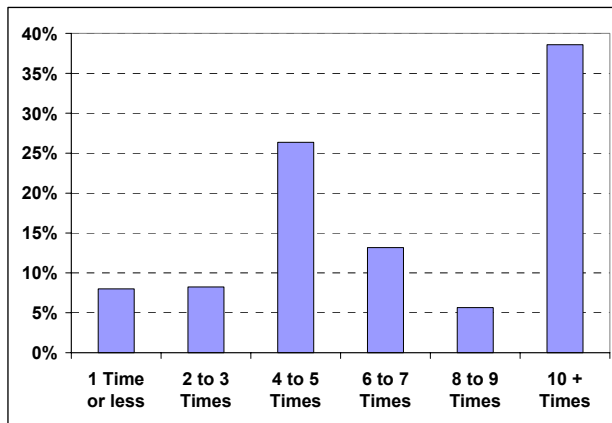


Figure 3-4. Train-to-Bus: How often do you ride the bus on a one-way trip in a typical week, Monday – Friday?

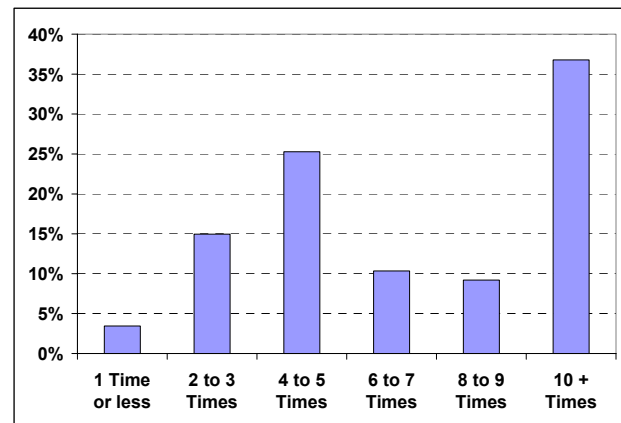


Figure 3-5. On-Board: How often do you ride the bus on a one-way trip in a typical week, Monday – Friday?

A bus trip is defined in terms of a particular bus route at a particular time and place. Thus, these rider interviews were conducted on a bus associated with a bus trip. Some of the riders were on bus trips that were protected by the Connection Protection (CP) program and some were not. It is assumed that most of the riders are unaware of whether or not a bus trip is protected by CP. Table 3-2 shows the number and percent of survey respondents on trips at each of the TRAX stations that were protected and not protected. Over all the surveys and TRAX stations, 53% of the riders surveyed were on protected bus trips.

Table 3-2. Number and Percent of Protected Trips by TRAX Station and Rider Type

TRAX Station	Train-to-Bus Riders		On-Board Passengers	
	Protected	Unprotected	Protected	Unprotected
Millcreek	55 (31%)	121 (69%)	6 (10%)	51 (90%)
Historic Sandy	48 (65%)	26 (35%)	6 (50%)	6 (50%)
Sandy Civic Center	153 (84%)	30 (16%)	10 (50%)	10 (50%)
Totals:	256 (59%)	177 (41%)	22 (25%)	67 (75%)

A different look at the rider survey data is shown in Table 3-3, providing the number of interviews completed on each bus trip at each of the three TRAX stations over the three-day survey period. Some of the bus trips experienced more than one survey over two of these days. Also, in Table 3-3 different trips at different times on the same bus route are combined; hence, for example, 11 different trips on the 811 Provo run were surveyed over the three-day period and are combined in Table 3-3. As shown in Table 3-3, over half of all the completed surveys (56%) came from respondents on three bus trips, one at each TRAX station. These included the 811 Provo from Sandy Civic Center, the 90 WB from Historic Sandy, and the 37 WB from Millcreek. Most of these individual bus trips were designated CP protected trips.

Table 3-3. Distribution of Survey Respondents by TRAX Station and Bus Trip

Bus Trip	Number of Interviews	Percent of Interviews
Sandy Civic Center TRAX Station		
811 Provo	140	69%
33 NB	14	7%
46 SB	10	5%
345 OB	8	4%
816 Provo	6	3%
41 NB	5	2%
47 SB	5	2%
133 IB	4	2%
222 NB	3	1%
124 IB	2	1%
125 IB	2	1%
143 NB	2	1%
12 NB	1	<1%
24 NB	1	<1%
Total:	203	100%
Historic Sandy TRAX Station		
90 WB	40	51%
94 EB	28	36%
24 SB	10	13%
Total:	78	100%
Millcreek TRAX Station		
37 WB	107	46%
137 WB	35	15%
31 EB	33	14%
131 EB	23	10%
41 SB	18	8%
31 WB	17	7%
Total:	233	100%

The full details for each individual bus trip are shown in Appendix D. An estimate of the completion rate for the survey is 77%, based only on the first day of the three days of the survey and computed as the ratio of completed surveys (188 on day one) to the total number of bus riders enumerated by the survey takers, covering all three TRAX stations (244 on day one). The other two days of data are not included in this calculation because they include an unknown number of riders on those buses who will have already taken the survey on one of the prior days and therefore would not be eligible to respond a second time.

3.3.2 Train-to-Bus Transfer Rider Results

These survey respondents reported that it is “very important” (80%) or “somewhat important” (16%) to be sure that they make their connection between the TRAX train and their preferred bus. Thus, for almost all these transfer riders (96%), connecting to their bus is something they care a lot about. The train-to-bus riders were asked: “How many times in the past month have you missed your scheduled bus connection at this TRAX station because the TRAX train was late?”

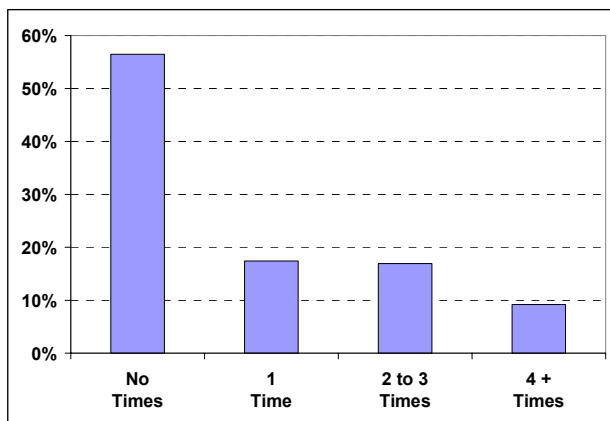


Figure 3-6. How many times have you missed your bus connection in the past month at this TRAX station?

Figure 3-6 shows that over half the survey respondents (57%) said they experienced no missed connections in the past month. On the other hand 39 transfer riders (9%) said they had missed their connection four or more times in the past month. The highest frequency of missed connections was reported for trips at Millcreek (50%) and the fewest at Sandy Civic Center (37%). As shown in Table 3-2 earlier, Sandy Civic Center had the highest percentage of CP protected respondent trips (84%) and Millcreek had the lowest percentage (31%). Although there is a greater likelihood that respondents will report experiencing one or more missed connections for trips that are not CP protected (47%)

compared with CP protected trips (41%), the relationship is not statistically significant. Though not statistically significant due to the small numbers, riders who were not on CP protected trips were about twice as likely as riders on CP protected trips to report missing four or more connections in the past month (13% versus 7%).

Unfortunately for the purposes of this evaluation, due to a failure during all of October, the CP system was actually operating only for a few of the trips (route 811 and route 816 to Provo from Sandy Civic Center) when the survey was conducted. What is more difficult to demonstrate is the extent to which the bus operators on the CP designated routes have learned from experience with CP to wait for late trains, regardless of whether or not a CP message is issued for any particular late train trip. This study suggests that this may in fact be occurring.

Riders transferring from the TRAX train to a bus were asked whether the bus operator waits for them if their train is late, and 21% of them said either that their train is never late or that they do not know whether the bus operator waits or not. Figure 3-7 shows the responses to this question. Overall, 29% of the train-to-bus riders said the bus operator never waits for them, and about one quarter (16%) said the operator waits most of the time or always. The rest (34%) reported that the operator waits only occasionally. For those trips that are usually subject to CP protection compared with those trips that are not protected, there is *no* reported greater likelihood that the operator will wait for the transferring bus rider on the protected trips based on responses to this survey.

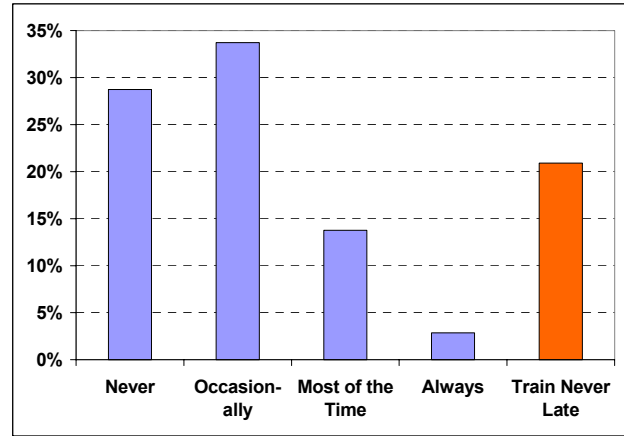


Figure 3-7. If your train is late, does the bus driver wait for you?

Survey respondents who were transferring from TRAX to bus also were asked what they are most likely to do when they miss their bus connection (Figure 3-8). The majority (66%) said they would wait for the next bus, and the rest reported a variety of other strategies, such as calling family or a friend for a ride. The amount of time they reported having to wait for either the next bus or another form of transportation is shown in Figure 3-9. Most respondents reported having to wait from 16 minutes to a half-hour (45%). Less than 10% have a short wait of 15 minutes or less, and 39% said they usually have to wait more than a half-hour. It is reasonable to assume that the longer the wait time, the more likely these respondents would be to say that being sure they will make their bus connection is important to them, and that connection protection would have a high benefit in these circumstances in terms of avoided wasted time. However, the survey data indicate that almost all the riders said making their connection is important (97%), regardless of their actual wait time experience.

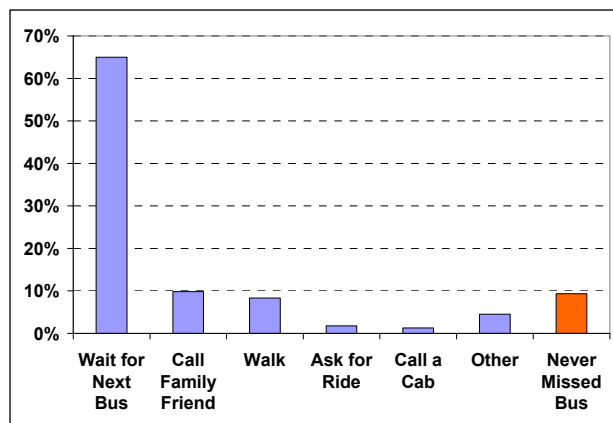


Figure 3-8. What are you most likely to do when you miss your bus connection?

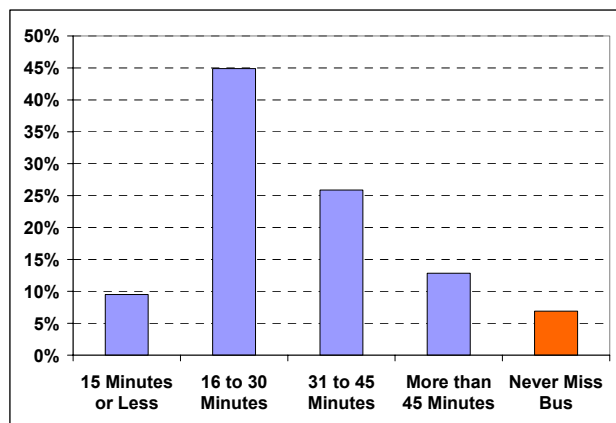


Figure 3-9. If you miss your bus connection, how long do you usually have to wait?

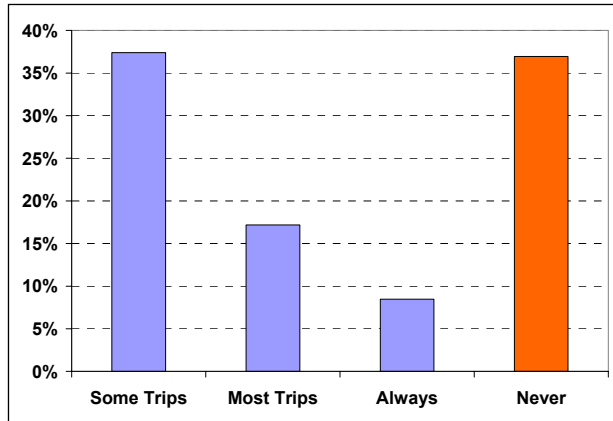


Figure 3-10. In the past month how often have you taken an earlier TRAX train to avoid a missed bus connection?

One way to reduce the likelihood of missing a transfer connection from the TRAX train to a bus is to take an earlier TRAX train. Because the trains run about every 15 minutes, a known extension of trip length by 15 minutes is likely to be preferred by many over the risk of a missed bus connection with an uncertain delay that is typically longer than 15 minutes, especially given that the buses often run less frequently than the trains. The transferring riders were asked how often they took an earlier TRAX train to avoid missing their bus connection. The results, shown in Figure 3-10, indicate that almost two-thirds (63%) of the survey respondents had done this in the past month, and 26% reported that they take an

earlier train for most or all of their trips involving a connection with a bus. Interestingly, while it would be expected that transfer riders might be less likely to take an earlier train if their bus trip is CP protected, this is not apparently the case. There is *no* relationship at all between the propensity to take an earlier train to avoid a missed connection and whether the connecting bus trip is CP protected or not. There also is no significant difference in the propensity to take an earlier train among respondents at each of the three TRAX stations surveyed.

About half the transfer riders reported that they have additional bus connections they need to make after leaving the TRAX station. This is expected to constitute another factor that affects the importance of making a connection from the train to the first bus. They were asked whether

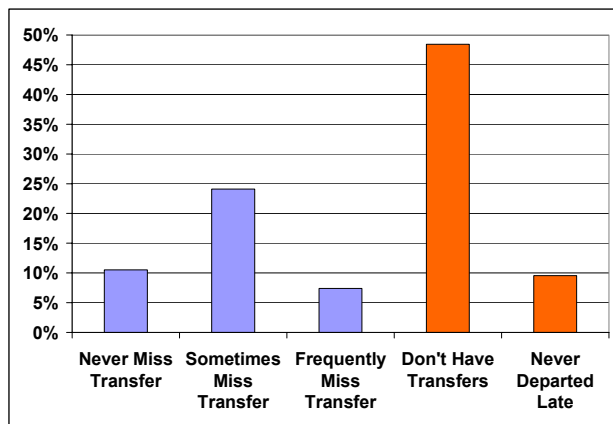


Figure 3-11. If your bus is late due to a late train arrival, do you ever miss your next bus transfer down the line?

they ever miss their next bus transfer down the line if their bus departs late from the TRAX station due to a late train arrival. In such a late train situation, CP could assure that they get on the first bus but could result in enough of a trip delay that they miss their next connection. Among those riders who have a down-line connection to make, those who said they “sometimes” or “frequently” miss their down-line transfer are much more likely to say they take an earlier TRAX train for at least some (or more) of their trips (statistically significant).

Figure 3-11 shows the responses to the question regarding respondent experience with missed connections down the line. About half said that they do not have any transfers after

boarding at the TRAX station (49%) and 20% said they either never have departed late from the TRAX station or have never missed a transfer connection. The rest (31%) said they sometimes or frequently miss their transfer down the line. Of those who are apparently at risk of potentially missing their down-line transfer connection (i.e., those who have subsequent transfers or do not

report never having departed late), the more frequent riders are more likely to experience missing their transfer compared with those who report traveling less frequently.

Finally, the survey respondents were asked how satisfied they were with their experiences connecting from the TRAX train to their preferred bus. Overall, 86% said they were “very” or “somewhat” satisfied. Only 14% said they were “somewhat” or “very” dissatisfied. The results are illustrated in Figure 3-12.

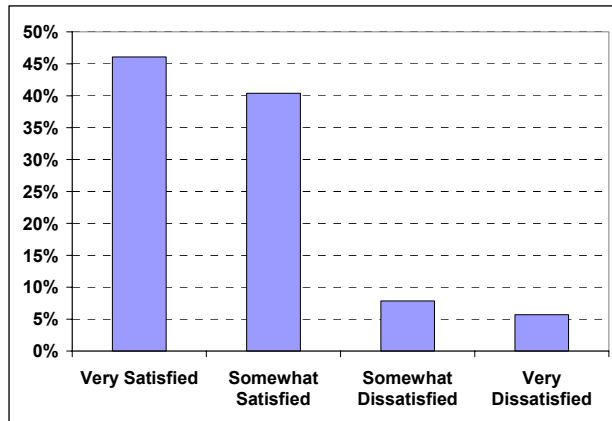


Figure 3-12. Overall, how satisfied are you with connections from the TRAX train to your preferred bus?

There are no significant differences in the expressed satisfaction by the three TRAX stations. Although there is not much variation in level of satisfaction with connection experiences (most are satisfied), being dissatisfied is more likely among the more frequent riders (defined as 6 or more trips a week) (16%) than among the less frequent riders (9%). This is a statistically significant difference, and may be associated with the greater likelihood of experiencing missed connections due to taking more trips a week. In fact, those who said they have experienced missed connections in the past month are more than three times more likely to say they are dissatisfied (22%)

compared with those who have not missed any connections (6%). Although this is statistically significant, the number of dissatisfied riders overall is low. Not surprisingly, the longer riders said they have to wait after missing a connection, the less satisfied they were with their experiences connecting from train to bus. All riders who never miss their bus (26, or 6% of the respondents) reported that they are “very satisfied,” and only 42% of all those who experience a delay of any amount due to a missed connection reported being “very satisfied.” Reporting being “very satisfied” declines as the wait time increases, with only 30% of riders faced with more than a 45-minute wait saying they are “very satisfied.” Finally, riders who were surveyed on trips that were CP protected were only slightly more likely to report being “somewhat” or “very satisfied” (87%) compared with those who were not on CP protected trips (85%), a difference that is not statistically significant. Thus, from the point of view of the bus transfer riders, though they are for the most part unaware of CP, the presence or absence of CP on their particular bus trips does not appear to make any difference in their reported satisfaction with connections.

