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Publication Date

1997-10-01

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The Impact of Intelligent Transportation Systems on Bus Driver Effectiveness

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THE IMPACT OF INTELLIGENT TRANSPORTATION SYSTEMS ON BUS DRIVER EFFECTIVENESS

August 25, 1997

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ABSTRACT

Intelligent Transportation Systems (ITS), when employed on public buses, have the potential for improving overall coordination of bus transit systems. In this paper, their potential for improving bus driver effectiveness is examined. Analysis of data gathered from observations at nearly 300 bus stops indicates that while ITS may have a small potential for improving driver effectiveness, current practices among drivers and passengers alike are likely to limit actual gains. The clearest benefits of ITS come in the automatic processing of information related to transferring passengers, and in the increased speed with which emergency and maintenance calls can be handled. However, it is unlikely that individual bus driver effectiveness measures will improve with the implementation of ITS technologies.

Keywords: Driver Effectiveness, Transit, Bus Transportation, Schedule Adherence, Tracking

EXECUTIVE SUMMARY

Recently, bus transit service providers have begun to adopt Intelligent Transportation Systems (ITS) technologies such as Global Positioning Systems (GPS), Mobile Data Terminals, and Electronic Fare Boxes. These systems taken together have the potential to reduce the cost of providing transportation services through the execution of real-time control strategies, performance monitoring systems and data collection to support service realignment.

The objective of this project, "Efficient Transit Service Through the Application of ITS" (PATH MOU 280), is to investigate the application of ITS technologies to improve overall efficiency and productivity of transit service. The focus of this paper is on investigating the potential of improving the productivity and effectiveness of bus drivers through the use of ITS. In a companion working paper, the project has also developed a simulator for evaluating ITS capabilities. A final report will be delivered in the summer of 1998 covering all project elements.

Data were gathered from observations at nearly 300 bus stops in Orange County. The resulting analysis focused on four measures of bus driver effectiveness: pull-out lateness, stop lateness, boarding and debarking times, and total length of run. The greatest emphasis was placed on boarding and debarking times, which were analyzed through a dwell time metric. Two factors that most increased dwell times were passenger questions and the boarding and debarking of wheelchair/disabled passengers. Accordingly, ways in which ITS might aid in dealing with both these situations were examined. Potential benefits in other areas were also investigated.

Overall, the findings of this report suggest that while ITS may have a small potential for improving certain measures of driver effectiveness, current practices among drivers and passengers alike are likely to limit actual gains. Gains are also limited simply because so many events that occur in the course of driving a bus over a run are beyond the control of an individual driver (e.g. traffic, wheelchair boarding, etc.) regardless of the amount of information he or she receives. Specifically,

- ITS is not expected to have much impact on pull-out lateness measures, especially for bus lines with considerable slack.

- ITS does have potential for reducing stop lateness by alerting drivers to upcoming large groups or wheelchair/disabled passengers. However, other, less expensive options, such as telephone call-boxes, could provide this service instead.

- Although ITS could provide information that would enable drivers to better pace their buses over their runs, it is not clear that they would do so. Many seem to enjoy long breaks at major stops. Thus, although there is great potential for the use of ITS to improve the pacing of buses over their routes, that potential can only be realized with changes in work rules and their enforcement.

- When passengers ask questions, boarding times are raised, which increases dwell times. However, it is not clear if ITS can remedy the problem by providing automated information. For a number of reasons, passengers may continue to prefer having questions answered by a human driver.

- Calls regarding transferring passengers, which currently constitute the most frequent cause for radio communication, can be handled directly and efficiently through ITS, with the possibility of improving a number of system-wide measures of effectiveness. However, there is the chance of simultaneously diminishing individual driver effectiveness measures, thereby setting up mismatches between driver incentives and system goals.

1.0 Introduction

Intelligent Transportation Systems (ITS) such as Global Positioning Systems (GPS) and other vehicle tracking technologies have been successfully employed in a number of industries. In the trucking industry, for example, wireless vehicle tracking devices have enabled firms such as Walgreen, Hyman Freightways, and Pepsi-Cola to reduce driver overtime, improve driver productivity, reduce service time for breakdowns and emergencies, and improve customer service (Deierlein, 1995). When employed on public buses, ITS has the potential of greatly improving overall coordination of the transit system. In a study of a Los Angeles transit agency, Hall et al. (1997) show that while ITS can reduce transfer times per passenger by enabling better dispatching of buses at timed transfer points, the cost of the systems still outweigh the benefits. The intent of this paper is to discern the potential benefits of ITS in terms of bus driver effectiveness. In particular, the paper will examine the possible use of ITS in enabling decisions or actions on the part of bus drivers that will ultimately improve both quantitative and qualitative measures of driver performance.

ITS Technology

ITS can range from vehicle tracking systems to electronic fare collection to automatic passenger counters. Options, costs, advantages, and disadvantages of various components of an ITS are presented in detail in other sources (e.g. Hall et al., 1997; Casey and Labell, 1996; Morlok et al., 1993; Behnke, 1993). For the purposes of this paper, an ITS will be considered to include the following basic capabilities and features: vehicle tracking, wireless communication, and a data terminal for driver input, with the necessary software and hardware needed to support such a system. For the purposes of this research, we do not investigate signal pre-emption technology, as this has a smaller impact on how the driver does his job. We also do not focus on fare collection here, as this is being investigated in other PATH projects (the "Smartcard" project).

<u>Description of the Bus Driver's Job and Tasks</u>

The driver's job and tasks can be divided into three categories: driving, boarding and debarking processes, and off-line activities.