At the end of the survey the respondents were given an opportunity to offer comments or suggestions for UTA regarding rail-to-bus connections. Out of the 433 survey respondents who were transferring from rail to bus, 166 offered comments (38%). Some comments involved detailed route-specific recommendations for schedule adjustments, for example, and others involved general expressions of pleasure or displeasure with some aspect of the system operation. Comments of particular interest for the evaluation of rail-to-bus connections reflected rider perceptions about schedules that were not well coordinated between bus and rail, late bus arrivals/departures, some operators who would not wait when the train was in sight, and frequency of bus service.

All the comments and suggestions were reviewed and some were selected as illustrative of the range of all the comments provided. The comments presented here are not intended to represent the opinions of all the riders covered in the survey, both because only about one-third of the riders provided written comments, and because only a small set of those comments are presented here as illustrative examples. The following quotes illustrate this range of comments and suggestions from all those provided by the transfer riders. They help give a flavor of rider opinions in the actual words of the riders.

Selected comments and suggestions of the rail-to-bus riders on the CP program

“I wish there were more buses to ride at night to connect from the train.”

“Is it possible to schedule bus arrival/departure times more closely to the TRAX schedules?”

“My bus is too late many times.”

“Please adjust bus schedules by 2 minutes to match the 2-minute change to the TRAX schedule.”

“The biggest problem is the bus arriving late.”

“UTA is doing a great job. They were excellent during the Winter Olympics.”

“I understand timetables, but it would be nice if the bus would wait for the TRAX that is supposed to arrive near the time of its departure. And vice versa also. Many times the bus is late and TRAX didn’t wait, and I was 15 minutes late. Thanks for letting me do this survey.”

“The buses are NEVER on time anymore.”

“The problem is the OTHER way; buses from Utah County arrive late to catch the train in.”

“Trains are rarely late; buses are always late – you guys already know that.”

“Good service. Can be improved if more frequent buses can be employed on important routes.”

“I would like to see the frequency of route 811 increased to at most 45 minutes apart.”

“I would be ecstatic if the 811 would come by every half hour instead of every hour so I didn’t have to wait as long.”

“You should survey those who drive to the TRAX; they do it because they think the connections are not good.”

Selected comments and suggestions of the rail-to-bus riders on the CP program (continued)

“I wish the bus schedule from TRAX could be more frequent.”

“[Provide] more buses at hours of TRAX service. TRAX seems to be designed around people who can drive to the stop. Night ride service is definitely designed around drivers and not bus passengers.”

“Some bus drivers wait for the train to go before they leave, some don’t.”

“My gripe is not with late trains. It’s [with] late buses. If you start a survey on that, I would love to fill it out as well.”

“I have more of a problem connecting to the train from the bus. A lot of times I miss my train connection because the bus is late. And I am late for work because of it.”

“Train to bus is okay. Bus to train needs improving. More buses.”

“If it weren’t for your nice drivers, I would probably hate the bus/TRAX.”

“Rail-to-bus connections are generally not a problem for me. Bus-to-rail connections, however, almost always are. There are about 5 buses that have stops near my home, and none of them consistently gets me to TRAX in a comfortable time before the train leaves. I almost always have to wait 10 minutes or more.”

3.3.3 On-Board Rider Results

Just as riders transferring to their bus want to be sure they can make their preferred connection without having to wait for a next bus, riders who are on the bus arriving at a TRAX station want their bus to be on schedule. Timeliness is important for a number of possible reasons, including connecting from bus to TRAX, connecting to another bus at that station, being able to make a down-line transfer connection, and arriving at one’s final destination on time. All things equal, they would be expected to prefer that the bus not be required to wait for late trains, as that increases the risk that they will fail to meet one or more of the objectives noted above. These on-board passengers were asked how many times in the past month they have been on the bus when it arrived late at this TRAX station. The results, as shown in Figure 3-13, indicate that over half of the riders (53%) said they have experienced one or more late bus arrivals. One-quarter of the respondents (25%) said that their bus was late four or more times in the past month. Not surprisingly, the more frequent riders tended to experience more late arrivals, but half of the riders who said they were late 4+ times in the past month said the delays caused no problems at all for them. Most of those who reported no problem with the delays either do not have a down-line transfer to make or said they have never missed a later transfer if they do have a transfer (65%). But among those who do have a transfer, the few who said they frequently miss that

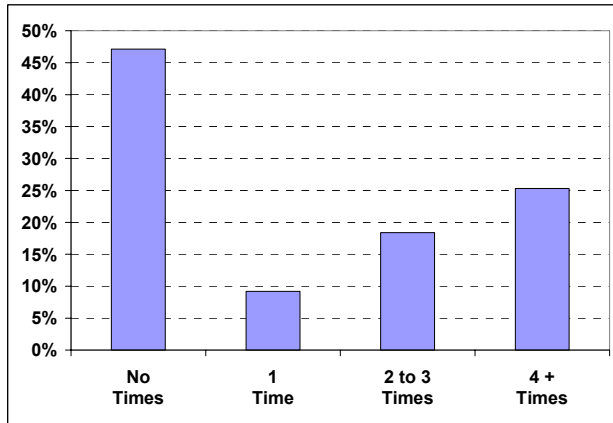


Figure 3-13. How many times in the past month have you been on this bus when it arrived late at this station?

transfer are more likely to be those who reported 4+ times experiencing late arrivals at the TRAX station. The more times bus riders report arriving late at the TRAX station, the greater the likelihood they also reported frequently being late at their final destination. Of those who reported being late at their final destination 4+ times in the past month, 73% said they were also late 4+ times at this TRAX station, and 76% of those who reported never being late at their final destination in the past month also said they were never late at this station (statistically significant). Also, the frequency of arriving late at the final destination is highly correlated with the frequency of waiting at the TRAX station for a

late train connection.

Another, more positive, effect of a late arrival at a TRAX station is that it increases the likelihood of successful rail-to-bus connections when the train and bus schedules are too close to assure successful connections, or in situations when the train arrives late. Depending on the frequency of late bus arrivals at TRAX stations, a portion of all possible missed connections may be avoided without requiring a CP hold. Thus, some of the observed successful connections during late train events may not be due to CP, but rather to a late bus arrival. This would also help explain why so many CP messages (64%) are judged unnecessary by the operators.

Buses that arrive on schedule may wait past their scheduled departure to pick up late passengers or passengers who may be having difficulty getting from a TRAX train to their bus if the connection time is short, especially if they have a handicap or are elderly. The decision to wait can be due either to receipt of a CP “hold until” message or due to the operator’s independent decision without a specific hold request. Regular operators who have come to know many of their regular passengers over time might be expected to be more likely to wait, regardless of CP, than extra board operators who may be new to the particular bus route. There are other factors that may affect the decision to wait. For example, operators who have experienced CP “hold until” messages may have learned to wait when they believe the train is late, whether or not they know their individual passengers and independently of whether they actually receive a CP “hold until” message. Another factor is the tightness of the bus schedule; operators on trips where there is little or no slack time are expected to be less likely to wait for a late train, or to wait a shorter time, than operators whose trips have built in schedule slack. These issues will be addressed more closely in Section 3.4 from the perspective of the operators themselves, but are relevant here in examining the perspective of riders on the buses. Figure 3-14 shows the bus riders’ responses to the question asking how many times in the past month their bus waited past its scheduled departure time at this TRAX station because the train was late. The majority of respondents (58%) said this did not happen to them in the past month, but 42% said that their bus waited for a late train one or more times. A higher percent of the respondents at Millcreek said this (48%) compared with the other two TRAX stations (32%); however, the difference is not

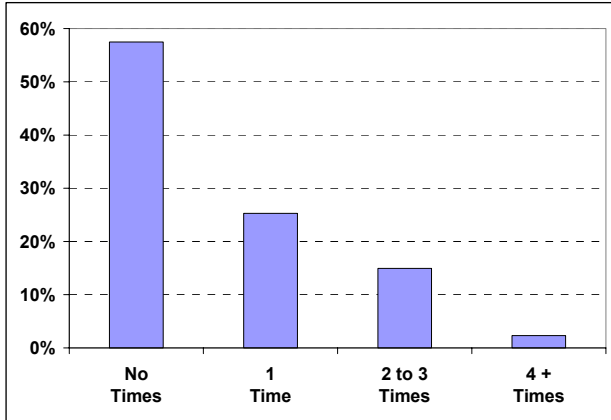


Figure 3-14. How many times in the past month has this bus waited past its scheduled departure for a late train?

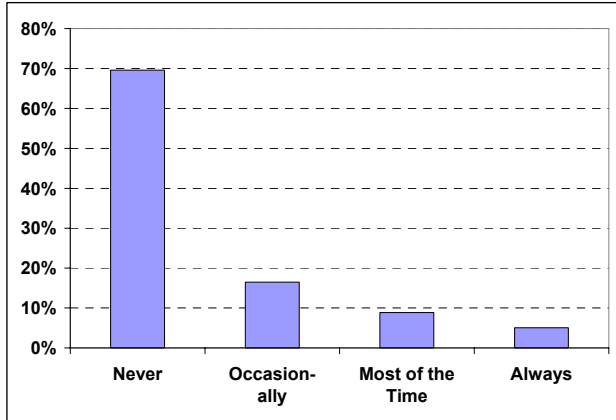


Figure 3-15. When the train is late, does the bus operator discuss whether to wait with the bus passengers?

statistically significant due the small number of respondents interviewed at Sandy Civic Center and Historic Sandy.

Passengers have no idea why the bus waited, unless the operator tells them. Because they are not aware of CP messages issued on the bus operator’s MDT, they are likely to assume the operator is making the decision independently. The bus riders were asked whether the operator discusses the need to wait for train passengers or whether it is OK with the passengers to wait for a late train. Figure 3-15 shows that 70% of the respondents said their bus operator never does this. Although riders who report that their operator “never” or “occasionally” discusses the need to wait are about twice as likely to report that they are dissatisfied with how bus operators deal with late train connections as riders who say they do discuss this (21% versus 9%), the relationship is not statistically significant. Nevertheless, communication between bus operators and their passengers appears to be a factor in understanding the perceived efficacy of CP on the part of bus riders.

The bus riders were asked whether it is a problem for them if their bus is delayed because of a late train connection (Figure 3-16). The majority said it is “no problem at all” or “not much of a

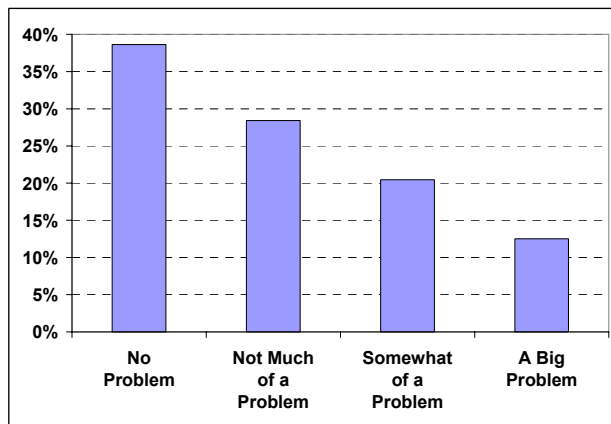


Figure 3-16. Is it a problem for you if your bus is delayed because of a late train connection?

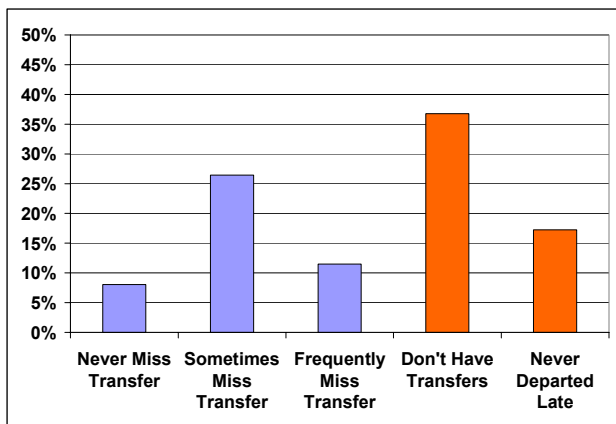


Figure 3-17. If your bus departs late due to a late train arrival, do you ever miss your next bus transfer down the line?

problem” (67%). For 13% of these riders, delayed departures (one of the consequences of CP) were reported to be “a big problem.” Riders who said they “sometimes” or “frequently” miss a later bus transfer connection down the line from the TRAX station were much more likely to be among those who said that it is a problem for them to wait past their scheduled departure for a late train (statistically significant). As shown in Figure 3-17, only 38% of the riders reported that they miss connections down the line. The rest either reported not having any bus transfers past the TRAX station (37%), or said they have never experienced a late departure from the TRAX station (17%), or, if they have sometimes departed late, they have never missed their transfer connection (8%).

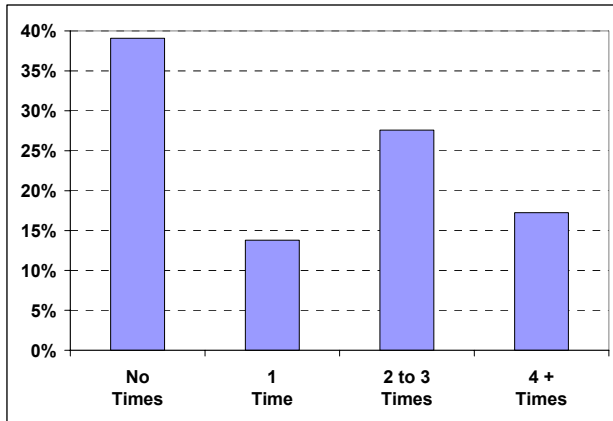


Figure 3-18. How many times in the past month has this bus arrived late at your final destination?

There are many reasons why a bus might arrive late at its destination, and waiting for a late train is only one of those. Traffic conditions, passenger volume, the need to manage handicapped passengers or persons needing to stow a bicycle, weather, and the bus schedule timing are among a number of other factors. Bus passengers in this survey were asked how many times in the past month their bus had arrived late at their final destination. The results, as shown in Figure 3-18, indicate that about 60% of the riders say they have arrived late one or more times in the past month.

destination (which could be the next stop or many stops past the TRAX station), it would be difficult to show that CP, which occurs on only a small proportion of all bus trips, has a measurable effect on whether a rider experiences delayed arrival at his/her final destination. In fact, there is at best very weak evidence in these data to suggest that CP may make it more likely that a rider will experience one or more late arrivals at their final destination. About 58% of the

respondents on bus trips not protected by CP said they arrived late at their final destination one or more times in the past month, while 67% of riders on CP protected trips said that; however, the difference is not statistically significant. Arriving on time at their final destination is, however, related to how satisfied bus riders report they are with how the bus operators deal with late train connections. Riders who said they had no late arrivals at their final destination in the past month almost all reported that they were satisfied (97%), compared with 74% of those who experienced one or more late arrivals (statistically significant).

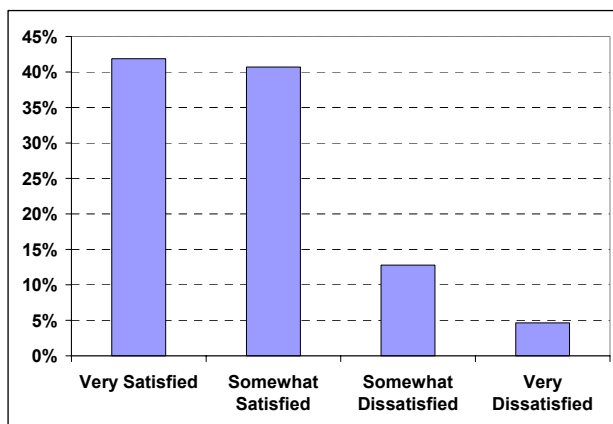


Figure 3-19. Overall, how satisfied are you with how the bus operators deal with late train connections?

Looking at the overall level of satisfaction of the on-board passengers (Figure 3-19), the great majority (82%) report that they are “very” or “somewhat” satisfied with how the bus operators deal with late train connections. This is comparable to the level of satisfaction reported by the rail-to-bus transfer riders with their experiences connecting from the train to their preferred bus—86% were satisfied, as discussed in Section 3.3.2. The on-board passengers who were on bus trips protected by CP were more likely to report being satisfied (90%) compared with riders who were not on CP protected trips (80%). Although this relationship between CP coverage and overall rider satisfaction is somewhat stronger than that for the rail-to-bus transfer riders, it is not statistically significant. Alternatively, the data indicate that, although dissatisfaction is low overall (only 17%), riders who are on trips not protected by CP are twice as likely to report dissatisfaction (20%) compared with riders on CP protected trips (10%). Again, this association is not statistically significant.

3.4 UTA Bus Operator Surveys

There are an estimated 900 bus operators working for UTA, and they are divided between approximately 790 regular full-time operators and about 110 “extra board” operators. The extra board operators have less experience and serve as substitute operators for absent regular operators, covering vacation days, sick leave, and excused days when a regular operator is not available. They usually transition to regular operators after about three years of experience. The operators have varying experience with the CP program, depending on the routes they typically drive. A short survey questionnaire was distributed to the operators with their pay checks, and supervisors encouraged the operators to complete the survey. A total of 251 surveys were completed, and the results are analyzed and presented in this section.

3.4.1 Background

The UTA bus operator survey is shown in Appendix F. It was designed to learn more about the experience of operators with the CP program and how operators respond under various circumstances in which trains may be late and CP messages may be issued. Operator opinions about the CP program were solicited in the survey. The questionnaire was kept short and focused on the key issues associated with the CP program to make it easy to complete the survey. Operators were offered an incentive to fill it out by having a chance to win a drawing for a dinner for two, and most of the respondents (94%) volunteered their driver ID number to be entered into the drawing.

The survey was originally intended to be implemented over the Internet, as this was assumed to be an easy way for operators to respond and an efficient and reliable way to tabulate the results. However, on the recommendation of the UTA Operations Supervisors and Work Dispatchers, it was decided to provide the operators with a hard copy version of the survey and give them the option to complete a written questionnaire or alternatively enter their responses on-line using one of the computers available to them at their dispatch office. This proved to be a prudent approach, because 96% of the surveys were returned in written form; only 9 surveys were completed on-line.

3.4.2 Operator Survey Results

Table 3-4 shows the distribution of responses by operator category and the estimated response rates for the operator survey. A significantly higher proportion of the extra board operators responded to the survey (60%) compared with the regular operators (23%). The lower response rate for the regular operators, and the non-random nature of the sample, reduces the validity of the results from this survey. The detailed frequency distributions for this survey are shown in Appendix G.

Table 3-4. Responses to the Operator Survey

Operators	All UTA Operators (Est.)		Survey Respondents		Response Rate (Est.)
	Number	Percent	Number*	Percent	
Regular	790	88%	183	73%	23%
Extra Board	110	12%	66	27%	60%
Totals:	900	100%	249	100%	28%

*2 operators did not give their operator category. Total N = 251.

The operators were asked to indicate how long, in years and months, they had been a bus operator for UTA. The results are shown in Figure 3-20, with categories identified that allow an unambiguous assignment of years and months. Across all the respondents, the average tenure at UTA is 8 years and 9 months. Very few operators reported a year or less (6%), and a large number of operators reported working at UTA for more than 20 years (12%). As expected, the regular operators have much longer average tenure with UTA (11 years and 1 month) than the extra board operators (1 years and 10 months). Across all the operator respondents, there is a substantial amount of experience with the UTA bus system that underlies their responses and comments.

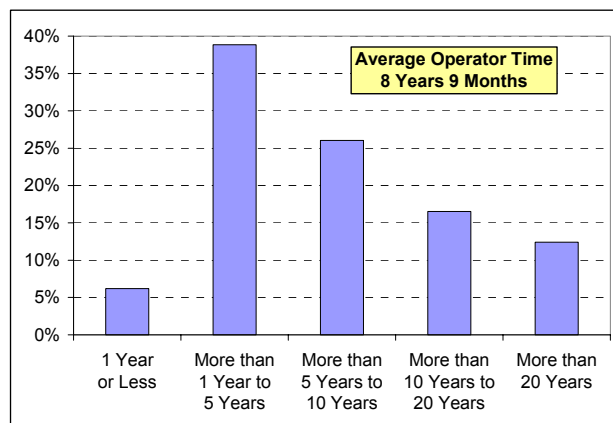


Figure 3-20. Length of Time Operating a UTA Bus

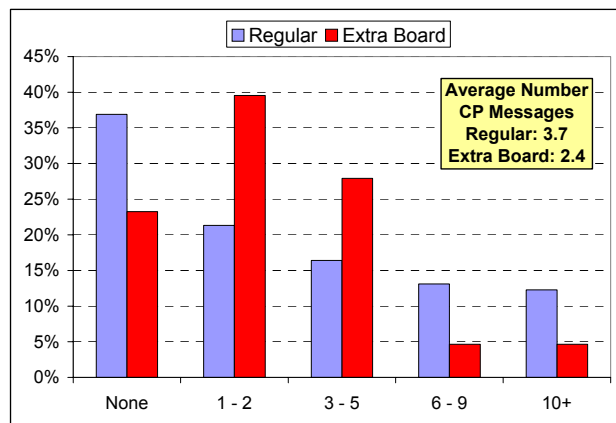


Figure 3-21. Number of CP "Hold Until" Messages Received in Past 30 Days

The primary interest in examining the perspective of the bus operators is to understand how they are responding to late train events in general, and to the CP program in particular. Figure 3-21 shows the reported number of CP “hold until” messages that operators said they received in the prior 30-day period on their MDT asking that they hold their bus at a TRAX station beyond their scheduled departure time. The average number of CP messages received per operator in that month, according to their responses, is 3.4 (mean value) or 2.0 (median).³ The mean number of CP messages received by regular operators is 3.7 and by the extra board operators is 2.4, though this difference is not statistically significant. However, 15 of the regular operators reported receiving 10 or more CP messages in this period, while only two extra board operators reported that many. As a result, the mean number of messages received by regular operators is skewed higher than for the extra board operators.

The operators were asked to indicate how many of the CP “hold until” messages they had received in the past 30 days actually turned out to not be needed in their judgment because the

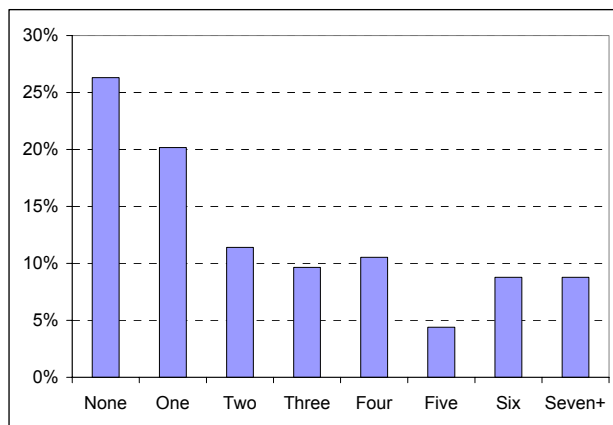


Figure 3-22. Number of Times CP “Hold Until” Message Received was not Needed

TRAX train was on time or close enough to on time that they could board all the transferring passengers. It is also possible that their bus was late arriving at the TRAX station and for that reason connections could be made from a late train without requiring any further hold on the part of the bus operator. The survey data indicate that 64% of the CP messages received were considered by these operators to be unnecessary. The distribution of responses (Figure 3-22) shows that only one quarter of the operators (26%) indicated that all the messages they received were needed (conversely, “none” were said to not be needed). On the other hand, almost one quarter of the operators (22%) reported that

they received five or more unnecessary CP messages to hold at a TRAX station. One interpretation of these results is that less than half of all the CP messages issued are considered useful by the UTA bus operators.

Over time many bus operators get to know their regular passengers and develop a working kind of relationship with them that tends to personalize the bus riding experience for both the rider and the operator. This is much more likely to happen with regular operators who drive the same route or routes than with the extra board operators who are likely to be assigned to any number of different routes on an irregular basis. The operators in the survey were asked whether they know most of their regular passengers by sight, and 92% of the regular operators said they do, while only 13% of the extra board operators said they do. It is expected that knowing one’s passengers on an individual basis, and understanding something of their travel habits, would

³ The mean is somewhat skewed because there are a few respondents who indicate a large number of CP “hold until” messages; therefore, the median may be a more meaningful measure of the average (half the respondents are below the median and half are above). When there are a few particularly large values, as in this instance, the median will be lower than the mean.

make it more likely that a bus operator would be willing to wait for passengers they believe are late for their bus. These operators were asked how often they wait past their scheduled departure time for passengers whom they believe are likely to be connecting from TRAX in situations when they do not receive a CP “hold until” message. In such situations, it is clearly a matter of operator discretion as to whether or not they will wait. Among all the operators, 47% said they “always” wait, 45% said they “sometimes” wait, and only 8% said they “never” wait. However, the regular operators are only slightly more likely to say they will always wait compared with the extra board operators (48% versus 43%) and only slightly less likely to say they never wait (8% versus 10%). Operators who say they know their passengers by sight are more likely to say they always wait compared with those who do not know their passengers by sight (50% versus 37%). However, these differences are not statistically significant. UTA encourages their operators to wait when they feel they need to, and most of these operators apparently do wait much of the time, regardless of whether or not they receive a CP message directing them to wait.

The operators were asked what the longest amount of time was they were willing to wait to allow late passengers to board in situations when they do not receive a CP “hold until” message. The results for both types of operators are shown in Figure 3-23. About one quarter of the operators

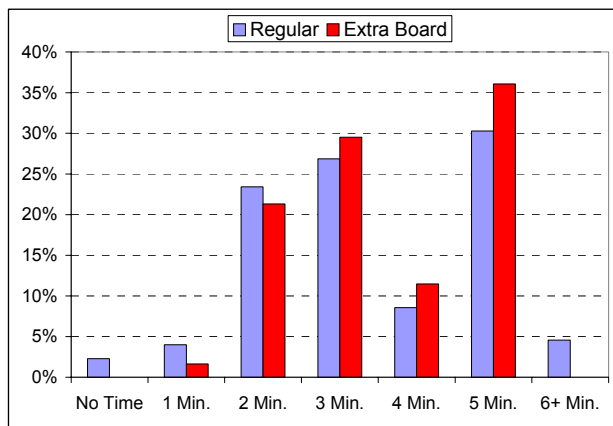


Figure 3-23. In the absence of a CP “hold until” message, how long are you willing to wait past your scheduled departure?

(28%) are willing to wait up to two minutes, but 32% say they will wait up to 5 minutes. Very few are willing to wait beyond that. Those who agree that UTA policy is supportive of bus operators making their own decisions about whether or not to wait are much more likely to say they will wait longer than those who disagree. The average amount of time all operators are willing to wait is 3.7 minutes (3.7 minutes for regular operators and 3.6 minutes for the extra board operators). Based on this survey, knowing the passengers personally or being a regular operator is not significantly associated with the likelihood of waiting or the length of time an operator is willing to wait, but

buying in to UTA’s policy supporting waiting is associated with a much greater likelihood that the operator will wait and wait a longer period of time.

Among the regular operators, those who agree that their bus routes are often so tightly scheduled that it is difficult for them to wait for late trains are about half as likely to say they always wait compared with those who disagree (38% versus 69%), and this is a statistically significant difference. As shown later in this section, the most common complaint among the bus operators is that schedules are too tight and need to be adjusted to provide more flexibility for the operators.

Operators were asked whether they let their passengers know the reason for a delayed departure from a TRAX station when it is decided to hold for a late train. The majority of the operators said they “sometimes” (32%) or “always” (62%) let their passengers know. Only 7% said they

“never” do that. The extra board operators are somewhat more likely to always let their passengers know (67% versus 60% for the regular operators), but this difference is not statistically significant. Only 3% of the extra board operators said they never do that, and only 8% of the regular operators said they never inform their passengers. When the UTA bus passengers who were on a bus waiting at a TRAX station to pick up passengers from a late train were asked whether their bus operators discuss the need to wait for train passengers or asks the bus passengers if it is OK with them to wait, the great majority of surveyed riders (70%) said the bus operator “never” discusses this with them (see Section 3.3.3). It is not clear why there should be such a discrepancy in these two perspectives, except perhaps to point out that UTA’s values and policy strongly support a positive, interactive form of customer relations, and operators are “expected” to be open with passengers on matters such as this that could impact their ability to stay on time.

Bus operators were asked to express their opinions on several statements dealing with policy, preference, or driving experience. Their responses are shown in Figure 3-24, separately for regular and extra board operators, along with the percentage of respondents expressing agreement or disagreement, and the average level of agreement on each item on a scale from 1 to 5, where 1 equals “strongly disagree” and 5 equals “strongly agree.”

The first statement in Figure 3-24 is “UTA policy is supportive of bus operators making their own decisions about whether to wait for late passengers.” Just over half of the regular operators agree with this statement (“agree” plus “strongly agree”); whereas, 75% of the extra board operators agree. This difference is statistically significant between these two operator groups. The issue is important because it reflects the likelihood that operators will feel comfortable

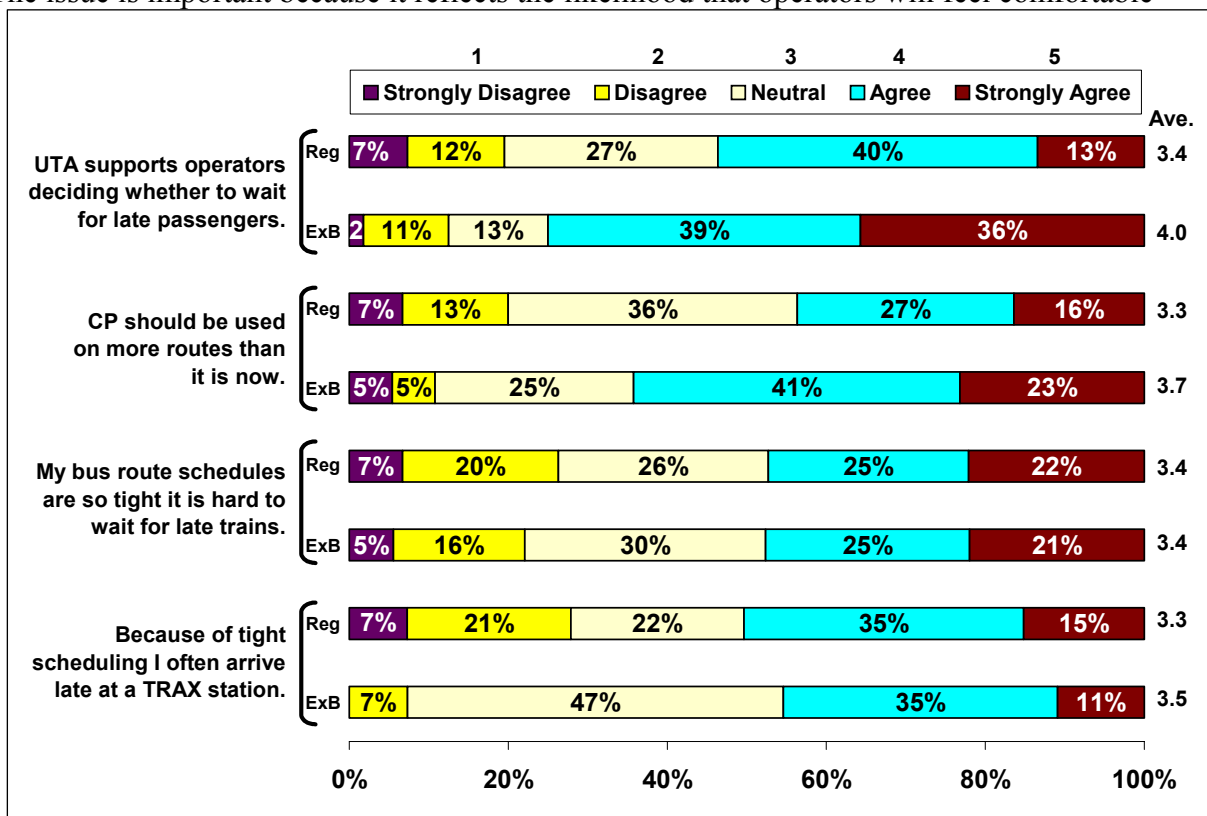


Figure 3-24. Bus Operator Opinions on Four Statements: Regular and Extra Board

operating independently to wait for late TRAX trains, even in the absence of a CP message. The 20% of regular operators who feel that UTA is not supportive of operators making such decisions are less likely to wait in the absence of a CP message, or if they do wait, they are only willing to wait shorter periods of time.

The second statement in Figure 3-24 is “The CP program should be used on more routes than it is now.” Again, the extra board operators express higher levels of agreement overall with this statement (64%) compared with the regular operators (44% agree), though this difference just fails to achieve statistical significance. This may be considered a general statement of the perceived value of the CP program by the operators, and over all operators not quite half (49%) believe that the program should be expanded.

The third statement in Figure 3-24 is “My bus routes are often so tightly scheduled that it is difficult to wait extra time at a TRAX station for late trains.” Here there is virtually no difference in opinion between the regular and the extra board operators. Overall, about 47% agree with this statement and 25% disagree. The results of the survey show that operators who strongly agree that they are faced with very tight schedules are less likely to wait for late trains, or wait less time, and this is true for both the regular and extra board operators.

The fourth statement in Figure 3-24 is “Because of tight scheduling I often arrive late at a TRAX station.” Just under half of all the operators agree with this statement (49%). However, there is higher average agreement (statistically significant) among the extra board operators compared with the regular operators, due to much less disagreement among the extra board operators (bottom bar—7% of the extra board operators disagree, compared with 28% of the regular operators). The implication is that many buses are arriving late at TRAX stations, and this fact alone may account for the ability to make many connections with late trains that might otherwise have been missed if the bus had arrived on time. On the other hand, many riders commented that late buses have caused them to miss their connections with other buses or with TRAX. Thus, a connection *benefit* for a rail-to-bus transfer rider can be associated with a *disbenefit* to a bus-to-rail rider. Again, the experience of tight schedules also implies that operators will be more reluctant to wait for late trains, or wait long enough to make a successful connection, than if they felt they had more slack in their schedule.

The operators were asked to comment in their own words on what aspects of the CP program they liked and what aspects they did not like. About two-thirds of the operators offered their thoughts (67% of the regular operators commented and 62% of the extra board operators commented). The following summarizes their thoughts in response to what they do and do not like about Connection Protection. Most of the operator comments are paraphrased (a few are quoted) and organized by general topic, with an indication of about how many operators had similar comments in each category (in parentheses).

All the comments were reviewed and a classification scheme developed that reflected the major themes underlying the set of comments. Then the individual comments were organized under the headings for each main idea, and the total number of comments of a similar nature was noted in parentheses next to the heading to give a sense of the frequency with which that type of comment was mentioned. Illustrative comments, either quoted or paraphrased, were listed under

each of the headings. Note that some operators provided several comments, while others didn't comment. Therefore, the numbers next to each comment heading reflect the number of times a comment was provided consistent with that topic, and does not add up to the number of operators.

What aspects of the CP program do you like?