Driving. During the times when the bus is in motion, the driver must negotiate his way through traffic, determine whether or not to stop at each bus stop (e.g. does he see passengers waiting at the stop? has someone rung the bell to debark?), deal with emergency situations (e.g. unruly passengers, mechanical failure), and report via radio dispatch new construction or detours he observes along his route. The Americans with Disabilities Act of 1990 requires bus drivers to call out major transfer points, intersections, destination points, etc. sufficient to allow passengers with visual impairment to orient themselves. In addition, the driver may radio in to dispatch if he has passengers who wish to transfer to a bus on another line so that the connecting bus can be alerted to wait for them.

Boarding and Debarking Processes. As passengers board, the bus driver must monitor fare collection. For example, he may check passes, coupons, and transfers, and help to place money into the collection device. He must issue transfers (which he cuts appropriately to reflect the proper amount of time for which they are valid), answer passenger questions, and otherwise assist passengers in entering the bus and locating a space to stand or sit. When a wheelchair passenger boards, the driver must operate the lift mechanism, clear the wheelchair seating area, and secure the passenger into place. As compared to boarding, the debarking process requires little operator involvement other than to release the back door. In the case of a wheelchair, the driver must release the chair from its position and again operate the lift.

Off-line Activities. The bus driver has few off-line responsibilities. He must check in for work, typically at the terminal station. At this time, he might read posted material informing him of new policies and procedures, and deal with any administrative matters related to him (e.g. disciplinary matters). He also may conduct a safety inspection of his vehicle prior to leaving the bus yard. At the end of his route, he checks out, again often via computer.

Quantitative Measures of Bus Driver Effectiveness

Four areas of bus driver effectiveness and their related metrics will be examined: pull-out lateness, stop lateness, boarding and debarking times, and total length of run. The metrics considered here are effectiveness measures in the terminology of Fielding et al. (1978) in that they compare services actually provided to output or intended objectives. In this sense, they differ from efficiency measures, which compare the ratio of service inputs and outputs, often from a cost perspective (Gleason and Barnum, 1982). In contrast to the rather large literature on overall transit system effectiveness (e.g. Fielding, 1992; Hensher, 1992; Takyi,1993), the measures in this paper focus on the micro-level of the bus operator. Little work exists at this level among bus transit studies, although driver productivity is examined in other domains, such as motor carrier pickup and delivery operations (e.g. Shrock et al., 1979).

Pull-Out Lateness. Driver pull-out time can be used to determine how much of the delay in a bus run occurs at its very beginning. The time at which both bus and driver are ready is compared to the scheduled terminal departure time. Pull-out lateness can be defined as the difference between the actual pull-out time and the scheduled pull-out time. Negative lateness values indicate early departures. Ideally, lateness should be zero, as on-time departures are preferred over early or late ones. The pull-out lateness metric is influenced by factors concerning both the driver and the bus. If the ITS can provide information regarding bus location that can be used for dispatching decisions at the terminal, spare or otherwise available buses may be assigned to runs whose incoming bus has been delayed, thereby reducing lateness.

Stop Lateness. Schedule adherence is another area related to bus driver effectiveness. We wish to capture the accuracy with which a driver meets the scheduled arrival times for the stops on his run. For each stop, we can define stop lateness as the actual arrival time minus the scheduled arrival time. Negative lateness indicates an early arrival at the stop. Typically in public transit, we prefer that drivers

be neither early nor late at each stop. A driver may improve his stop lateness metric by speeding up or slowing down as he drives along his route. Information about what lies ahead for a driver might be used to alter his behavior as he drives between stops. For example, an on-schedule driver may be informed that he will be held at a downstream stop for a connecting bus that has fallen behind schedule. He may use this information to slow his pace so that he spends less time waiting at the transfer stop. Note that in doing so, he may worsen his own stop lateness values. Paradoxically, by doing so he may improve one measure of customer service in that his actions would permit more passengers to catch his bus at each of the intermediate stops prior to the transfer stop. This example suggests that the employment of ITS may transform the way in which schedule accuracy should be measured. Rather than calculating run-by-run metrics, with a separate value for each driver, we might wish instead to configure a more global measure of total integration and customer service.

Boarding and Debarking Times. Departure from a bus stop is prolonged by passenger boarding and debarking processes. The more passengers who board and debark, the longer the bus must wait at the stop. Boarding passengers often request transfers, or ask questions, perhaps regarding the arrival of buses on nearby connecting lines or of express buses soon to appear on the given line. If passengers become aware that ITS can provide drivers with access to information about other buses, the number of inquiries may well rise. Boarding times would be expected to increase in such a scenario. To remove this possible ill-effect of ITS, the system might be implemented in such a way as to provide passengers with direct information. For example, computerized information kiosks could be installed at major stops. Passenger questions would be diverted from the driver to the kiosk, thereby speeding up the boarding process.

Total Length of the Run. The global measure of how rapidly a driver finishes his run is captured in the comparison of his completion time to the allotted time for the run. A driver hours ratio (i.e. the ratio of actual to scheduled hours worked for a driver over a shift) gives an idea of how much slack time is built into scheduled runs. If the slack is sufficient to allow a driver to catch up at the end of his run

for any time lost at the beginning, the value of the driver hours ratio should be close to one. Values lower than one (indicating a driver completed his run early) would be considered as undesirable as those above one (indicating a driver completed his run late). Note that if a driver has a high pull-out time, then his driver hours ratio will be high unless (a) he speeds up along his route to make up for lost time, or (b) there is sufficient slack time built into the schedule for the run. It is quite conceivable that the driver hours ratio will be adversely affected by the implementation of ITS, as the delay of a bus at a stop to accommodate transferring passengers might increase the hours worked by the driver of the connecting bus.

When selecting measures of performance, one should be cautious against choosing metrics that might lead to perverse behavior on the part of system participants (Hatry, 1980). For instance, a metric such as "number of tickets per police officer year" might provide a misleading incentive to police officers. Likewise, certain of the metrics above may lead to inappropriate actions on the part of bus drivers. The example was given in the case of stop lateness. If too much emphasis is placed on stop lateness, drivers will have a disincentive to wait for transferring passengers. Other such conflicts may be prompted by this set of metrics, and will be investigated as part of this study.