- **Helpful to our riders. (27)**
 - CP helps passengers be sure to make their connections.
 - It allows riders to make connections that would involve a long wait if missed.
 - Passengers can count on making their connection.
 - Passengers don't have to wait in bad weather.
 - Not having to wait a long time for their bus is a safer situation.
 - We should wait whatever time is necessary if it's the last bus of the day.
- **Supports good customer relations. (21)**
 - Bus riders are appreciative when you wait.
 - CP demonstrates better customer service.
 - Helping passengers in this way shows a more human touch.
 - As an operator, I like being customer oriented in my job.
 - "I like the fact that we are at least trying to make passengers a little happier."
 - CP "shows that we care about our riders."
 - It shows we can be flexible to meet the needs of our passengers.
 - It helps increase ridership.
- **Keeps me well informed as an operator. (20)**
 - Lets me know if the train is late or if there are passengers needing my bus.
 - Indicates how long I need to wait at a TRAX station for the train.
 - Allows operators some latitude for decision making.
 - It is an example of good communications—a good heads-up advisory.
 - It gives operators helpful advance warning.
 - Operators can let passengers know why the bus is waiting.
 - "The fact that we are aware of when a train is late as many of us (extra board operators especially) don't know all the train schedules."
- **The concept is good. (10)**
 - "I feel very strongly that this is a step in the right direction."
 - It is good in theory, as long as it works properly.
 - It especially is helpful for extra board operators who are less familiar with the TRAX schedules.
 - I like it when it is accurate and the train is actually late.
 - "It's a good idea, but it is not always possible or practical." For example, when bus schedules are tight.
 - It would be good if it always functioned as intended, but sometimes it didn't seem to be working properly.

What aspects of the CP program do you like? (Continued)

- **The mechanics are good. (6)**
 - It frees up the radio dispatchers time because it is automatic.
 - It is working and in use now.
 - I like the text messages.

What aspects of the CP program do you not like?

- **Bus schedules are too tight for CP to work well. (24)**
 - The TRAX rail and bus schedules are not coordinated and adjusted properly.
 - Need to focus on fixing the schedules on the busy bus routes first.
 - “If the TRAX/bus connection is so important that we want passengers to be able to walk from the train to the bus without waiting, then bus schedules should be loosened up and coordinated better with TRAX.”
 - CP “blows reliability on the buses—it’s hard to make up time.”
 - Bus schedules are too tight on most routes, making it difficult to make up time lost to waiting for a train.
 - “Transfer time should be part of regular schedules.”
 - It is very stressful for operators when CP puts you behind schedule and you are trying hard to do your job right.
- **The CP program often doesn’t function as intended. (18)**
 - I don’t like having to wait when I don’t need to, as when you end up not having anyone to pick up.
 - “I think it should only be used if a train is actually late.”
 - You don’t know whether there is anyone who will be transferring if you wait.
 - I don’t like “being told to wait 5 minutes for a train that is not late.”
 - Sometimes we just sit there for nothing.
 - “It hasn’t functioned as needed.”
 - I get “false information from the MDT.”
 - “Last Friday the trains were actually late, but I got no message on my MDT. We were informed by RCC on an all call. I waited for my regular passengers.”
 - “Every time so far there has been no one needing my bus.”
 - Usually when you wait, no passengers show up.
 - On the many times I have been asked to wait, no train ever arrived after my scheduled departure time. In other words, I delayed for nothing!
 - I don’t like “getting useless messages.”
- **The CP program is one-sided. (16)**
 - “TRAX passengers are considered more important than bus passengers.”
 - “It’s all one sided. I think trains should wait for passengers off the buses if we’re there on time.”
 - “I wish that both the bus system and the TRAX system would have the same [CP] system.”

What aspects of the CP program do you not like? (continued)

- “Not waiting for someone running to the train because of a late bus is not right.”
- “What’s good for the goose ought to be good for the gander – if the train can detain the bus and prevent us from getting our passengers to their connections on time, we should be able to disrupt the train as well.”
- It needs to work the other way—bus to train.
- **The CP program is not equitable. (15)**
 - It is inequitable to hold a bus for one transferring passenger and cause many others already on the bus to miss their subsequent transfers.
 - Delays that cause others on the bus to miss their connections is very stressful on the bus driver.
- **Just don’t like the CP program. (5)**
 - I don’t like it if it makes operators late—we miss our break at EOL.
 - It doesn’t tell you what you are waiting for.
 - “Let bus operators make their own decisions.”
- **Various procedural issues. (13)**
 - It is not clear how CP works when a bus is already late at a TRAX station.
 - CP “should not affect buses that run every 20 to 30 minutes apart.”
 - Late trains are rare, and the train operator can usually make up lost time.
 - The CP system presents a safety distraction, with the extra noise and such.
 - “People begin to expect you to always wait.”
 - “Passengers don’t understand why we are holding for trains. They need to be better informed about what we are doing.”
 - “The time given should be when the train should be seen, not 2 minutes later when the bus leaves.”
 - CP often requires an operator to wait too long—5 minutes or more.
 - “Holding past 2 minutes.”
 - I don’t like “that the text message says I have to wait a certain time and not just to wait for a certain train.”

At the end of the survey, operators were asked to offer any additional comments, suggestions, or other observations. Comments, in addition to those given in response to the questions above about likes and dislikes, were offered by about a quarter of the respondents (29% of the regular operators and 21% of the extra board operators). These cover a range of ideas and perspectives, and are mostly presented verbatim as written on the survey forms, with only minor editing.

These comments were reviewed and examples selected that were illustrative of the range of comments offered. They are generally grouped by the substance of the comment to make it easier to see what the operators had to say about various aspects of the CP program. Each comment is identified as provided by either a regular or extra board operator. The comments are provided in Appendix H.

3.5 UTA Bus Operator Interviews

Members of the evaluation team visited the UTA bus dispatch center of the Salt Lake Business Unit in mid-November, 2003, and at that time informally interviewed nine available bus operators, both regular and extra board. Initially, the intent as described in the detailed test plans had been to organize groups of operators in order to hold structured discussions; however, that proved to not be logistically possible given the time constraints of the site visit. Instead, the interview guide shown in Appendix I was used to guide individual discussions with operators that took place very informally in their dispatch center staging and meeting area. Interaction with a few of the operators is useful because it allows the evaluators to connect in a more personal way with individual operators and hear first hand how they talk about the CP program and their experiences with it. It is important to recognize that the opinions expressed by these few operators do not represent the opinions of the operators as a group.

3.5.1 Operator Interview Results

The operator interviews were conducted in November 2003 on two separate days before and during the afternoon and morning shift changes. The bus operators were interviewed individually and in small groups in the waiting lounge and break room at the UTA Meadowbrook bus facility.

Overall, the observations by these few operators reflected similar points of view that were expressed in the operator survey; hence, nothing new or surprising resulted from these interviews. However, the comments offered some additional, personalized perspectives on various aspects of the CP program.

Several bus operators who received CP messages expressed skepticism about the accuracy of the CP messages they had received. They claimed that, in many instances, they actually saw the train arrive at and depart from the TRAX station before they received the “hold until” message. Most bus operators said they typically radioed the Radio Control Coordinator (RCC) to confirm the train status before deciding how to respond to the CP message.

Some operators apparently did not realize that CP messages were generated automatically and were confusing them with other messages sent by the RCC. This reportedly happened when CP was turned on after it was accidentally disabled during October. After the system was turned on again in early November, some bus operators called in to the RCC when they received a CP message after the train passed by. The RCC explained that the message was sent automatically by the CP system. One of the bus operators indicated that the inquiry to the RCC is time consuming and unnecessary and he just departed without calling in when the same situation happened the next day and a few days later.

As noted before, UTA bus operations employ about 110 extra board and 790 regular operators. The extra board operators (or vacation fill-ins) receive their assignments at 3:00 p.m. the day before and the assignment changes from day to day.

When asked about waiting for customers at TRAX stations, the extra board bus operators indicated they would normally wait, but they often choose to adhere to the schedule because of their unfamiliarity with the route. All the regular operators interviewed indicated that they know most of their regular customers and would wait for them at TRAX stations. Some regular operators indicated that they do not always know or remember how train and bus schedules are sequenced because the train schedule information is not readily available. The supervisors indicated that train schedules are provided in a resource book along with a lot of other information that is available to all the operators but is not required to be brought along on the bus.

The operators generally supported the concept of CP but suggested that the bus schedule could be adjusted to be more reasonable and to make it easier to conform to the suggested CP wait times. Several bus operators (regular and extra board) provided information on routes that are scheduled too tightly and indicated that it is difficult to further delay the bus on those routes (e.g., routes 30, 31, 37, 39, 45, and 137). Other scheduling issues were mentioned, including concern with the wait times at TRAX stations related to uncoordinated bus and train schedules (e.g., route 25, train and bus are scheduled to leave at the same time).

One operator suggested the need to protect the bus-to-rail transfers, in addition to the rail-to-bus transfers currently covered by the CP program. This was a comment offered frequently in the surveys. This operator indicated transferring passengers become increasingly anxious when the bus is approaching the TRAX station, particularly if scheduled connections are close or if the bus is late. Reportedly, when the bus is running behind the schedule, some bus operators may slow down when approaching the TRAX station to avoid seeing the train leaving. In addition, some of the operators indicated that they observe that people run for the train and walk from the train to the bus.

In summary, these operators who were interviewed in person tended to elaborate on bus operator experiences and opinions that were identified in the operator survey, thereby offering a small bit of additional insight into their points of view on the CP program. It would have been preferable to have been able to conduct more such interviews, and to have a designated interview session in which a more structured protocol could have been followed.

3.6 UTA Radio Control Coordinators and Route Supervisor Interviews

During the site visit in November 2003, members of the evaluation team also met with many of the UTA Radio Control Coordinators (RCCs). There are seven RCCs who work shifts in a control room at the Meadowbrook office of UTA. There are three console stations at which the RCCs can monitor and communicate with their bus fleet. While any CP messages that may be issued are automatically generated and sent to the appropriate buses by the CP program, these messages appear on the RCCs' monitors. Bus operators often call in to discuss the CP message with the RCC if they have any questions based on their on-the-ground assessment of the need to wait for a TRAX train. The informally conducted evaluation interviews with the RCCs and the route supervisors were guided by the set of questions presented in Appendix J.

3.6.1 Interview Results

The RCCs said that many bus operators who receive a CP message assume that the RCC is issuing that message to them, rather than realizing that CP messages are automated. The perspective of the RCCs is that the rapid pace at which new technologies are being introduced into UTA operations is making it a challenge to provide adequate training to the estimated 900 operators. Thus, part of the challenge of the CP program from their perspective is managing operators who do not yet fully understand the system and how it works.

One of the issues is that some operators (though few apparently) fail, or forget, to log onto their MDT system at the start of their trip. Failure to log-in subjects the operator to disciplinary action. One consequence of not logging in is that CP messages will not be received by that operator. Situations like this create frustrations for the RCCs in the few instances in which they occur (estimated about 1% of operators do not log-in regularly). Furthermore, if an operator is sent a CP message while his/her system is logged off, the RCC usually is not monitoring that kind of situation, and the result will be a “missed” hold request at a TRAX station. While the rider and operator surveys suggest that operators will often hold anyway in the absence of a CP message, log-in failures are almost certainly going to result in some missed connections.

The operator survey showed that some operators are willing to wait for connecting passengers longer than others, though 5 minutes seems to be the upper limit they can tolerate, and the average reported wait time is 3.7 minutes. The RCCs say they recommend waiting no more than 3 minutes in consideration of the on-board passengers who stand to miss their down-line transfers or appointments when a bus is held for CP. Thus, there is some likelihood that the operators’ judgment, the radio control coordinators recommendations, and the automated CP instructions may sometimes be at odds with one another in terms of the recommended wait time for particular hold situations.

One of the RCCs interviewed noted that from time to time they receive messages on their computer screens that a particular CP message is no longer valid, but according to them this information is not sent out to the bus operator. There are pros and cons in considering whether to send a message to the bus operators every time that a change in train status (e.g., a train originally projected to be late has made up time) impacts the validity of an earlier CP message. While the operators would be receiving more current, accurate information about the status of train arrival and the need for a CP hold, doing so would potentially generate a significant increase in the number of messages being issued to the operators, creating more annoyance than assistance.

Several operations supervisors were interviewed, offering yet another perspective on how the CP program works and the benefits it provides. UTA is motivated to provide successful connections in part to assure satisfied customers and avoid customer complaints. They have learned from experience that if a transit customer misses their bus three times, there is a good probability that the customer will leave transit, so CP is perceived as benefiting ridership levels. The supervisors, radio control coordinators, and vehicle and work dispatchers all work in a coordinated way with the bus operators to provide a smoothly running transit system for the benefit of their customers. As a general matter, UTA prefers to not burden their operators with having to decide whether or not to wait for a TRAX train. Either the automated CP system

provides the “hold” decision or the operator can call in to the RCC for access to the current TRAX schedule and any other guidance in helping decide whether it is appropriate to wait for the train under the circumstances. According to the supervisors, if the bus operators can see the train coming, UTA’s policy is that they will wait until all transferring passengers have boarded the bus before leaving the station. The supervisors acknowledge that a lot of time has been trimmed out of the bus schedules, making the current schedule quite tight. As has been discussed in Section 3.4.2, operators are acutely aware of the difficulties these tight schedules present in trying to satisfy their and UTA’s desire to accommodate connecting passengers from late trains. There is obviously going to be tension between the operators’ desire to keep on schedule and their desire to satisfy all their customers.

Part of the job of a route supervisor is to check bus schedule reliability. They understand that decisions to wait for passengers past a scheduled departure time are going to put operators behind, and where the schedules are tight, it is understood that it may be impossible to make up that time. UTA recognizes that there are perfectly legitimate reasons for being late, and they try to impress on the operators that lateness per sé is not a punishable offense. Another part of the supervisor’s job is to convey to their operators a sense of empathy with their riding customers—an important component of the UTA culture.

One of the reasons for instituting CP is for the protection it offers operators from being criticized for not adhering to their schedule. Nevertheless, the operators report that it can be quite stressful to fall behind in their schedule, particularly when some passengers are being inconvenienced by that. One thing that the supervisors point out is that a bus that is running behind schedule can be backed up by a bus that is behind them. Some of the operators noted that CP does not seem to take into account that it may be more efficient for the system, the passengers, and the operators for a later bus scheduled to arrive in a reasonable time to make the connection instead of asking the first bus to hold. Whether this is a better option depends on the details of the schedule and where the buses are in terms of schedule adherence in a particular situation.

The supervisors point out that regular bus operators almost always wait for their late passengers because they know many of them and have built up a rapport over time on their bus route. The extra board operators are presumed to be mostly focused on schedule adherence. With the CP system in place, regular operators are instructed to hold at a TRAX station in the event of a late train, but in the opinion of the supervisors, most of them would have waited even in the absence of CP. Based on the operator surveys, this belief is largely supported, as 92% of the operators said they “sometimes” or “always” wait for a late train in the absence of a CP “hold until” message. However, the survey of riders transferring from train to bus showed that 29% reported that their bus “never” waits if their train is late. Obviously, there is a difference in perception here, but on balance most operators seem to be willing to wait most of the time. The main factors for the operators appear to be their sense of whether their schedule has enough slack to facilitate waiting plus the number of on-board passengers who would be inconvenienced by waiting.

The supervisors said that most of the experienced operators assist with the training of new operators. UTA employs Line Platform Instructors who provide route training, and Operations Instructors who are involved in the hiring process. UTA also has a mentor program as another

way to build a sense of team spirit among the operators. From the supervisors' perspective it takes time to create a culture of customer service and an understanding of the real-world conditions and challenges faced day to day by bus operators. CP and the willingness to wait for late passengers, with or without CP operating, is closely intertwined with driving skill and experience, attitude toward the job, schedule structure, and human relations. UTA recognizes that this complex interplay of factors has a central bearing on the success or failure of CP in any given connection situation.

3.7 UTA Complaint Logs

A total of 620 complaints were received by the UTA customer service department between August 2002 and November 2003 regarding service problems that are potentially associated with the CP program. Those complaints were extracted from a much larger database based on search of key words that would link to possible complaints related to CP. The customer complaints have been systematically recorded in a computer database by UTA customer service representatives whose role is to communicate with the customers and provide resolution to individual complaints by following up with the radio control coordinators and/or the bus operations supervisors.

The majority of complaints were made via telephone, and some in e-mails and letters. The log contains the nature, time, location of the reported complaints, and in most cases, the resolution to the specific complaint. Unfortunately, the complaints captured in the database are only since August 2002, after the implementation of CP (January 2002), and thus a comparison of the number and content of train-to-bus transfer-related complaints before and after the CP cannot be conducted, as planned in the detailed test plans. The very small number (22) of train-to-bus transfer-related complaints in the existing database also prevented any meaningful quantitative analysis by time, location, CP status, and other service attributes. However, the review of complaint logs has been beneficial in understanding the complicated nature and wide array of operational issues involved in the transit operations that could directly or indirectly affect the CP performance.

3.7.1 Comment Log Findings

Review of the 620 complaints identified 22 train-to-bus transfer-related, 2 bus-to-train transfer-related, and 225 complaints regarding buses departing earlier than the scheduled time at locations other than the TRAX stations. The rest of the complaints, ranging from vehicle/infrastructure problems to the operator's demeanor, were determined to not be applicable to the CP system.

The very small number of transfer-related complaints over the 16 months showed that train-to-bus connections represent only one of the many challenges in providing reliable transit services, and that most of the connection experiences most likely have been positive. The relationship between the connection problems experienced and those reported is unknown. Also, these complaints represent only the comments of a relatively small number of UTA's customers, and do not represent the opinions or experiences of UTA's full customer base. The 22 cases are generally categorized in four groups by the nature of the complaints.

- Bus departed as the train pulled in (the transferring passenger saw the bus leaving) (7 cases) – it suggests that bus operators may have been aware of the train when leaving the station early.
- Bus departed earlier than the scheduled departure time (train not in sight) (6 cases) – this may also be a schedule adherence problem.
- Complaints about the uncoordinated bus and train schedules, including cases where supervisor asked the bus operator to systematically wait after the departure time (7 cases) – indicating passengers expecting more coordinated schedule between train and bus operations. Some resolutions to comments include instructing operators to wait past their scheduled departure time.
- CP not working (2 cases). Comments suggested that connection protection was not working correctly.

An interesting observation from the review of compliant logs is that early departure of buses is equally critical if not less tolerable to bus riders in terms of service reliability. For example, many complaints were about the bus departing just 1-2 minutes before the schedule. There were also specific complaints about the bus running ahead of the schedule to the end of line (where there is a longer scheduled slack) and departing late from the end of line. A plausible explanation is that the bus operator might have tried to maximize his/her break at the end of line by “squeezing” the run time. However, it was also evident that some early departure cases were attributable to the inexperience of the bus operator, or discrepancy between customer’s watch and the UTA time. Nevertheless, it provides a possible incentive for the bus operators not to delay for trains when the TRAX station is not the end of the line.

Bus departed as the train pulled in (7)

“Customer claims that he was off the TRAX and trying to get to the bus when the driver pulled out.”

“Customer upset that our operators are making a rolling stop when they exit the Historic Sandy TRAX Station.”

“This passenger got off the train at the Ft. Union TRAX station. He stated that it is very common for the bus drivers on the routes that serve this station to pull out of the bus zone when trains are pulling into the station. He would like someone from UTA to observe what is happening there. He stated that it happens all throughout the service day.”

“The bus was leaving before the TRAX customers got off the train. The customer sees the bus still in the stall as the train pulls in.”

“The customer claimed that the bus was not waiting for the TRAX train that is scheduled to arrive one minute before his bus is scheduled to leave the Meadowbrook TRAX Station.”

“This bus driver was not waiting for passengers coming off the TRAX train at 15:25.”

Bus departed as the train pulled in (7) (Continued)

“The customer claimed this driver pulled out of the TRAX stall early. He saw the bus leaving.”

“I arrived at the Meadowbrook TRAX station off the SB train at 9:21 and saw the 9:25 WB 39 pulling out of the station. It wasn't due to leave until 9:25.”

Bus departed early before train arrived (6)

“The customer claimed the driver left early from the TRAX station.”

“The customer claimed the bus left TRAX early.”

“The bus was not waiting for the NB TRAX. A note was placed with the block asking the drivers to wait and the Thursday morning driver was called by RCC and asked to wait.”

“The driver left the Central Point TRAX station 7 minutes early. See radio control notes.”

“The customer claimed the driver left City Center TRAX at 15:49, 5 minutes early on outbound 23. The customer used the time at the TRAX station at City Center and it was the same as the MDT on the bus. The customer rides the 23 every day at various times in the afternoon.”

“The customer is calling to say this (bus) block is not waiting for the 18:48 southbound TRAX train on Sundays. The supervisor will tell the driver to wait for this train. A note has also been placed on this block so other drivers will wait.”

Missed connections attributable to uncoordinated schedules (7)

“The customer is requesting a schedule change for the route 222 or the TRAX vehicle. The bus leaves at 07:52 and the TRAX arrives at 07:53. The regular driver is off and will be back Monday.”

“The customer claimed the buses were leaving the TRAX early. There is no regular driver at this time. Placed a note in the block sheet directing the drivers not to leave the TRAX station before 07:50 a.m. and to look for the TRAX vehicle. The customer called 1/21/2003 and said the bus left again without waiting for TRAX. Supervisor will put a new note on the block telling the drivers to leave at 07:52 a.m. 2 minutes after the regular schedule. Copy of request given to planning.”

“The customer is asking the bus to wait 2 to 4 minutes for the TRAX vehicle to arrive. The bus driver is scheduled to leave at 08:16 the TRAX is scheduled to arrive at 08:18. The driver was sent a text asking him to wait for the TRAX if he is running a little late and sees the TRAX pulling into the station.”

“The customer would like to see the 40 East and Westbound interline better with the TRAX. Customer said that the bus leaves two minutes before the train arrives. I have checked the headways and this happens only a couple of times between this route and the train.”

Missed connections attributable to uncoordinated schedules (7)

(Continued)

“The 17:47 route 30 west bound is leaving before the 17:49 southbound TRAX arrives. The route supervisor looking into this issue, planning has been notified.”

“The route 22 block 1119 is leaving on time just before the train arrives. This run is not on connection protection and may not be running late enough to activate it.”

“The customer is requesting we change the schedule of the route 52 outbound block 4054 from 17:04 to 17:09 so the TRAX can meet it if it runs late. The driver of the 52 was contacted and will look for the TRAX for a couple extra minutes. Apology made.”

Connection Protection not working (2)

“The southbound TRAX scheduled to arrive at 18:05 was 4 minutes late so the driver left. The connection protection was not working. I contacted the driver he will wait for this train.”

“The Southbound TRAX scheduled to arrive at Historic Sandy at 18:52 was 4 minutes late so the bus left. The connection protection was not working. The driver was contacted and will wait for this train.”

3.8 Summary of Findings

Overall, riders transferring from train to the bus and riders on the bus at the TRAX stations report a high level of satisfaction with their connection experience. For the transferring passengers, 86% said they were “very” or “somewhat” satisfied. On the other hand, transferring riders who report missing one or more connections in the past month are three times more likely to say they are dissatisfied (22%) compared with those who have not missed any connections (6%), a statistically significant difference. Riders who were surveyed on trips that were CP protected were only slightly more likely to report being “somewhat” or “very” satisfied (87%) compared with those who were not on CP protected trips (85%), a difference that is not statistically significant. The likelihood that riders who are not connecting to a CP protected bus trip will report a high number of missed connections at their TRAX station (4 or more in past 30 days) is twice as great as riders on CP protected trips. Overall, 41% of transferring riders reported missing one or more connections on bus trips under CP versus 47% for trips without CP. While these effects suggest a small but positive effect of CP as measured by rider reports of trip satisfaction and connection success, the differences are not statistically significant.

The lack of a significant difference is evidently partly related to the fact that bus operators say they are very likely to wait for connecting passengers *regardless of whether or not they receive a CP “hold until” message*. Only 8% of operators said they will “never” wait without a CP message and 47% said they “always” wait. Even though there is a difference in perspective between the operators and transferring passengers, it seems likely that most bus operators will wait most of the time for between two and five minutes for passengers connecting from late trains. This reported lack of variation in waiting behavior on the part of bus operators makes it

difficult to detect any significant differences between the probability of waiting for CP and non-CP protected trips from the perspective of the user.

An important factor that influences the willingness of operators to wait for late trains is the tightness of their bus schedule. Regular operators who agree that their routes are so tightly scheduled that it is difficult for them to wait are about half as likely to say they always wait compared with operators who do not report tightly scheduled routes (38% versus 69%). That is, seven out of ten regular operators said they always wait if their schedules are not too tight; otherwise, only four in ten will wait if they perceive their schedules to be tight. Open-ended comments and suggestions from the operators included many related to their perception of a need for better scheduling.

Over all the bus operators, about half (49%) agreed with the idea that CP should be used on more routes than it is now. Fewer than one in five operators disagreed with that idea, and the rest were neutral. If endorsement that CP should be extended to additional routes can be interpreted as operator support for the CP program, then these results are mixed, with the operators evenly split on the matter.

About half of all the operators (49%) agreed that tight scheduling often causes them to arrive late at the TRAX stations. Over half of the riders on the bus (53%) reported that they have been on the bus when it arrived late at the TRAX station one or more times in the past month. To the extent that many buses are arriving late at the station, this is expected to account for many of the successful connections that otherwise would have been at risk of being missed if the bus had arrived and departed on schedule, assuming no CP message was issued. In such situations when a CP message is issued, it is likely to be perceived by the bus operator as unnecessary when the bus is late enough to pick up late arriving TRAX passengers anyway. In fact, the bus operators reported that 64% of all the CP messages they received were unnecessary anyway, either because the train had made up time and arrived close enough to schedule, or presumably because the bus was late enough in arriving that the connection was successful without needing any additional wait time, or perhaps because no passengers actually transferred from the train when it did arrive.

While CP offers clear benefits to TRAX passengers trying to make connections to buses, passengers arriving at the TRAX station or boarding from the station's park-and-ride are depending on the bus leaving on time and adhering to its schedule along the way. When CP causes the bus to wait, that jeopardizes bus-to-TRAX connections down-line for some of the bus riders, including those who connect from TRAX and the on-board passengers. Waiting past the scheduled departure at the TRAX station is associated with missing other transfer connections and with being late arriving at their final destination, and riders who have these experiences are less likely to say they are satisfied compared with those who do not. There is some evidence that suggests that CP may make it more likely that a bus rider will experience one or more late arrivals at their final destination, so this needs to be factored in to an overall assessment of the impact or benefit of CP. In fact, the bus operators report their perception of the inequity of a CP message that requires them to wait for an uncertain number of connecting passengers knowing that the passengers already on their bus will potentially be negatively affected by the wait time.

In summary, the rider and operator surveys and interviews suggest that CP is a useful tool that can help operators better meet the needs of their customers, but operator judgment is a key ingredient in determining when and how long to wait with or without a CP message, and in balancing the effects of bus schedule constraints, current on-time status of their bus, observed TRAX train status, and the needs of their on-board riders versus the needs of their likely TRAX transfer riders. CP is perceived to make a difference in only some of the CP protected trips, for a number of reasons: 1) TRAX can often make up lost time after a CP message is issued, 2) most operators are conditioned to waiting where possible such that more than half the time they consider CP messages that have been issued to have been unnecessary, and they wait most of the time even when no CP message was issued, and 3) due to tight scheduling, buses often arrive behind schedule at TRAX stations making it easy to pick up late arriving TRAX passengers without additional wait time.

4.0 Conclusions and Recommendations

This section presents conclusions based on the findings from the evaluation of system performance and feedback from users, and recommendations for making further improvements to the Connection Protection system. The objectives and hypotheses originally proposed in the Evaluation Plan are revisited in light of the data and findings.

4.1 *Evaluation Hypotheses and Findings*

The evaluation hypotheses associated with system performance and user perceptions of CP were identified and discussed in the Evaluation Plan [Ref. 1]. Because these hypotheses were framed very early in the evaluation process, some additional hypotheses were developed later in the evaluation that were based on a more detailed understanding of the evaluation potential, to take advantage of refinements in the test plans, and to support more focused evaluation components. Table 4-1 presents each of these hypotheses and summarizes the findings relevant to each of them.

Accurately measuring bus departure times under reasonable cost and logistical constraints, without impacting operations, was a challenging task because each possible approach had cost or operational limitations. Although a number of different approaches were utilized to maximize the number of bus trips where departure times were measured and there was a late train event, the data collection efforts resulted in roughly one-half of the anticipated number of observations suitable for data collection. Therefore, some of the hypotheses initially proposed could not be investigated because of the limited sample sizes or lack of data. Additionally, some system performance information, primarily that associated with assessing unintentional impacts, was not available. However, sufficient data and information were collected so that an evaluation of many of the hypotheses of interest could be performed, including an assessment of the effectiveness of CP in increasing the number of successful train-to-bus connections.

As indicated in Table 4-1, some of the user perception hypotheses could not be addressed because of the lack of adequate or appropriate data. Because the quantitative assessment relied on directly measured system performance and the qualitative assessment relied on the stated preferences and opinions of users of the system (both riders and operators), differences in findings can be expected on aspects of the CP system. Even within the qualitative assessment, the perceptions of riders and operators sometimes differed substantially, for example in their estimate of the frequency of the bus operator conferring with riders about the reasons for waiting at a TRAX station.

Table 4-1. Hypotheses Addressed by the Evaluation

Objectives	Hypotheses	Findings*
Evaluation of System Performance		
Assess the effectiveness of the CP System in reducing the number of missed connections	CP prevents missed connections that would otherwise be missed (i.e., CP increases the overall number of successful connections). [SUPPORTED]	<ul style="list-style-type: none"> • Train riders meeting a bus trip when CP was active and a “hold until” message was issued are 3 to 4 times more likely to have a successful connection than were train riders meeting the same bus trips when CP was inactive, and 2 to 3 more likely to have had a successful connection than train riders meeting a bus when CP was active but a “hold until” message was not issued (statistically significant). • Bus operators tended to hold the buses longer past their normal scheduled departure time when a CP “hold until” message was issued than when a “hold until” message was not issued.
	CP prevents missed connections in extreme situations (e.g., last bus of the day). [PARTIALLY SUPPORTED]	<ul style="list-style-type: none"> • There is only a limited amount of information on last bus trips of the day where there was a late train and a recorded bus departure measurement. Information was obtained for only 1 of 3 bus routes for 3 of 15 late train events. • Nevertheless, the overall results do indicate that CP increases successful train-to-bus connections (see first hypothesis). This is some evidence to suggest that this would likely be true for the last bus of the day.
	There are no bus trips that are not being currently protected that should be (i.e., cases where CP could have a significant impact). [NOT TESTABLE]	<ul style="list-style-type: none"> • There was insufficient information that could be used to address this hypothesis. Information for 65 different bus trips where CP was inactive was obtained for 161 instances where these bus trips were waiting on a late train. However, only 9 of these bus trips had more than 3 observations.
Assess the operational aspects of the CP system, not to include software or hardware	Messages are being issued when they are supposed to be. [NOT SUPPORTED]	<ul style="list-style-type: none"> • There was no statistically significant association between issuance of a CP message and the actual lateness of the train. This suggests that some messages are not being issued when they are supposed to be, or that some messages are being issued when they are not needed. • Qualitative interviews with operators suggested that over half (64%) of the CP messages issued were perceived as not needed, either because the train was not late, or perhaps because no passengers transferred when the train did arrive.
	When a message is issued, operators receive the message. [NOT TESTABLE]	<ul style="list-style-type: none"> • Information on “Missed” messages is available. However, it is not clear why these messages were missed. Possible reasons include: the operator is not logged into the radio system; the system is incorrectly specified, etc. There is no information that confirms the receipt of a “hold until” message.
	Operators do not ignore the messages. [PARTIALLY SUPPORTED]	<ul style="list-style-type: none"> • Overall, only 51.3% of the bus operators who received a “hold until” message departed at or after the CP suggested departure time. Bus operators who left after the CP suggested hold time left 1-2 minutes on average after the suggested CP departure time. Bus operators who left before the CP suggested departure time (48.7%) left one minute on average before the suggested hold time.

Table 4-1. Hypotheses Addressed by the Evaluation (continued)

Objectives	Hypotheses	Findings*
	CP messages are targeted for the correct trips. [NOT TESTABLE]	<ul style="list-style-type: none"> • See last hypothesis under Assess the Effectiveness of the CP System in Reducing the Number of Missed Connections.
Determine if there are unanticipated impacts as a result of implementing the CP system	CP does not increase safety risks (i.e., operators do not travel at faster speeds to “make up” time lost from a CP hold). [NOT TESTABLE]	<ul style="list-style-type: none"> • This could not be tested. Bus arrival and departure times were essentially available for only bus trips starting or ending at the TRAX station.
	CP does not have lasting impacts on bus routes (e.g., buses are back on schedule within a few stops of the CP hold). [NOT SUPPORTED BUT NOT FULLY TESTABLE]	<ul style="list-style-type: none"> • Same as above. Data from the bus operator surveys suggest that this depends on how tight the overall schedule is for the given bus route. • Over half of the riders report they have arrived late at their final destination one or more times in the past month, but this is only somewhat more likely on CP protected trips than on unprotected trips (67% versus 58% -- not statistically significant). A little over one-third of on-board passengers (38%) report they have missed transfers down the line due to holding for late trains. • Half of all the operators in the survey reported they often arrive late at a TRAX station due to tight scheduling. The most common concern expressed by operators was that tight schedules hindered the successful operation of the CP program.
	Buses have greater occupancy when CP messages are issued than without (more cost effective). [NOT TESTABLE]	<ul style="list-style-type: none"> • Information on bus occupancy was not available. It is also likely that UTA implemented CP on the more heavily traveled bus routes. To adequately test this hypothesis, before and after CP data and CP issuance rates would be needed for a sample of bus routes.
Evaluation of User Perceptions		
Increase satisfaction of transit users	TRAX rail riders perceive that bus connections are reliable, and more reliable than they used to be. [PARTIALLY SUPPORTED]	<ul style="list-style-type: none"> • 57% of the rail riders reported no missed connections in the past month. Riders not on CP protected trips were twice as likely as riders on CP trips to report missing four or more connections (not statistically significant). No historical data are available to address changes in connection reliability over time.
	Bus riders are satisfied by (not bothered by) connection delays at TRAX stations. <i>New hypothesis:</i> Bus riders transferring from TRAX are satisfied with their ability to successfully make their connection from rail to bus. [SUPPORTED]	<ul style="list-style-type: none"> • 86% of transferring riders reported they are “very” or “somewhat” satisfied with their connection experience, and 82% of riders on the bus were satisfied with how the operator handled connections. There is no significant difference in satisfaction by whether or not the bus trip was CP protected. While riders can accommodate delays, those who missed rail to bus connections were three times as likely to be dissatisfied compared with those not missing any connections (statistically significant)
	<i>New hypothesis:</i> Rail-to-bus riders on CP protected routes report they are more likely to make their connections than those on non-protected routes. [PARTIALLY SUPPORTED]	<ul style="list-style-type: none"> • 59% of riders transferring to a CP protected bus said they never missed their connection in the past month, while 53% on unprotected buses said the same (not statistically significant). Frequently missing a connection (4+ times in past month) is almost twice as likely on unprotected trips (13% versus 7% if protected – not statistically significant)

Table 4-1. Hypotheses Addressed by the Evaluation (continued)