Qualitative Measures of Bus Driver Effectiveness

Bus service does more than just provide a means of transportation for area residents. Having bus service available also increases the quality of life in a community. A recent Transit Cooperative Research Program report reconfigures measures of major transit impacts such that the topmost summary measure is quality of life (TCRP Report 20, 1996). Lower-level elements, such as measures of mobility, access, and cost-effectiveness, are evaluated in terms of their input to quality of life. Quality of life as affected by bus driver actions might be measured through observed passenger behaviors and comments while on board buses, or through customer attitude and satisfaction surveys. In this study, we will

employ the former method by observing the nature of the interaction of bus drivers with the riding population they serve.

Outline of the Rest of the Paper

Background on the bus transit operation selected for this study is provided next. A description of the various data collected is then given, followed by a discussion of the results of analyses of the quantitative and qualitative data. The discussion section presents insights for how ITS might be employed in public bus transit operations based on the findings of this study. The paper concludes with key points and ideas for further investigation.

2.0 Background

The site for the study was the Orange County Transportation Authority (OCTA), which provides fixed-route bus service throughout Orange County over a range of urban, suburban, and sparsely populated areas. OCTA bus service is not frequent. In the middle of the day, most buses run once per hour; during rush hours, the frequency is increased to once every 30 minutes, and in some cases, every 15 minutes. In this section, background information is provided on relevant job categories within OCTA, OCTA policies on bus driver timeliness, and the current state of OCTA's bus tracking software.

Job Categories

There are four major job categories at OCTA that concern us in this paper: bus driver (operator), dispatcher, field supervisor, and radio dispatch operator.

Bus Driver. The task of the bus driver at OCTA is largely self-evident: namely, to operator a bus over a run, much as described in the introduction. There are only a few points that are of extra interest. OCTA policies require drivers to complete a thorough inspection of their bus, including its safety

features, wheelchair lift mechanism, etc., prior to beginning each run. Drivers check in for their shift in a large building in the bus yard. They log their batch number and pin code into computers set up near the drivers' lounge. Upon logging in, the driver is presented with his run for that day, his assigned bus and its location in the yard, and as warranted a few additional remarks (e.g. customer complaints). Although driver check-in times are thus captured electronically via the check-in procedure, driver check-out times at the completion of their shifts are not. Drivers often end their runs at points distant from the bus yard. The next driver of the bus is dispatched with a car to that point; the completing driver returns the car to the terminal. (Buses typically leave the yard in the early morning, about 5 a.m., and do not return until evening.) Although OCTA has a computerized checking-out procedure, drivers are not required to follow it, and thus approximately one-third of the drivers never log out. Even if the procedure were followed, the difference in the check-in and check-out times would not reflect the actual time of the run, as it also includes the time taken for the extra leg taken from the run's end back to the terminal in the OCTA car.

Dispatcher. The dispatcher works in an office beside the driver lounge and check-in area. He is responsible for making sure that drivers check in on time for their shifts. If a driver logs onto the computer system more than one minute late, an alarm is set off on the dispatcher's computer. If a driver is too late or calls in sick, the dispatcher arranges for an extra driver to cover that run. The dispatcher also is notified of bus breakdowns, and makes decisions as to whether new buses and drivers should be dispatched to replace disabled vehicles.

Field Supervisor. The field supervisors monitor bus operations and service in the field. They patrol defined regions (there are four regions and four supervisors on-duty at a time, each covering a separate region) in OCTA cars. Their tasks include investigating detours and construction along bus routes; noting graffiti and vandalism of bus property; supporting bus safety by replacing broken mirrors from a fresh supply kept in the car's trunk, as well as ensuring that drivers wear seatbelts, turn on headlights, and use turn signals; monitoring bus driver behavior and appearance; and timing bus arrivals

at major checkpoints. One field supervisor estimates that he times an average of 20 buses per day; results are recorded by hand on a form. Buses chosen for timing are those about whose drivers recent complaints from customers or field supervisors have been received. The names of these drivers are entered on a "watch list" carried by each supervisor on duty. Drivers on the list are observed for a total of four hours before their name can be removed from the list. If a bus should leave early from a stop, a field supervisor may be called upon to transport passengers who missed the bus. Supervisors cannot contact bus drivers directly, but must route their messages through radio dispatch. They can, however, hear all transmissions between the drivers and the dispatch operators.

Radio Dispatch Operator. Radio dispatch operators typically work in pairs in a control room in a building across from the bus yard. They handle all communication to and from bus drivers, including that between bus drivers. They assist in coordinating the transfer of connecting passengers by receiving requests from one driver and alerting the other driver to wait at a given stop. This, in fact, is the most common type of communication they handle. Other common calls concern wheelchair problems, flooding, detours, farebox failure, breakdowns, and accidents. They also facilitate communication between the driver and the dispatcher in the event of a breakdown. They give operators directions for how to handle unruly or distraught passengers, and are responsible for calling in police or emergency support personnel if needed. They receive information from bus drivers and field supervisors alike regarding new construction.

Timeliness

There is a clear emphasis placed on bus driver timeliness at OCTA. The "Coach Operator Performance Standards Policy" notes that operators must maintain their watches to ensure accurate time, check their watches against the master clock at the operations base before going on duty, and show their watches to supervisors upon request. There are a number of penalties for drivers who fail to maintain timeliness in their schedules. These penalties are meted out in the following manner. Points are

accumulated for infractions of written OCTA policies. The policies are divided into four categories: operations rules/policies, service standards, safety and motor vehicle codes, and accidents. Twenty-five points issued within a category earns a driver a verbal warning, 50 points a written warning, 75 points a 3-day suspension without pay, and 100 points (or 200 points total across categories) a hearing for discharge. The minimum penalty for almost all infractions is 25 points. The service standards include the following infractions related to earliness (each with 25 points): running ahead of schedule, failure to pace schedule, and failure to wait three minutes for customers transferring from other lines when directed to do so by radio dispatch. For lateness, the i&actions consist of leaving the base terminal late without just cause, failure to notify dispatch when leaving the yard more than three minutes late, and failure to notify dispatch when down for 15 or more minutes. Earliness is of great concern to OCTA, as a passenger who misses a bus may have to wait up to one hour to catch the next one. That timeliness is a measure of how well a bus driver performs his job is made evident by these policies.

Current Vehicle Tracking Systems

OCTA operates an automated information system called the "Bus Automated Tracking System." However, this system does not provide real-time tracking of the location of buses. Rather, it generates a series of three reports: a bus assignment sheet, an operator assignment sheet, and a dispatch record. These reports indicate which bus is on what route and driven by whom, and whether or not any given bus left the yard on time. However, they do not track bus locations in real time.

3.0 Methodology

Data Collection

Data were collected from eight bus ride-alongs (lasting on average 1.5 hours each), a six-hour ride-along with a field supervisor, a two-hour observation of the dispatch window in the bus yard, and a

two-hour observation at radio dispatch. Observed employees were interviewed during lapses in their task activity. The bus ride-alongs incorporated stop-watch time studies and event coding. Buses covered runs ranging from suburban and beach areas to more crowded urban areas, and included runs considered to be among the busiest for OCTA.[1] For comparison purposes, two other bus ride-alongs, averaging two hours each, were conducted on a similar bus service operated by the Los Angeles County Metropolitan Transit Authority (MTA).[2]

<u>Quantitative Data</u>

The bus ride-alongs were used to collect the following quantitative data:

bus departure time from a stop (DT)	measured as the time at which the bus driver closed the front door and began to maneuver the bus back into traffic
bus arrival time at a stop (AT)	measured as the moment at which the bus driver opened the front door after pulling up to a stop
number of passengers boarding (B)	a count of entering passengers at a stop
number of passengers debarking (D)	a count of exiting passengers at a stop
the number of transfer passes issued (T)	a count of the number of transfers issued at a stop
whether or not a question was asked of the driver (Q)	binary indicator for each stop independent of the number of questions asked. Questions asked while the bus was in motion were not included.

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[1] Specifically, the runs covered lines 1 (Long Beach, Newport Beach, and San Clemente areas, beginning southbound at about 8:30 a.m., ending northbound about 1 p.m.), 56 (Santa Ana, Garden Grove, and Cypress areas, beginning westbound at 9:30 a.m., ending eastbound at 1 p.m.), 57 (Santa Ana, Costa Mesa, and Newport Beach areas, beginning southbound at 10 a.m., ending northbound at 1 p.m.), and 65 (Santa Ana, Tustin, Irvine, and Balboa areas, beginning southbound at 8:30 a.m., ending northbound at 1 p.m.). Three of the four round-trip rides began at the Santa Ana Transit Terminal, the fourth at the Veterans Administration Hospital in Long Beach. All rides were on weekday mornings.

[2] The MTA runs were on line 177 (Glendale area, beginning eastbound at 11 a.m., ending westbound at 3 p.m.).

whether or not a wheelchair or disabledpassenger boarded or debarked (W)	binary indicator for each stop independent of the number of wheelchair or disabled passengers boarding or debarking
driver-induced wait (DIW)	binary indicator for whether or not the driver waited at the stop with the front door open longer than was necessary to board and debark passengers

From this data, two metrics were calculated:

dwell time (DW)	the difference between the tune the bus arrived at a stop and the time the bus left it

$$DW = DT\text{-}AT$$

Note that, in the absence of driver-induced wait, the dwell time is by definition the maximum of either the boarding time or the debarking time, although neither of these times was explicitly captured. As most passengers debarked through the back door and all passengers except those in wheelchairs loaded through the front door, the tune it took to board one set of passengers was largely independent of the time it took for others to debark.

dwell time per passenger (D WPP)	the dwell time divided by the maximum of the number of persons boarding or the number of persons debarking

$$D\ W\ P\ P \frac{DW}{\overline{Max}(B,D)}$$

Qualitative Data

In addition to the quantitative data, qualitative data were also collected. During the bus ride-alongs, these data were noted on the collection forms designed for the study, and included information such as the nature of any questions asked, the predominant demographic make-up of the passengers on board at the time, any special incidents in boarding, and any unusual passengers, such as those with surfboards or bicycles. Additional data came from the interviews.

<u>Analysis</u>

The quantitative analysis draws mostly upon descriptive statistics, t-tests, and regression modeling. The qualitative data were examined for hints to help explain the quantitative analysis results, as well as to answer questions not addressed by the quantitative data.

4.0 Results

<u>Descriptive Data</u>

Table 1 shows descriptive data from the bus ride-alongs. A major stop was defined using OCTA's distinction of major transfer points and intersections on each run. OCTA publishes schedules with times listed only for major stops. The data represents only stops for which a dwell time was measured. Thus, stops at the beginning and end of each run are not included, nor are stops that were skipped due to no passengers. Altogether, five major stops were skipped due to no passengers; the number of skipped minor stops was not collected.