Objectives	Hypotheses	Findings*
	<p><i>New hypothesis:</i> On-board passengers with down-line transfers are at greater risk of missing those connections on CP protected trips. [PARTIALLY SUPPORTED]</p>	<ul style="list-style-type: none"> • 38% of on-board passengers said they have missed transfers due to holding for late trains (33% on protected trips and 39% on unprotected trips – not statistically significant). Bus riders are only somewhat more likely to say they have arrived late one or more times at their final destination when on CP protected than on unprotected trips (67% versus 58% -- not statistically significant).
	<p>Bus/rail rider complaints are reduced, or less related to connection issues. [NOT TESTABLE]</p>	<ul style="list-style-type: none"> • This hypothesis could not be tested because the comment/complaint logs were not available prior to the implementation of CP and the comment database does not contain information on whether the trip in question was CP protected or not. Also, in the aggregate there are very few complaints registered regarding the CP program or connection experiences per se.
	<p>Transit users who have rail/bus transfers use transit for their travel more often. [NOT TESTABLE]</p>	<ul style="list-style-type: none"> • The original intent of this hypothesis was to test whether riders who have successful transfers under CP ride transit more than those who do not. In fact, a higher percent of riders on trips not under CP are frequent riders (10+ trips a week) compared with those on non-CP trips (42% versus 37%, not statistically significant). A valid test of this hypothesis would require a longitudinal data set, but that is not available.
<p>Increase satisfaction of bus operators, dispatchers, and transit system managers</p>	<p>Bus operators are more satisfied with connection performance. [PARTIALLY SUPPORTED BUT NOT FULLY TESTABLE]</p>	<ul style="list-style-type: none"> • Bus operator satisfaction with CP has been measured indirectly. 49% of operators agreed that CP should be used more. Comments were about equally split on operator likes and dislikes about CP. No data are available on operator satisfaction with connection performance prior to the CP program.
	<p>Bus operators report fewer passenger complaints with connection performance. [NOT TESTABLE]</p>	<ul style="list-style-type: none"> • This cannot be addressed, because operator responses to the survey were anonymous and individual operators were not identified with CP or non-CP bus routes. Many operators drive both types of routes.
	<p>System operators/dispatchers/managers are satisfied with rail/bus system performance. [SUPPORTED]</p>	<ul style="list-style-type: none"> • Interviews with supervisors, radio control coordinators, and UTA managers indicate a strong positive value attached to CP as one way to serve their customers better. Their general perception is that the system works well, at least when it is operating as designed. UTA is always open to ways to improve as well.
	<p>Interviewees [operators, dispatchers, managers] perceive a beneficial effect of CP on connection success and bus schedule performance/adherence. [PARTIALLY SUPPORTED]</p>	<ul style="list-style-type: none"> • Although most operators say they will wait for late trains regardless of whether or not they receive a CP hold message, operators and their supervisors acknowledge that CP messages appear to increase connection success for their passengers, particularly on runs conducted by extra board operators who are less familiar with those runs and generally more inclined to focus on bus schedule adherence. These interviewees also acknowledge that waiting for late trains, whether under a CP hold or not, can put buses behind schedule, especially on runs where the schedules are tight to begin with.

Table 4-1. Hypotheses Addressed by the Evaluation (continued)

Objectives	Hypotheses	Findings*
	<p><i>New hypothesis:</i> Bus operators are more likely to wait for a late train with a CP “hold until” message than without a CP message. [PARTIALLY SUPPORTED]</p>	<ul style="list-style-type: none"> Evidence however is only weak in support, and indirect from all three surveys: 47% of operators reported that, without CP, they “always” wait, 45% said they “sometimes” wait, and 8% said they “never” wait. Less than half (42%) of on-board passengers said their bus waited one or more times. There was no significant difference by whether CP was operating on that trip. 47% of transferring riders said they missed one or more connections when the trip was not CP protected compared with 41% when it was covered by CP (not statistically significant). Riders transferring to unprotected bus trips were twice as likely as riders on CP protected trips to report missing 4+ connections in the past month (13% versus 7% -- not statistically significant).
	<p><i>New hypothesis:</i> Regular operators are more likely to wait for late trains than extra board operators, regardless of CP “hold until” messages. [PARTIALLY SUPPORTED]</p>	<ul style="list-style-type: none"> The assumption was that regular operators know their passengers better and are more likely to espouse UTA’s wait policy, and extra board operators are primarily concerned with schedule adherence. Without a CP “hold until” message, 48% of regular operators reported that they always wait compared with 43% of extra board operators (not statistically significant). 50% who said they know passengers by sight wait versus 37% who do not (not statistically significant). There is no significant difference between regular and extra board operators in the length of time they are willing to wait or in reported schedule constraints affecting ability to wait.
	<p><i>New hypothesis:</i> Overall, bus operators report that most of the CP messages they have received are helpful and needed. [NOT SUPPORTED]</p>	<ul style="list-style-type: none"> While CP is helpful and needed in many instances, operators reported that the majority of CP messages received (64%) were not needed (no train arrived late; no passengers were waiting).
	<p><i>New hypothesis:</i> Bus operators regularly communicate with their passengers about waiting for TRAX trains beyond scheduled departure, and are more likely to do that on CP protected trips than on trips not protected by CP (i.e., when the wait is discretionary). [NOT SUPPORTED]</p>	<ul style="list-style-type: none"> Over all trips, 62% of operators say they “always” let their passengers know why they are waiting (32% say “sometimes”), but 70% of passengers on the bus said the operator “never” discusses the need to wait (74% on CP protected trips and 68% on unprotected trips – not statistically significant).
	<p><i>New hypothesis:</i> Bus operators who report tight schedules are less likely to wait for passengers or to wait shorter periods of time than operators whose schedules have more slack. [SUPPORTED]</p>	<ul style="list-style-type: none"> 47% of operators agreed that it is difficult to wait due to tight schedules. Those who said they have tight schedules are half as likely to say they always wait compared with those who said their schedules are not so tight (38% versus 69% -- statistically significant).

Table 4-1. Hypotheses Addressed by the Evaluation (continued)

Objectives	Hypotheses	Findings*
	<p><i>New hypothesis:</i> The more experience an operator has with CP and as a bus operator with UTA, the more supportive they will be of the CP program. [NOT SUPPORTED]</p>	<ul style="list-style-type: none"> 60% of operators with five years or less experience agreed that the CP program should be extended to more routes, while 38% of operators with more than five years agreed (statistically significant). 55% of operators who have never received a CP message supported extending CP versus 46% of operators who have received a CP message (not statistically significant). Operators who have received the most CP messages (6+) were only somewhat more likely to agree on extending CP (50%--not statistically significant).

*“Statistically significant” and “not statistically significant” mean the effect is or is not statistically significant at the 95% confidence level.

4.2 Conclusions

Based on the quantitative and qualitative components of the evaluation, this section presents the main conclusions from the evaluation of the CP system. A more detailed and comprehensive treatment of the findings and conclusions has already been covered in the previous sections of this evaluation report.

CP improves the probability of successful train-to-bus connections

Based upon the system performance data, CP does significantly increase the percentage of successful train-to-bus connections. Train riders meeting a bus trip when CP was active and a “hold until” message was issued to the bus operator were 3.1 to 3.9 times (depending upon the definition of a successful connection) more likely to have a successful connection than were train riders meeting the same bus trips when CP was inactive, a finding that is statistically significant. Additionally, train riders meeting a bus when CP was active and a “hold until” message was issued were two to three times more likely to have had a successful connection than train riders meeting a bus when CP was active but a “hold until” message was not issued, which was a statistically significant improvement. Finally, train riders meeting a bus trip when CP was active, but no “hold until” message was issued are 1.0 to 1.2 times more likely to have had a successful connection than train riders meeting a bus trip when CP was inactive, which was not statistically significant. These results indicate that significant improvements were observed only when actual “hold until” messages were issued, and hypothesized improvements because of increased awareness and sensitivity by bus operators simply through activation of CP could not be substantiated with the collected system data.

Bus operators tended to hold the buses longer past their normal scheduled departure time when a CP “hold until” message was issued than when a “hold until” message was not issued. This result was significant for comparisons where CP was active (roughly one minute longer on average), but not significant when compared to late train events where CP was inactive (41 seconds longer on average).

Overall satisfaction among riders with connection experience is generally high; operator opinion on the value of CP is mixed.

For the most part, bus riders are unaware of the CP program; they only know whether or not they make successful connections. Riders transferring from train to the bus and riders on the bus report a high level of satisfaction with their connection experience. Not surprisingly, those who have missed connections tend to be the least satisfied. About half (49%) of the bus operators agree with the idea that CP should be used on more routes than it is now. Fewer than one in five operators disagree with that idea, and the rest are neutral. If endorsement that CP should be extended to additional routes can be interpreted as operator support for the CP program, then these results are mixed, with the operators evenly split on the matter.

The level of reported rider satisfaction is only weakly related to whether the bus trip is CP protected.

Riders who were surveyed on trips that were CP protected were only slightly more likely to report being “somewhat” or “very” satisfied (87%) compared with those who were not on CP protected trips (85%). Riders connecting to bus trips unprotected by CP were twice as likely to report a high number of missed connections compared with those connecting to CP protected bus trips. Missed connections under CP are somewhat less likely than missed connections with CP operating (41% versus 47%). While these effects suggest a small but positive effect due to CP as measured by rider reports of trip satisfaction and connection success, none of these differences is statistically significant. The presumptive benefits of CP are positive but of less magnitude as measured in the qualitative component of the evaluation than in the quantitative component.

Bus operators report a high number of unnecessary CP messages received.

Almost two-thirds (64%) of all CP “hold until” messages received by the bus operators surveyed were reported by them to have turned out to be unnecessary, presumably because the train made up time and was not late enough to cause missed connections, or because no train showed up after waiting, or because no riders transferred to the bus, or perhaps the bus was running behind the schedule.

CP effectiveness is less than it could be

- Periods of non-operational CP. During the course of the evaluation, there were at least two instances where the CP system was non-operational for significant periods of time (at least three weeks) because assignments for bus trips were not entered into the system. For example, during most of October 2003, and unbeknownst to the evaluation team at the time, CP was inactive, and this was the main period of time over which riders and operators were being asked to reflect on CP performance and benefit.
- Low operator compliance with CP “hold until” messages. Only 51.3% of bus operators who were sent a suggested departure time (i.e., a “hold until” message) by CP departed after the suggested departure time. However, if 100% of the operators followed the suggestions of CP, then the percentage of successful connections would be *increased* by

28% to 57% for the 120- and 180-second requirement, respectively, raising the overall percentages of successful connections to 99.3% and 85.3%.

- Lack of accuracy in issuance of a CP “hold until” message. There was no statistically significant difference in the distribution of train arrival times between bus trips that received a CP “hold until” message and bus trips that did not, given that CP was active. That is, there is a significant percentage of late train events where a “hold until” message could be issued (i.e., the train is more than two minutes late) but is not and a significant percentage of late train events where a CP “hold until” message is issued but the train is only slightly late (less than one minute). Related to this finding is the high percentage of CP messages judged by the bus operators as being unnecessary (64%).
- Failure of some bus operators to log on to their MDT. The number of operators who forget or otherwise fail to log onto their MDT is reportedly low. Nevertheless, some CP messages will be at risk of not being received in these circumstances, thereby further limiting potential effectiveness of connection protection.
- Many experienced transfer riders have learned to take an earlier train in order to avoid missing their bus connection. 63% of the train-to-bus transfer riders report that they at least sometimes take an earlier TRAX train to be sure they make their connection, and one-quarter of them (26%) do this for most or all of their trips. There is no difference in the proportion of riders who do this by whether their bus trip is CP protected or not. The potential benefit of CP to riders is reduced to the extent that more than half of all transferring riders feel a need to travel 15 minutes earlier than normal to be assured of making their connection.

Most bus operators will wait most of the time to pick up train passengers, regardless of whether they receive a CP “hold until” message.

Only 8% of operators say they “never” wait without a CP message, and 47% say they “always” wait. The reported willingness to wait most of the time makes it more difficult to detect an independent effect of CP on propensity to wait. This willingness to wait is a positive endorsement of UTA management’s customer orientation that they frequently communicate to all their bus operators as an “expected” way to behave toward their passengers. Scheduling constraints appear to be the main factor limiting willingness to wait. Bus operators expressed concern that the advantages to transferring passengers of waiting for late trains is offset by the disadvantages to on-board passengers who are put at risk of missing their later connections or on-time arrival.

The CP system is a relatively low cost “insurance policy” to help increase connection success.

CP is an intelligently integrated system that aims to improve the reliability of rail-to-bus connections. The cost of the CP system is relatively low compared to other transit ITS systems. The moderate capital cost is achieved by utilizing the existing system data (e.g., train status, schedules, etc.) and the delivery mechanism (e.g., Mobile Data Terminal, radio data server, bus and train radio systems) already deployed for other ITS functions (see Figure 1-1 for a CP high

level system configuration diagram). The operating and maintenance costs also are moderate because the CP operation (determination to hold a bus and issuance of a message) is fully automated without the need for human intervention.

CP targets relatively rare late train events to improve the probability of successful connections. This rationale was affirmed by the evaluation data that there were only 4,641 (2%) recorded late train events (out of over 187,000 arrivals) that subsequently triggered 1,508 “hold until” messages during the three months of data collection. Despite its marginal benefits compared to other transit ITS functions (e.g., train control systems, computer-aided dispatch), CP fills an important niche in a combined light rail and bus transit system. As shown in this evaluation, CP improves the probability of successful rail-to-bus connections, especially for the high transfer TRAX stations, evening or last bus service, and low frequency bus routes where the adverse consequence of missing a connection is high. The value of such system is significant.

4.3 Recommendations

Recommendations are made based on the quantitative and qualitative findings and conclusions with recognition of the limitations of the available data and analyses. They are presented in the spirit of suggestions for consideration not only by UTA but also for other transit operators who may be considering implementing a similar connection protection program in their area.

Provide for reliable, continuous monitoring of system performance. Mainly due to lack of oversight during this period of internal reorganization and transitioning of responsibilities, the UTA CP system was non-functional for substantial periods of time during the evaluation period, apparently without anyone at UTA knowing that the system was “down.” Procedures to establish a defined responsibility path, especially during times of transition, should be implemented to eliminate these preventable down times from occurring.

Consider changes in management integration of CP. This could include an assessment of the complex interdependencies between ITS systems, and of the responsibilities for various components of the system that must be effectively linked and coordinated. Examples include separate database components in different parts of the organization, and the multiple positions in the organization with responsibility for the CP assignment data. Also, seek to be sure there is a common understanding throughout UTA regarding recommended wait times among the RCCs, UTA management, and bus operators.

Increase compliance through training and education. UTA has worked diligently to create a culture of customer service in all aspects of its program, including CP. However, the quantitative analysis suggests that there is still a significant level of non-compliance among operators who wait less time than a CP “hold until” message suggests. Part of the solution, as suggested by findings from the operator survey and interviews, may lie in increasing the reliability of the CP messages (increase trust), adjusting schedules to accommodate such waits (more equitable treatment of transfer riders and on-board riders), and further clarifying UTA policy regarding wait decisions versus schedule adherence, considering the consequences for both transferring and on-board passengers.

Improve the predictive accuracy of CP messages. Inaccurate messages have led many operators to say that the majority of CP messages they receive are not needed. A major reason for this is assumed to be due to trains' ability to make up time between stations. Options for addressing this problem may include reducing the forecasting horizon to less than three TRAX stations in advance of the anticipated connection, or sending out a follow-up message to rescind the "hold until" message when it is determined that the train no longer meets the lateness threshold.

Review bus schedules with respect to their effects on connection success. Consider selectively providing more schedule slack to accommodate more comfortable waits at TRAX stations, or at least the capacity to make up lost time at critical points in the bus trips. Assess why many bus trips are reported by riders to be behind schedule and seek solutions where problems are found.

Seek to obtain and integrate information about bus location with train location in fine-tuning the CP algorithm. When buses are running late, a CP message may not be needed. When a train makes up lost time, a CP message may not be needed. When a later bus on a given trip can more efficiently pick up passengers from a late train, a CP message may not be needed. Given the lack of real-time bus location information, the current CP algorithm does not consider the bus status in the computation. As UTA considers the Automatic Vehicle Location (AVL) system for its bus fleet in the future, it is highly desirable to incorporate bus status as part of the CP parameters.

Increase rider awareness of UTA efforts to increase connection success. Both riders and operators expressed concerns in the qualitative evaluation surveys that bus and rail schedules were not adequately coordinated, that buses were often late, and that the CP program was "one sided" in its focus on rail-to-bus transfers and not bus-to-bus or bus-to-rail. These kinds of concerns could be mitigated by providing more information and rationale about the CP program.

References

- [1] Evaluation Plan: Utah Transit Authority Connection Protection System, prepared by Battelle for the ITS Joint Program Office, Federal Highway Administration, August 27, 2003.
- [2] Detailed Test Plans: Evaluation of Utah Transit Authority Connection Protection System, prepared by Battelle for the ITS Joint Program Office, Federal Highway Administration, October 31, 2003.