	Overall	Major stops	Minor stops
Number of stops	293	50	243
Average number of passengers boarding per stop	1.4	1.9	1.3
Average number of passengers debarking per stop	1.4	2.1	1.3
Number of stops at which a transfer was requested	68	16	52
Average number of transfers issued per stop	0.4	0.5	0.3
Number of stops at which a question was asked	22	2	20
Number of stops where a wheelchair or disabled passenger boarded or debarked	28	4	24
Number of stops with driver-induced wait	25	17	8
Average dwell time (DW) (sec)	25.3	65.4	17.1
Average dwell time per passenger (DWPP) (sec/pass)	11.7	25.0	9.2
Standard deviation of DWPP (sec/pass)	2.2	2.2	2.1

Table 1. Descriptive Data from Bus Ride-Alongs

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Several items stand out in the data in Table 1. First, a question was asked at only two major stops in 50 observations (in percentage terms, questions were asked at 4% of major stops). By contrast, questions were asked at 20 minor stops in 243 observations, or at 8.2% of the minor stops. The most frequent type of question concerned how to get to a particular place, such as a shop or a park. Other common questions concerned the route and schedule of the current bus. Also asked were: where to catch the bus on the return trip, will the next bus be empty, and how many rides can be taken with a transfer. A few miscellaneous inquiries also occurred; for example, one passenger lost her purse and wanted to know how she might get it back. Questions were asked at the rate of 1.7 questions per hour of service. Most questions were asked as the passenger boarded the bus.

At over a third of all major stops, drivers waited more time than was necessary to board and debark passengers. The figure for minor stops is less than one-tenth of that. Typically, drivers waited at stops because they were running early. One driver noted that he always waits one stop before the timed checkpoint (i.e. at the last minor stop before a major stop) if he is running early, then he arrives on time at the checkpoint. He doesn't slow down so as to spread his slack time over the intermediate minor stops because he wishes to save that time in case someone with a bicycle or in a wheelchair boards. Overall, bus drivers did not seem to be in a hurry to make their schedule. The bus doors were never opened before the bus came to a halt, nor did any bus leave a stop prior to closing its doors, in accordance with written OCTA policy.

The average dwell time for major stops is 3.5 times that at minor stops; this difference persists even when the figures are normalized for the number of passengers, as reflected in the DWPP values. However, when we remove from the sample the observations in which driver-induced waits occurred, the DWPP figures are 9.9 seconds/passenger for major stops and 8.2 for minor ones, which suggests that boarding and debarking processes are only slightly more time-consuming per passenger at major stops than at minor ones. A t-test confirms no significant difference between the mean DWPP times for major and minor stops when long wait observations are removed (see Table 4 below). The driver-induced waits

often occurred because drivers were running early, but sometimes the driver waited while elderly passengers found a seat. They also occasionally waited (with the door still open) because a stop light at the stop had just turned red.

Pull-Out Lateness

To analyze pull-out lateness, we can look at the start and stop times for the eight ride-alongs and compare them to the scheduled times. Of the eight runs, six started late, none started early, and two started on-time, as depicted in Table 2.[3] Yet every bus that started late was able to finish early. The sole late bus had an on-time start. Because each set of two rides was linked (e.g. a northbound run combined with a southbound run, both with the same driver), the late starts for rides 2, 4, and 8 were not caused by delays in having either bus or driver, as runs 1, 3, and 7 finished early. These rides started late at the driver's discretion. Ride 6 was the completing ride for one driver; thus his 5.7 minute late completion time may have affected the start time of whatever run next required his bus. The small number of rides limits what we can conclude about current values of bus pull-out lateness.

Pull-out Times Summary		
(times are in minutes)		
Ride	Start of Line	End of Line
1	6.0 late	6.4 early
2	6.0 late	2.7 early
3	3.0 late	2.5 early
4	2.0 late	0.3 early
5	2.0 late	5 . 7 9
6	on time	5.7 late
7	on time	0.2 early
8	2.0 late	4.5 early

Table 2. Summary of Pull-Out Times

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[3] Each driver upon checking in at the bus yard is expected to check his watch against a master clock. The observer did not begin his ride-alongs at the terminal, and thus did not set his own watch by the master clock. Thus, there is the possibility of discrepancy between time as the driver viewed it and as the observer viewed it. However, this difference should be less than one minute, as the observer's watch was accurately set to broadcasts of local time (since the broadcasts lack a reading of seconds, the possibility of one minute's difference exists). However, given the rather large figures in Table 2, where buses are late by as much as six minutes, this possible difference does not greatly affect the analysis. Note that the problem of synchronization does not affect dwell time calculations, as these were made with a stopwatch independent of actual time.

The bus that ended late started out on time. It waited at its first three major stops because it was running early. But by the fourth major stop, the bus was running 4.7 minutes late. It never managed to catch up, arriving at its last stop 10.2 minutes late. What happened in between the third and fourth major stops to cause the bus to run late? Nothing, it seems, out of the ordinary. One passenger reported losing her purse, which caused a short delay. Two senior citizens boarded at one stop, taking a bit longer; boarding passengers at another stop were delayed by a passenger who exited via the front door. The most time-consuming stop was one where a large number of people boarded (17 in all, with five others debarking). No wheelchairs or noticeably disabled persons boarded the bus at any time during the run. The only way the driver could have avoided the late ending would have been to not wait at the beginning stops at which he was running early, but to do so might have caused other passengers along the line to miss the bus.

Stop Lateness

Stop lateness for this dataset was calculated as the difference between the time the bus left a stop and the scheduled time for the bus at the stop. The departure time rather than the arrival time was chosen as the basis for this metric because OCTA's primary concern is that buses do not leave stops early, which they define as leaving before the posted time. Results are presented in Table 3. We note occurrences in which the bus was late more than six minutes, as they constitute violations of OCTA policy for lateness. Earliness of any amount also violates OCTA policy. We make special note here of occurrences of early departures in excess of one minute due to the issue of synchronization of the observer's watch, as one minute is the maximum the observer's watch is expected to be off from true time.

Total number of stops	**50**
Number of stops at which bus was late	**30**
Number of stops at which the bus was late by more than 6 min.	**3**
Average lateness among late stops	**2.4** min
Number of stops at which the bus left early by any amount	19
Number of stops at which the bus left early by more than one minute	11
Average earliness among early stops	**1.3** min

Table 3. Stop Lateness Data for Major Stops

It was noted earlier that drivers often waited at major stops when they believed they were running early. Yet, at 11 stops among the sample of 50, the driver left earlier than the scheduled time even *after* waiting. Overall, drivers left stops before the scheduled time at 38% of the major stops. (These values do not include the first or last stops of each run, which were considered separately above.) Such a high rate of earliness is all the more surprising given that OCTA harbors "zero tolerance" for departing early (there is no regulation against *arriving* early). In other words, while a bus driver may be up to six minutes late in arriving at a stop without penalty, he cannot depart from a stop even so much as one second early, according to the field supervisor. The earliest driver departed from a stop 4.3 minutes ahead of schedule; the average was 1.3 minutes. A number of drivers were observed to read paperback books during the times they waited. Possibly, these drivers don't mind running early, as it gives them a longer stretch in which to read. This process would be quite similar to that found among factory workers who hurry up their pace so as to take longer breaks.

There is no posted schedule for minor stops, so the drivers cannot be charged with being early or late at them. However, OCTA policy does list "failure to pace schedule" as an infraction of service standards that could lead to a 25-point penalty for a driver. If drivers are purposefully arriving early at the major stops, they must also believe the probability of being timed, caught, and written up by a field supervisor for failure to maintain a pace to be rather low. In observation, it appeared that buses were

timed because the field supervisor happened to be in the area, say for inspection of a bus detour route. In a six-hour period, the observer never saw the supervisor refer to the watch list, although it was in his possession.

Profiles of stop lateness over the course of each run are displayed in Figure 1. Here, the starting and ending times have been added for completeness. The profiles make clear the slack in the schedules. Drivers were able to make up for late starts; in every case but one, they were even able to make up for lateness that occurred late in the run. Early or on-time buses typically were made late by events such as large groups, wheelchair or bicycle loading, and passenger questions.
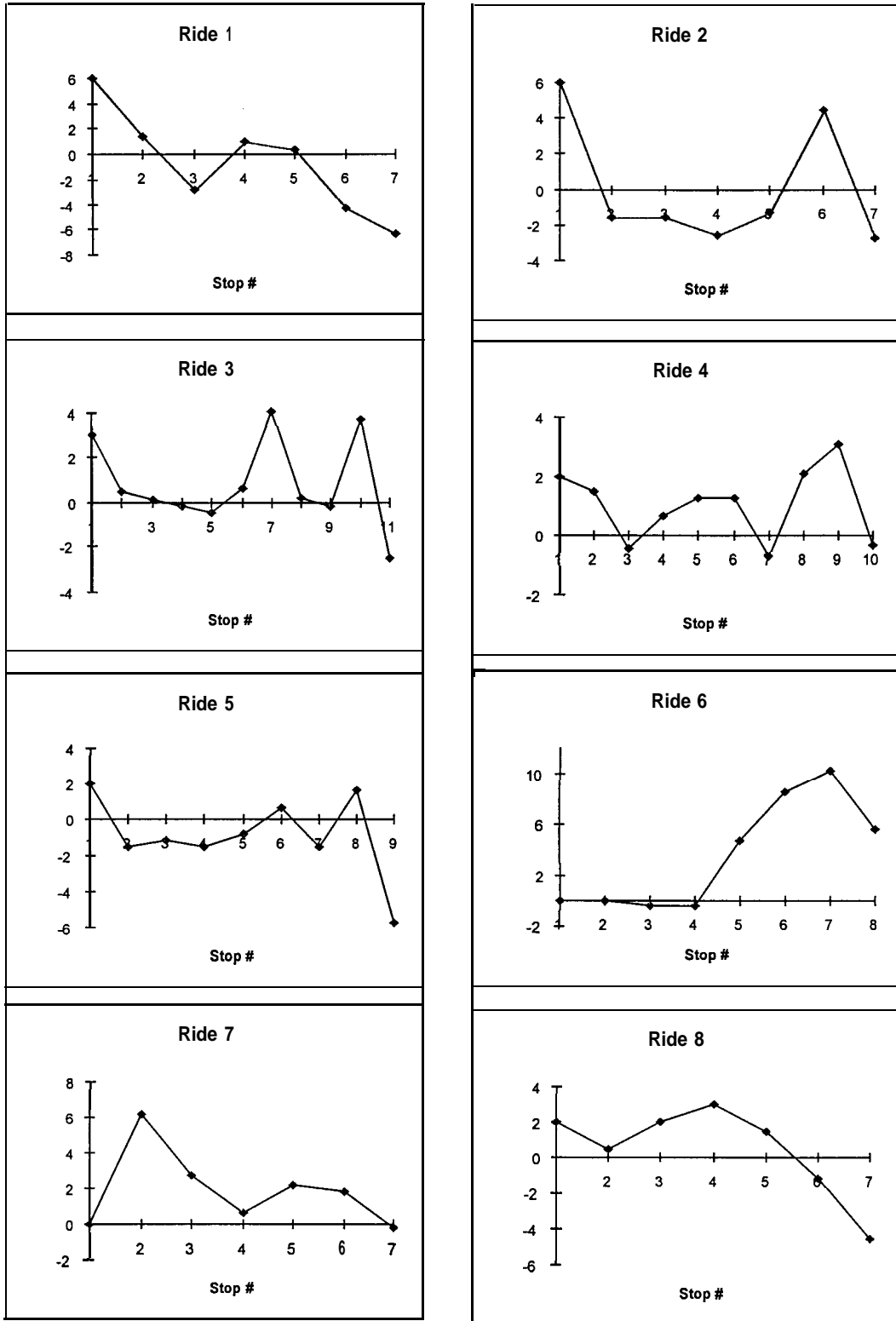
Figure 1. Profiles of Stop Lateness Over the Length of Each Ride

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<u>Boarding and Debarking Times</u>

The boarding and debarking times were not captured individually, but they implicitly form the basis for the dwell time (and dwell time per passenger) calculations. Here, we use the normalized dwell time (DWPP) to examine three questions related to boarding and debarking times:

1. Does the time to issue a transfer significantly increase the DWPP?

2. Does a passenger asking a question significantly increase the DWPP?

3. Does loading or unloading a wheelchair or disabled passenger significantly increase the DWPP?

T-tests were conducted to answer these questions. Stops with driver-induced waits were removed from the sample prior to conducting the tests, as this inflation of the stop time would not be due to the items considered in the questions. Since there is no significant difference between the DWPP values for major and minor stops when long waits are removed (as indicated in the first test in Table 4 below), the data were not separated according to type of stop for the remaining analyses.