Appendix A

UTA TRAX Train and Bus Schedules

Historic Sandy 900S TRAX

35 buses (12 Protected; 23 Un-Protected)

Sandy Civic Ctr 1000S TRAX

69 Buses (20 Protected; 49 Un-Protected)

Millcreek 3300 S TRAX

40 Buses (7 Protected; 33 Un-Protected)

701 NB TRAX	7:26 PM
701 NB TRAX	7:31 PM
701 SB TRAX	7:37 PM
701 NB TRAX	7:46 PM
701 SB TRAX	7:52 PM
701 NB TRAX	8:01 PM
701 SB TRAX	8:07 PM
124 IB	8:14 PM
701 NB TRAX	8:16 PM
701 SB TRAX	8:22 PM
701 NB TRAX	8:31 PM
701 SB TRAX	8:37 PM
124 OB	8:40 PM
701 NB TRAX	8:46 PM
701 SB TRAX	8:52 PM
701 NB TRAX	9:01 PM
701 SB TRAX	9:07 PM
124 IB	9:14 PM
701 NB TRAX	9:16 PM
701 SB TRAX	9:22 PM
701 NB TRAX	9:31 PM
701 SB TRAX	9:37 PM
124 OB	9:40 PM
701 NB TRAX	9:46 PM
701 SB TRAX	9:52 PM
701 NB TRAX	10:01 PM
701 SB TRAX	10:07 PM
124 IB	10:14 PM
701 NB TRAX	10:16 PM
701 SB TRAX	10:22 PM
701 NB TRAX	10:31 PM
701 SB TRAX	10:37 PM
124 OB	10:40 PM
701 NB TRAX	10:46 PM
701 SB TRAX	10:52 PM
701 NB TRAX	11:01 PM
701 SB TRAX	11:07 PM
124 IB	11:14 PM
701 NB TRAX	11:16 PM
701 SB TRAX	11:22 PM
701 NB TRAX	11:31 PM
701 SB TRAX	11:37 PM
124 OB	11:40 PM
701 NB TRAX	11:46 PM
701 SB TRAX	11:52 PM
701 SB TRAX	12:07 AM
124 OB	12:10 AM

46 SB	6:43 PM
701 NB TRAX	6:49 PM
701 SB TRAX	6:54 PM
124 IB	7:02 PM
143 NB	7:02 PM
133 IB	7:04 PM
24 SB	7:05 PM
701 SB TRAX	7:09 PM
701 SB TRAX	7:19 PM
701 SB TRAX	7:24 PM
811 to Provo	7:29 PM
125 IB	7:36 PM
701 SB TRAX	7:39 PM
701 SB TRAX	7:54 PM
124 IB	8:02 PM
143 NB	8:02 PM
133 IB	8:04 PM
701 SB TRAX	8:09 PM
701 SB TRAX	8:24 PM
125 IB	8:36 PM
701 SB TRAX	8:39 PM
811 to Provo	8:44 PM
701 SB TRAX	8:54 PM
124 IB	9:02 PM
143 NB	9:02 PM
133 IB	9:04 PM
701 SB TRAX	9:09 PM
701 SB TRAX	9:24 PM
125 IB	9:36 PM
701 SB TRAX	9:39 PM
816 to Provo	9:44 PM
701 SB TRAX	9:54 PM
124 IB	10:02 PM
143 NB	10:02 PM
133 IB	10:04 PM
701 SB TRAX	10:09 PM
701 SB TRAX	10:24 PM
125 IB	10:36 PM
701 SB TRAX	10:39 PM
816 to Provo	10:44 PM
701 SB TRAX	10:54 PM
124 IB	11:02 PM
143 NB	11:02 PM
701 SB TRAX	11:09 PM
701 SB TRAX	11:24 PM
701 SB TRAX	11:39 PM
701 SB TRAX	11:54 PM
701 SB TRAX	12:09 AM

701 NB TRAX	7:16 PM
701 SB TRAX	7:22 PM
137 WB	7:25 PM
701 NB TRAX	7:31 PM
701 SB TRAX	7:37 PM
701 NB TRAX	7:46 PM
701 SB TRAX	7:52 PM
137 WB	7:55 PM
701 NB TRAX	8:01 PM
701 SB TRAX	8:07 PM
131 EB	8:11 PM
701 NB TRAX	8:16 PM
701 SB TRAX	8:22 PM
137 WB	8:25 PM
701 NB TRAX	8:31 PM
701 SB TRAX	8:37 PM
701 NB TRAX	8:46 PM
701 SB TRAX	8:52 PM
137 WB	8:55 PM
701 NB TRAX	9:01 PM
701 SB TRAX	9:07 PM
131 EB	9:11 PM
701 NB TRAX	9:16 PM
701 SB TRAX	9:22 PM
137 WB	9:25 PM
701 NB TRAX	9:31 PM
701 SB TRAX	9:37 PM
701 NB TRAX	9:46 PM
701 SB TRAX	9:52 PM
701 NB TRAX	10:01 PM
701 SB TRAX	10:07 PM
131 EB	10:11 PM
701 NB TRAX	10:16 PM
701 SB TRAX	10:22 PM
137 WB	10:25 PM
701 NB TRAX	10:31 PM
701 SB TRAX	10:37 PM
701 NB TRAX	10:46 PM
701 SB TRAX	10:52 PM
701 SB TRAX	11:07 PM
703 SB TRAX	11:13 PM
701 SB TRAX	11:22 PM
137 WB	11:25 PM
703 SB TRAX	11:27 PM
701 SB TRAX	11:37 PM
703 SB TRAX	11:41 PM
701 SB TRAX	11:52 PM

Color Key
TRAX Train Routes
Protected Bus Routes
Unprotected Bus Routes

Appendix B

UTA Rail-to-Bus Transfer Rider Survey

UTA Rail-to-Bus Transfer Rider Survey

1. How often do you ride the bus (one-way trip) in a typical week (Monday through Friday)?

<input type="checkbox"/> 1 time or less a week <input type="checkbox"/> 2 to 3 times a week <input type="checkbox"/> 4 to 5 times a week	<input type="checkbox"/> 6 to 7 times a week <input type="checkbox"/> 8 to 9 times a week <input type="checkbox"/> 10 or more times a week
--	--

2. How many times **in the past month** (past 30 days) have you missed your scheduled bus connection **at this TRAX station** because the TRAX train was late?

<input type="checkbox"/> No times in the past month <input type="checkbox"/> 1 time	<input type="checkbox"/> 2 to 3 times <input type="checkbox"/> 4 or more times
--	---

3. What are you **most likely to do** when you miss your bus connection? (*check one box*)

<input type="checkbox"/> Never missed my bus <input type="checkbox"/> Wait for the next bus <input type="checkbox"/> Walk <input type="checkbox"/> Call a cab	<input type="checkbox"/> Call family member or friend to get me. <input type="checkbox"/> Ask someone for a ride <input type="checkbox"/> Other (specify: _____)
--	--

4. If you miss your bus, **how long** do you **usually** have to wait for the next bus, or for some other means of transportation? (*check one box*)

<input type="checkbox"/> Never miss my bus <input type="checkbox"/> Wait 15 minutes or less <input type="checkbox"/> Wait 16 to 30 minutes	<input type="checkbox"/> Wait 31 minutes to 45 minutes <input type="checkbox"/> Wait more than 45 minutes
--	--

5. If your train is late, does the bus driver wait for you?

<input type="checkbox"/> Never <input type="checkbox"/> Occasionally <input type="checkbox"/> Most of the time	<input type="checkbox"/> Always <input type="checkbox"/> Don't know / my train is never that late
--	--

6. **In the past month** how often have you taken an earlier TRAX train to make it more likely you will not miss your preferred bus connection at this station?

<input type="checkbox"/> Never <input type="checkbox"/> Some of my trips	<input type="checkbox"/> Most of my trips <input type="checkbox"/> Always
---	--

7. How important is it to you **to be sure** you will make your scheduled bus connection?

<input type="checkbox"/> Very important <input type="checkbox"/> Somewhat important	<input type="checkbox"/> Not very important <input type="checkbox"/> Unimportant
--	---

8. **If your bus departs late** from the TRAX station due to a late train arrival, do you ever miss your next bus transfer down the line?

<input type="checkbox"/> Don't have any bus transfers down the line <input type="checkbox"/> Never have departed late from the TRAX station	<input type="checkbox"/> Never missed a later transfer <input type="checkbox"/> Sometimes miss later transfer <input type="checkbox"/> Frequently miss later transfer
--	---

9. Your characteristics. (*check one box in each column*)

Gender <input type="checkbox"/> Female <input type="checkbox"/> Male	Age category <input type="checkbox"/> Less than 20 years <input type="checkbox"/> 21 to 64 <input type="checkbox"/> 65 or older	Is there any reason that makes it difficult for you to make your rail-to-bus connection? <input type="checkbox"/> No <input type="checkbox"/> Yes (specify: _____)
---	---	---

10. Overall, **how satisfied** are you with your experiences connecting from the train to your preferred bus?

<input type="checkbox"/> Very satisfied	<input type="checkbox"/> Somewhat dissatisfied
<input type="checkbox"/> Somewhat satisfied	<input type="checkbox"/> Very dissatisfied

11. Any comments or suggestions for UTA regarding rail-to-bus connections? (**Write on back**)

Appendix C

UTA Bus Rider Survey

UTA Bus Rider Survey

1. How often do you ride the bus (one-way trip) in a typical week (Monday through Friday)?

<input type="checkbox"/> 1 time or less a week	<input type="checkbox"/> 6 to 7 times a week
<input type="checkbox"/> 2 to 3 times a week	<input type="checkbox"/> 8 to 9 times a week
<input type="checkbox"/> 4 to 5 times a week	<input type="checkbox"/> 10 or more times a week

2. How many times **in the past month** (past 30 days) have you been on this bus when it arrived late at this station?

<input type="checkbox"/> No times in the past month	<input type="checkbox"/> 2 to 3 times
<input type="checkbox"/> 1 time	<input type="checkbox"/> 4 or more times

3. How many times **in the past month** (past 30 days) has this bus waited past its scheduled departure time at this TRAX station because the train was late?

<input type="checkbox"/> No times in the past month	<input type="checkbox"/> 2 to 3 times
<input type="checkbox"/> 1 time	<input type="checkbox"/> 4 or more times

4. When the train is late, does the bus driver discuss the need to wait for train passengers or ask the bus passengers if it is OK to wait?

<input type="checkbox"/> Never	<input type="checkbox"/> Most of the time
<input type="checkbox"/> Occasionally	<input type="checkbox"/> Always

5. Is it a problem for you if your bus is delayed because of a late train connection?

<input type="checkbox"/> No problem at all	<input type="checkbox"/> Somewhat of a problem
<input type="checkbox"/> Not much of a problem	<input type="checkbox"/> A big problem

6. If your bus departs late from the TRAX station due to a late train arrival, do you ever miss your next bus transfer down the line?

<input type="checkbox"/> Don't have any bus transfers down the line	<input type="checkbox"/> Never missed a later transfer
<input type="checkbox"/> Never have departed late from the TRAX station	<input type="checkbox"/> Sometimes miss later transfer
	<input type="checkbox"/> Frequently miss later transfer

7. How many times **in the past month** (past 30 days) has this bus arrived late at your final destination?

<input type="checkbox"/> No times in the past month	<input type="checkbox"/> 2 to 3 times
<input type="checkbox"/> 1 time	<input type="checkbox"/> 4 or more times

8. Your characteristics. (*check one box in each column*)

Gender	Age category
<input type="checkbox"/> Female	<input type="checkbox"/> Less than 20 years
<input type="checkbox"/> Male	<input type="checkbox"/> 21 to 64
	<input type="checkbox"/> 65 or older

9. Overall, how satisfied are you with how the bus operators deal with late train connections?

<input type="checkbox"/> Very satisfied	<input type="checkbox"/> Somewhat dissatisfied
<input type="checkbox"/> Somewhat satisfied	<input type="checkbox"/> Very dissatisfied

10. Do you have any comments or suggestions for UTA regarding rail-to-bus connections?

Appendix D

Survey Coverage of Bus Trips

Bus Number	Scheduled Departure Time (p.m.)	No. of passengers on the bus	Number of Completed Surveys Rail-to-Bus	Number of Completed Surveys On-Board
Sandy Civic Center TRAX Station				
12 NB	4:42	1	1	0
124 IB	7:02	1	1	0
124 IB	8:02	?	0	1
125 IB	7:36	1	0	1
125 IB	8:36	?	1	0
133 IB	7:04	2	2	0
133 IB	8:04	?	1	1
143 NB	7:02	2	2	0
222 NB	4:22	3	1	1
222 NB	5:22	2	1	0
24 NB	4:26	1	1	0
33 NB	4:14	6	6	0
33 NB	4:42	3	1	2
33 NB	5:12	1	1	0
33 NB	5:42	1	1	0
33 NB	6:12	4	3	0
345 OB	5:28	4	4	0
345 OB	5:58	3	3	0
345 OB	6:28	?	1	0
41 NB	4:34	4	0	3
41 NB	5:04	1	1	0
41 NB	6:04	?	0	1
46 SB	5:13	6	6	0
46 SB	6:13	3	3	0
46 SB	6:43	2	0	1
47 SB	5:00	6	2	2
47 SB	6:15	?	1	0
811 (to Provo)	4:44	8	8	0
811 (to Provo)	4:59	11	10	1
811 (to Provo)	5:14	20	14	0
811 (to Provo)	5:44	25	16	1
811 (to Provo)	5:59	12	9	2
811 (to Provo)	6:29	12	10	0
811 (to Provo)	7:29	23	15	0
811 (to Provo)	7:29	10	6	1
811 (to Provo)	8:44	15	11	1
811 (to Provo)	8:44	28	16	0
811 (to Provo)	4:14	33	18	1
816 (to Provo)	9:44	8	6	0

Bus Number	Scheduled Departure Time (p.m.)	No. of passengers on the bus	Number of Completed Surveys Rail-to-Bus	Number of Completed Surveys On-Board
Historic Sandy				
24 SB	4:24	6	1	3
24 SB	4:54	4	3	1
24 SB	5:24	2	1	1
90 WB	3:55	8	8	0
90 WB	4:25	8	5	0
90 WB	4:55	10	9	1
90 WB	5:25	6	5	0
90 WB	5:55	11	9	1
90 WB	6:25	10	5	3
90 WB	6:55	2	1	1
94 EB	4:25	4	4	0
94 EB	4:55	7	5	0
94 EB	4:55	12	8	1
94 EB	5:25	5	4	0
94 EB	6:25	6	4	0
94 EB	6:55	2	2	0

Bus Number	Scheduled Departure Time (PM)	No. of passengers on the bus	Number of Completed Surveys Rail-to-Bus	Number of Completed Surveys On-Board
Millcreek TRAX Station				
131 EB	7:11	2	2	0
131 EB	8:11	7	4	3
131 EB	9:11	7	3	2
131 EB	10:11	?	6	3
137 WB	7:25	28	12	3
137 WB	7:55	12	6	0
137 WB	9:25	8	3	2
137 WB	11:25	11	5	4
31 EB	4:10	?	6	3
31 EB	4:38	8	5	2
31 EB	5:23	11	3	2
31 EB	6:25	11	4	2
31 EB	6:25	5	2	0
31 EB	6:53	7	3	1
31 WB	4:10	8	2	3
31 WB	5:03	7	1	2
31 WB	5:25	2	0	1
31 WB	5:55	6	0	6
31 WB	6:10	3	1	1
37 WB	4:10	28	13	0
37 WB	4:10	31	4	4
37 WB	4:25	12	6	3
37 WB	4:40	23	15	4
37 WB	4:55	17	8	0
37 WB	5:10	18	10	0
37 WB	5:10	18	8	1
37 WB	5:40	20	9	0
37 WB	6:10	17	7	2
37 WB	6:40	19	12	1
41 SB	4:25	8	3	1
41 SB	4:55	3	3	0
41 SB	5:21	4	2	1
41 SB	5:55	6	6	0
41 SB	6:25	4	2	0

Appendix E

Frequency Distributions for Rail-to-Bus and On-Board Rider Surveys

UTA Rail-to-Bus Transfer Rider Survey⁴

1. How often do you ride the bus (one-way trip) in a typical week (Monday through Friday)?

1 time or less a week:	34	8%
2 to 3 times a week:	35	8%
4 to 5 times a week:	112	26%
6 to 7 times a week:	56	13%
8 to 9 times a week:	24	6%
10 or more times a week:	165	39%
Total:	426	100%

2. How many times in the past month (past 30 days) have you missed your scheduled bus connection at this TRAX station because the TRAX train was late?

No times in the past month:	240	57%
1 time:	74	17%
2 to 3 times:	72	17%
4 or more times:	39	9%
Total:	425	100%

3. What are you most likely to do when you miss your bus connection? (check one box)

Never missed my bus:	39	9%
Wait for the next bus:	280	66%
Walk:	41	10%
Call a cab:	5	1%
Call family member or friend to get me:	39	9%
Ask someone for a ride:	7	2%
Other:	16	4%
Total:	427	101%

⁴ Total responses for each question in the survey reflect only the number of individuals who actually answered the question. Since some respondents skipped one or more questions, the total number of responses for each question is typically less than 433. Due to rounding errors, the total percent may not equal 100%.

4. If you miss your bus, how long do you usually have to wait for the next bus, or for some other means of transportation? (check one box)

Never miss my bus:	29	7%
Wait 15 minutes or less:	41	10%
Wait 16 to 30 minutes:	189	45%
Wait 31 minutes to 45 minutes:	110	26%
Wait more than 45 minutes:	54	13%
Total:	423	101%

5. If your train is late, does the bus driver wait for you?

Never:	121	29%
Occasionally:	142	34%
Most of the time:	58	14%
Always:	12	3%
Don't know / my train is never that late:	90	21%
Total:	423	101%

6. In the past month how often have you taken an earlier TRAX train to make it more likely you will not miss your preferred bus connection at this station?

Never:	157	37%
Some of my trips:	159	37%
Most of my trips:	73	17%
Always:	36	9%
Total:	425	100%

7. How important is it to you to be sure you will make your scheduled bus connection?

Very important:	344	80%
Somewhat important:	70	16%
Not very important:	11	3%
Unimportant:	4	1%
Total:	429	100%

8. If your bus departs late from the TRAX station due to a late train arrival, do you ever miss your next bus transfer down the line?

Don't have any bus transfers down the line:	204	49%
Never have departed late from the TRAX station:	41	10%
Never missed a later transfer:	44	11%
Sometimes miss later transfer:	101	24%
Frequently miss later transfer:	31	7%
Total:	421	101%

9. Your characteristics. (check one box in each column)

Gender

Female:	144	34%
Male:	278	66%
Total:	422	100%

Age category

Less than 20 years:	80	19%
21 to 64:	335	79%
65 or older:	9	2%
Total:	424	100%

Is there any reason that makes it difficult for you to make your rail-to-bus connection?