Test #	Variable	# of Cases	Mean (sec/pass)	SD (sec/pass)	t-value	two-tailed significance
1	Major Stop	32	9.9	9.1	1.03	.312
	Minor Stop	235	8.2	4.9		
2	Question Asked	21	13.3	10.3	2.37	.027
	No Question Asked	246	8.0	4.8		
3	Transfer Requested	60	9.1	5.3	1.11	.266
	No Transfer Requested	207	8.2	5.7		
4	Wheelchair or Disabled Passenger	28	12.8	7.4	3.46	.002
	No Wheelchair or Disabled Passenger	239	7.9	5.1		

Table 4. OCTA t-test Results for Questions Regarding Factors Affecting DWPP

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The test results indicate that when a passenger asked a question of the bus driver, the time at the stop per passenger was significantly increased. The mean DWPP was 5.3 seconds/passenger higher when a question was asked. Likewise, boarding a wheelchair or disabled passenger similarly increased the DWPP value, from 7.9 seconds/passenger to 12.8. However, when passengers requested transfers, the time at the stop per passenger increased, but not significantly so. The difference between the mean DWPP values is less than one second/passenger.

To evaluate whether the results in Table 4 are biased by the type of area and population served by OCTA buses, these tests were repeated with the MTA data (see Table 5). After long-wait observations were eliminated, eighty-five data points remained. The t-test results for that data were largely similar to those of the OCTA data. There was no significant difference between the DWPP values for major and minor stops in the MTA tests. Asking questions did increase the DWPP (with moderate significance), while requesting transfers did not. The only test showing a different result was the one for wheelchairs, which showed that stopping to load a wheelchair or disabled passenger did not significantly increase the time at the stop. However, only three data points were present for wheelchair/disabled loading, which weakens the results of the test. All in all, the OCTA results do not seem to be distorted by the type of area and population served on the observed runs.

Test #	Variable	# of Cases	Mean (sec/pass)	SD (sec/pass)	t-value	two-tailed significance
1	Major Stop	12	14.0	8.1	.68	.50
	Minor Stop	73	11.4	13.3		
2	Question Asked	8	33.7	30.2	2.3	.06
	No Question Asked	77	9.5	6.1		
3	Transfer Requested	4	12.5	12.3	.13	.90
	No Transfer Requested	81	11.7	12.7		
4	Wheelchair or Disabled Passenger	3	12.9	8.1	.16	.87
	No Wheelchair or Disabled Passenger	82	11.7	12.8		

Table 5. MTA t-test Results for Questions Regarding Factors Affecting DWPP

As a final step in the quantitative analysis of boarding and debarking times, we build a predictive model of dwell time in the OCTA data using the causal factors discussed so far, namely, the number of passengers boarding, the number of passengers debarking, the number of transfers issued, and four indicator variables: major/minor stop, question asked/no question asked, wheelchair or disabled passenger boarded/ no such passengers boarded, and driver-induced wait/no wait. The regression results for this model are displayed in Table 6. Forty-six percent of the variance in dwell time is explained by the model, which exhibits a good fit of the data as indicated by the F-statistic. The t-statistics for the independent variables indicate that all but two variables (the number of passengers debarking and the number of transfers issued) are significant in the model. The insignificance of the transfer variable in predicting dwell time corresponds to the t-test results for the transfer indicator variable in regard to DWPP; it seems the process of issuing transfers adds very little to the boarding time overall. Note that the coefficient for wheelchair and disabled passengers is lower than might be expected when compared to the other binary variables. The wheelchair/disabled category in our sample was dominated by disabled passengers (i.e. people with crutches, canes, walkers, etc.), for whom boarding is longer than that for non-disabled passengers, but quite less than that of wheelchair passengers. Had the reverse been true, this coefficient would no doubt have been much higher.

Regression Statistics	
Multiple R	0.69
R Square	0.47
Adjusted R Square	0.46
Standard Error	31.16
Observations	293.00

ANOVA

	df	ss	MS	F	Significance F
Regression	7.00	247083.96	35297.71	36.36	0.00
Residual	285.00	276692.23	970.85		
Total	292.00	523776.18			

	Coefficients	Std Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	4.69	2.82	1.66	0.10	-0.87	10.24
Board (# of passengers)	4.31	1.15	3.75	0.00	2.05	6.57
Debark (#of passengers)	1.35	1.04	1.30	0.19	-0.69	3.40
Transfers (# passes issued)	-1.47	3.11	-0.47	0.64	-7.59	4.66
Questions (yes or no)	11.87	6.98	1.70	0.09	-1.88	25.61
Wait (yes or no)	83.84	7.28	11.51	0.00	69.51	98.17
Major Stop (yes or no)	20.18	5.46	3.70	0.00	9.44	30.92
Wheelchair/Disabled (yes or no)	16.41	6.35	2.58	0.01	3.91	28.92

Table 6. Regression Results for Predicting Dwell Time with OCTA Data

How well do the results from these tests correspond to the qualitative observations made while riding the buses? Most often when a passenger asked a question, they did so while standing beside the bus driver's seat. There was plenty of room for other boarding passengers to pass the individual posing the question in most instances. However, because a questioner might be standing in front of the yellow line, and because the passenger might not wish to board the bus depending on the answer to the question, the drivers often did not close the door while dealing with questions. Often all other passengers had boarded and taken a seat by the time the question had been satisfactorily answered. Thus, the qualitative data supports the conclusion that asking questions increased the dwell time, and hence the DWPP values.