No:	325	80%
Yes:	79	20%
Total:	404	100%

10. Overall, how satisfied are you with your experiences connecting from the train to your preferred bus?

Very satisfied:	194	46%
Somewhat satisfied:	170	40%
Somewhat dissatisfied:	33	8%
Very dissatisfied:	24	6%
<hr/>		
Total:	421	100%

UTA Bus Rider Survey⁵

1. How often do you ride the bus (one-way trip) in a typical week (Monday through Friday)?

1 time or less a week:	3	3%
2 to 3 times a week:	13	15%
4 to 5 times a week:	22	25%
6 to 7 times a week:	9	10%
8 to 9 times a week:	8	9%
10 or more times a week:	32	37%
Total:	87	99%

2. How many times in the past month (past 30 days) have you been on this bus when it arrived late at this station?

No times in the past month:	41	47%
1 time:	8	9%
2 to 3 times:	16	18%
4 or more times:	22	25%
Total:	87	99%

3. How many times in the past month (past 30 days) has this bus waited past its scheduled departure time at this TRAX station because the train was late?

No times in the past month:	50	58%
1 time:	22	25%
2 to 3 times:	13	15%
4 or more times:	2	2%
Total:	87	100%

⁵ Total responses for each question in the survey reflect only the number of individuals who actually answered the question. Since some respondents skipped one or more questions, the total number of responses for each question is typically less than 89. Due to rounding errors, the total percent may not equal 100%.

4. When the train is late, does the bus driver discuss the need to wait for train passengers or ask the bus passengers if it is OK to wait?

Never:	55	70%
Occasionally:	13	17%
Most of the time:	7	9%
Always:	4	5%
Total:	79	101%

5. Is it a problem for you if your bus is delayed because of a late train connection?

No problem at all:	34	39%
Not much of a problem:	25	28%
Somewhat of a problem:	18	21%
A big problem:	11	13%
Total:	88	101%

6. If your bus departs late from the TRAX station due to a late train arrival, do you ever miss your next bus transfer down the line?

Don't have any bus transfers down the line:	32	37%
Never have departed late from the TRAX station:	15	17%
Never missed a later transfer:	7	8%
Sometimes miss later transfer:	23	26%
Frequently miss later transfer:	10	12%
Total:	87	100%

7. How many times in the past month (past 30 days) has this bus arrived late at your final destination?

No times in the past month:	34	40%
1 time:	12	14%
2 to 3 times:	24	28%
4 or more times:	15	18%
Total:	85	100%

8. Your characteristics. (check one box in each column)

Gender

Female:	38	45%
Male:	47	55%
Total:	85	100%

Age category

Less than 20 years:	15	18%
21 to 64:	66	81%
65 or older:	1	1%
Total:	82	100%

9. Overall, how satisfied are you with how the bus operators deal with late train connections?

Very satisfied:	36	42%
Somewhat satisfied:	35	41%
Somewhat dissatisfied:	11	13%
Very dissatisfied:	4	5%
Total:	86	101%

Appendix F

UTA Bus Operator Internet and Paper Survey

UTA Bus Operator Survey of Connection Protection

This survey can be completed on this paper copy OR by going to a computer and entering the following URL: <http://www.sdas.battelle.org/uta/utalotin.asp>

Please only complete the survey once, either on paper or on the computer.

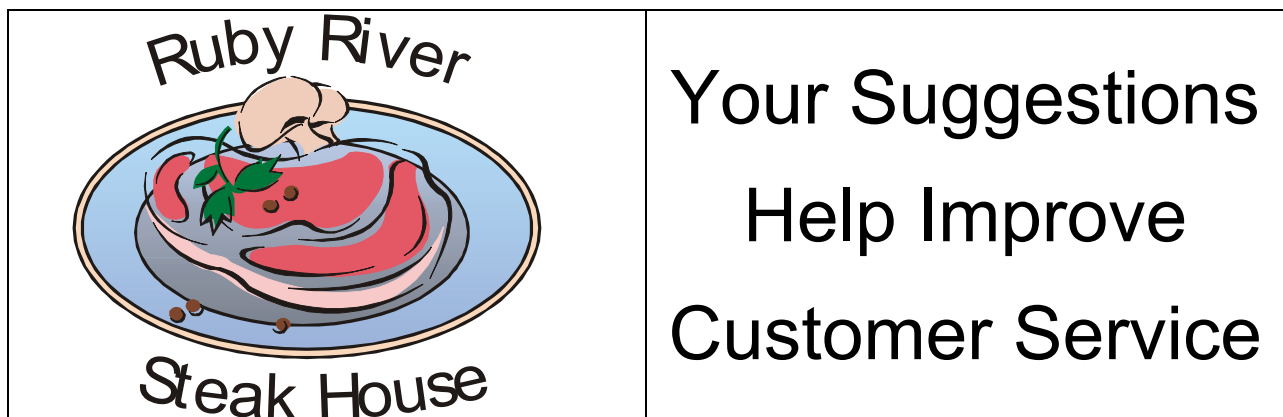
UTA's Connection Protection (CP) program helps bus riders avoid missing their bus connection at a TRAX station when the train is late. This survey asks for your point of view on the CP program to help us improve service for all riders.

If you want to be in a drawing for a \$50.00 gift certificate for Ruby River Steak House, please enter your badge number below so that we can contact the winner. If not, leave this space blank and complete the survey.

Please complete this survey as soon as possible, but no later than Friday November 21st.

Thank you.

*To be entered in the drawing,
Please write your **Badge ID** here: _____*



UTA Bus Operator Survey of Connection Protection

1. Please check your current operator category:
 Regular
 Extra Board
2. For how long have you been a bus operator for UTA?
Years: _____ Months: _____
3. Have you ever received a Connection Protection (CP) "hold until" text message (on your MDT) asking that you hold your bus at a TRAX station beyond your scheduled departure time?
Example: <<Hold at HIST SNDY until 09:59>>
 No (*skip to question 6*)
 Yes
4. Approximately how many such CP "hold until" messages have you received in the past 30 days?
Number of CP messages: _____
5. In how many of those situations (past 30 days) where you got a "hold until" message was the train actually on time or close enough to on time that you didn't need to hold after all?
Number of times "hold until" message was not needed: _____
6. Do you know most of your regular passengers by sight?
 No
 Yes
7. In situations when you don't receive a CP "hold until" message, how often do you wait past your scheduled departure time for the passengers whom you believe are likely to be connecting from TRAX?
 Never
 Sometimes
 Always
8. In situations when you don't receive a CP "hold until" message, what is the longest amount of time you are willing to delay your departure past your scheduled departure time in order to allow late passengers to board your bus?
Number of minutes of delay: _____
9. Do you let your passengers know the reason for a delayed departure from a TRAX station when you decide to hold for a late train?
 Never
 Sometimes
 Always

The following are several statements about your opinions. Please indicate the extent to which you agree or disagree with each statement. (Circle one response for each question below)

STATEMENT	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
10. UTA policy is supportive of bus operators making their own decisions about whether to wait for late passengers.	1	2	3	4	5
11. The Connection Protection program should be used on more routes than it is now.	1	2	3	4	5
12. My bus routes are often so tightly scheduled that it is difficult to wait extra time at a TRAX station for late trains.	1	2	3	4	5
13. Because of tight scheduling I often arrive late at a TRAX station.	1	2	3	4	5

14. What aspects of the Connection Protection program do you like?

15. What aspects of the Connection Protection program do you not like?

Please offer any additional comments, suggestions, or other observations (you may write on back of this sheet if you need more space).

Thank you for your participation. Please return completed survey to supervisor.

Appendix G

Frequency Distributions for Bus Operator Surveys

UTA Bus Operator Survey⁶

1. Please check your current operator category:

Regular:	183	74%
Extra Board:	66	27%
Total:	249	101%

2. For how long have you been a bus operator for UTA?

1 year or less:	15	6%
More than 1 year to 5 years:	94	39%
More than 5 years to 10 years:	63	26%
More than 10 years to 20 years:	40	17%
More than 20 years:	30	12%
Total:	242	100%

3. Have you ever received a Connection Protection (CP) “hold until” text message (on your MDT) asking that you hold your bus at a TRAX station beyond your scheduled departure time?

No:	79	32%
Yes:	166	68%
Total:	245	100%

⁶ Total responses for each question in the survey reflect only the number of individuals who actually answered the question. Since some respondents skipped one or more questions, the total number of responses for each question is typically less than 251. Due to rounding errors, the total percent may not equal 100%.

4. Approximately how many such CP “hold until” messages have you received in the past 30 days?

None:	55	33%
1 – 2:	43	26%
3 – 5:	32	19%
6 – 10:	18	11%
10+:	17	10%
Total:	165	99%

5. In how many of those situations (past 30 days) where you got a “hold until” message was the train actually on time or close enough to on time that you didn’t need to hold after all?

None:	30	26%
One:	23	20%
Two:	13	11%
Three:	11	10%
Four:	12	10%
Five:	5	4%
Six:	10	9%
Seven+:	10	9%
Total:	114	99%

6. Do you know most of your regular passengers by sight?

No:	69	29%
Yes:	173	72%
Total:	242	101%

7. In situations when you don't receive a CP "hold until" message, how often do you wait past your scheduled departure time for the passengers whom you believe are likely to be connecting from TRAX?

Never:	20	8%
Sometimes:	109	45%
Always:	114	47%
Total:	243	100%

8. In situations when you don't receive a CP "hold until" message, what is the longest amount of time you are willing to delay your departure past your scheduled departure time in order to allow late passengers to board your bus?

No time:	4	2%
One minute:	8	3%
Two minutes:	54	23%
Three minutes:	65	28%
Four minutes:	22	9%
Five minutes:	75	32%
Six or more minutes:	8	3%
Total:	236	100%

9. Do you let your passengers know the reason for a delayed departure from a TRAX station when you decide to hold for a late train?

Never:	17	7%
Sometimes:	78	32%
Always:	152	62%
Total:	247	101%

10. UTA policy is supportive of bus operators making their own decisions about whether to wait for late passengers.

Strongly Disagree:	13	6%
Disagree:	26	12%
Neither Agree nor Disagree:	51	23%
Agree:	88	40%
Strongly Agree:	42	19%
Total:	220	100%

11. The Connection Protection program should be used on more routes than it is now.

Strongly Disagree:	14	6%
Disagree:	25	11%
Neither Agree nor Disagree:	74	34%
Agree:	68	31%
Strongly Agree:	40	18%
Total:	221	100%

12. My bus routes are often so tightly scheduled that it is difficult to wait extra time at a TRAX station for late trains.

Strongly Disagree:	14	6%
Disagree:	41	19%
Neither Agree nor Disagree:	61	28%
Agree:	55	25%
Strongly Agree:	48	22%
Total:	219	100%

13. Because of tight scheduling I often arrive late at a TRAX station.

Strongly Disagree:	12	6%
Disagree:	38	17%
Neither Agree nor Disagree:	62	28%
Agree:	77	35%
Strongly Agree:	31	14%
Total:	220	100%

Appendix H

UTA Bus Operator Representative Comments, Suggestions and Observations

Comments, suggestions, and observations on the CP program

“I appreciate the opportunity to give some input on my own time. Please provide the chance to vent or suggest things more often. Please do not let this be one of the few surveys.”^R

“I like to think of myself as the CEO of my bus and my route. Who else knows better how to run my route other than me? I’ve waited for TRAX trains several times with passengers on board who have missed their transfers on down the line because of the schedule delay.”^R

“Are we still Utah Transit Authority or Utah TRAX Authority? We should be focused on accommodating bus riders primarily, not train riders.”^R

“Overall, more bus riders have difficulty making a TRAX connection than the other way around.”^R

“We need a method of legally holding a train for bus passengers arriving at a station while the train is there. An extra 30 seconds would be reasonable. Perhaps the bus operator, on his way into the station, could press a button that would send a message to the train operator to keep the doors open longer.”^R

“UTA should focus more on good scheduling than CP.”^R

“Adjust the bus and train schedules to allow adequate connection time.”^R

“There are some routes where the bus is scheduled to leave two minutes before the train arrives. These schedules need to be corrected.”^X

“Bus routes should be scheduled from the TRAX stations out and adjusted to include some recovery time so we can more easily wait for late passengers at the TRAX.”^X

“If we are expected to wait for late trains, build enough slack in the bus schedule that we can make up the lost time.”^R

“If operators were given 2-3 minutes layover at major transfer points, it would make many transfers easier.”^R

“If we had a little more schedule leeway, it would improve all aspects of UTA’s ability to provide reliable transit.”^X

“You can only reasonably go so far in matching bus and train connections.”^R

“When schedules are tight, operators should have more discretion.”^R

^R Regular operator.

^X Extra Board operator.

Comments, suggestions, and observations on the CP program (continued)

“Give the operator more discretion to leave when all connections have been made.”^R

“I have waited every time I got a CP message but it has never made a difference in someone catching my bus. And when the train was late enough to make a difference, I waited for the train even though I did not get a message to do so.”^R

“You know, I don’t mind waiting if I know *someone* is going to show up, but I do mind waiting for *nothing*.”^R

“Print the TRAX schedules on the block sheets when they are within 2-3 minutes of scheduled bus arrival. This would give the driver more flexibility.”^R

“We all should be aware of the TRAX time points and do the best we can. My humble observation is that most of the UTA drivers wait, especially for their regular passengers, because they have communication with them.”^X

“How does the CP program determine who waits, especially when my bus is late in arriving at the TRAX station?”^R

“Look at the number of short headways and consolidate blocks into 8 hour pieces where you can.”^R

“It seems like with all the extra traffic on the highways and streets, most of our EOL time has greatly diminished.”^R

“CP message would be better if it referenced a particular train rather than a particular wait time.”^R

“It should be mandatory for all drivers to wait for passengers when they see the TRAX train pulling into the station.”^R

“I keep a TRAX schedule with TRAX stop times highlighted for quick reference. If I see that a train is due shortly, I always wait for the train.”^X

“Please, use the CP as much as possible to help us and our passengers.”^X

Appendix I

UTA Bus Operator Interview Guide

UTA Bus Operator Group Discussion Guide

1. Ground rules

- (1) Individual identities are confidential
- (2) No right or wrong answers
- (3) Schedule to keep—limited to ½ hour
- (4) Audio-taping for notes only; tape will be erased. Use only if everyone consents.
- (5) Purpose of the interview: is to discuss how you handle late train events
 - (a) Discuss how you handle late train events
 - (b) Discuss awareness of and perceived value of Connection Protection program

2. Introductions

- (1) Explain role/function of the evaluation
- (2) This is an informal discussion, part of several different data collections
- (3) First name only
- (4) How many years driving a bus?
- (5) How long with Utah Transit Authority?

3. Discuss connection protection program

- (1) Have you heard of this CP program?
- (2) If so, what do you know about it?
- (3) Have you ever received a message asking that you hold your bus beyond your scheduled departure?
- (4) How often do you get these kinds of messages?
- (5) How do your bus passengers feel about such delays?
 - (a) Do the opinions of your passengers influence how you deal with decisions to wait for connecting passengers?
- (6) In the absence of a CP message, how do you deal with late train events?
- (7) Would you say a bus operator gets to know their regular customers personally?
 - (a) If so, how does that influence how you respond if they are late for their bus?
- (8) If you have to hold, how easy or difficult is it for you to make up that time in your schedule?
- (9) What is your management's attitude toward schedule adherence?
 - (a) Do they encourage you to wait for late passengers or do they just leave that decision up to your judgment?
- (10) Overall, from your point of view, what are the pros and cons of the CP program?
 - (a) What do you like best about CP? Least?
 - (b) Is the performance of the CP system reliable and consistent?
 - (c) What is the perspective of your passengers on this?
 - (d) Do you think the program should be applied to all bus runs that connect with a TRAX station?
 - (e) Does CP impact your job in any particular ways? If so, how?

4. Wrap up

- (1) Anything else you would like to say about these matters?

Appendix J

UTA Route Supervisor and Radio Controller Interview Guide

UTA Route Supervisor and Radio Controller Interview Guide

5. Ground rules

- (1) Individual identities are confidential
- (2) No right or wrong answers
- (3) Schedule to keep—limited to ½ hour
- (4) Audio-taping for notes only; tape will be erased. Use only if everyone consents.
- (5) Purpose of the interview: is to discuss the function and effectiveness of CP
 - (a) Discuss how you handle late train events
 - (b) Discuss your guidance to bus operators
 - (c) Discuss awareness of and perceived value of CP program

6. Introductions

- (1) Explain role/function of the evaluation
- (2) This is an informal discussion, part of several different data collections
- (3) First name only
- (4) How long with Utah Transit Authority?
- (5) How many years doing this job?

7. Discuss connection protection program

- (1) What is your understanding of the objective of the CP program?
- (2) Tell me how the CP program works and your specific role in it?
- (3) What are the main causes of late train events that trigger CP notices to the bus operators?
- (4) How frequently is CP actually implemented?
- (5) How does UTA view the trade-off between allowing schedule delays to assure successful connections, versus maintaining schedule adherence?
 - (a) Are bus operators encouraged to wait for late trains beyond their scheduled departure times, whether or not they are on a run covered by CP?
 - (b) How do bus operators generally respond to late train events in situations where CP is not operational
- (6) What is your sense of how the bus drivers view CP? Do they generally like it or not? Why or why not?
- (7) What is your sense of the benefit UTA and the customers are deriving from the CP program?
- (8) Are you getting specific feedback on the programs performance? If so, what is it telling you?
 - (a) From bus operators?
 - (b) From customers?
 - (c) Other sources?
- (9) Overall, from your point of view, what are the pros and cons of the CP program?
 - (a) What do you like best about CP? Least?
 - (b) How well or effectively would you say the program is working?
 - (c) Are there improvements to the program you would like to see?
 - (d) Do you think the program should be applied to all bus runs that connect with a TRAX station? Why / why not?
 - (e) Does CP impact your job in any particular ways? If so, how?

8. Wrap up

- (1) Anything else you would like to say about these matters?