It was quite clear from observation alone that loading a wheelchair or disabled passenger increased DWPP. When loading a wheelchair passenger, the bus driver left his seat, moved to the back of the bus, asked individuals sitting in the wheelchair area to relocate, activated the lift, loaded the wheelchair passenger, arranged the wheelchair in the designated area, reset the lift, and then returned to

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the driver's seat. This process was conducted after all debarking passengers had cleared the back door and after all fares had been collected from boarding passengers at the front door, so clearly the DWPP rose. At several stops, groups of about a dozen physically disabled youths boarded the bus. These events also increased DWPP values, as the driver often assisted in helping group members to find seats.

The transfer process was observed to be very smooth, as the driver was prepared with transfer slips to give to requesting passengers. Only twice did questions arise in connection with transfers that caused the boarding time to be delayed (these events were captured under the analysis of questions). Otherwise, there was nothing in the observations to contradict the finding that DWPP did not significantly increase due to transfers.

Driver Hours Ratio

Because OCTA does not collect data on driver completion times, the driver hours ratio cannot be calculated for this dataset. Implications for this ratio as gathered from observations made during the ride-alongs will be discussed in the next section.

5.0 Discussion

We divide the discussion section into three parts. The first two parts address questions of whether or not ITS can help improve quantitative and qualitative measures of bus driver effectiveness, as based on the results of this study. The third part examines possible improvements at a systems level rather than at the bus driver level.

Can ITS Improve Quantitative Measures of Driver Effectiveness?

In this section, we examine each of the four bus driver effectiveness measures in turn.

Pull-out Lateness. The pull-out lateness metric is affected whenever either the bus or the driver is late. In our sample, which in terms of buses is admittedly small, almost every bus returned on time,

and therefore was ready on-time for its next run. The ride profiles suggest that slack in the schedule facilitates on-time completion of runs, as even buses that were running late near the end of their run were almost always able to finish on time. Thus, for OCTA, the question is whether or not ITS might help to improve the on-time arrival of the driver. It seems that ITS would have little impact in this realm, as the current computerized check-in procedures are relatively quick. For transit operations with less slack in their schedules, ITS could conceivably aid in the pull-out measure by using information on connecting buses in hold decisions along a line. By doing so, they might increase the percentage of buses that complete their routes on time, and thereby boost pull-out time values.

Stop Lateness. The buses we observed typically ran late because they chose to do so (i.e. by starting out late on their runs, they ended up being late for their first few stops), or because either large groups of passengers or wheelchair passengers boarded. If ITS could provide drivers with information on the location of these passengers, then stop lateness might be more easily managed. For example, a driver might not choose to start off late if she knows a wheelchair passenger will board in an stop close to the beginning of the run. The ITS would thus need to collect information from waiting passengers. This information could be collected from kiosks at each stop, and might include information such as the number of people in the party, their destination, any special needs, etc. Via early identification of large groups of passengers, wheelchair passengers, and other disabled passengers, the expected time of a bus to reach various points could be updated, which would aid in decisions of whether or not to hold connecting buses at major stops. According to OCTA records, their ridership population features only 3.5% wheelchair or disabled passengers. While this number is small, the time to board a wheelchair is quite large, making this feature more attractive. One point to be noted, however, is that this type of information could be collected with a relatively inexpensive system, such as telephone call-boxes, rather than via a full-fledged (and more costly) ITS system.

Boarding and Debarking Times. The results of this study indicate that dwell times are not affected by the issuance of transfers, but they are lengthened by passenger questions and by the loading

of wheelchair and disabled passengers. While there is little that ITS might do to decrease the time it takes to actually load or disembark a wheelchair, ITS might help to improve dwell times by eliminating passenger questions. For this event to happen, the ITS must provide information to passengers via an interactive display. The display could be in the form of an information kiosk at each stop, or as a panel stationed within the bus itself. Interactive display terminals would allow passengers to conduct such inquiries as checking on the location of buses on the given line or of connecting buses, preferably with diagrammatic output.

But will such information displays reduce the frequency of passenger questions? And are they worth the cost? The data from our study show that questions are more frequently asked at minor stops than at major ones. Thus, if kiosks are to be effective, they must be installed at all stops, not just major ones. Obviously, this would greatly increase the overall cost. However, since many of the questions asked concerned the location of a particular shop, it is possible that local merchants might be willing to pay for "advertising" on the system. Passengers could enter a shop name, and be presented with a diagram depicting bus routes that serve it. Display panels on the buses instead of at the stops would reduce the overall number of panels needed, and have the further benefit of being less prone to vandalism and adverse weather conditions. However, since most passengers who asked questions did so as they boarded, it seems unlikely that they will use an information panel located further back in the bus. The logistics of the front door boarding area make placement of the panels near the front infeasible.

Even if a low-cost solution could be found, it is not clear that passengers, especially elderly ones, would resort to the information display when a driver is present. Drivers can point to where the bus coming in the other direction will stop for a return trip. They can gesture to indicate where a passenger should turn to find a shop slightly off the route. Through non-verbal communication, such as smiling and nodding, they can reassure anxious or confused passengers. They also provide real-time information for those who might suspect that the information system contains dated material. These functions simply cannot be replaced by an automated information system. As OCTA serves a large population of elderly

passengers (10.6% according to recent ridership records), it may be that kiosks are simply not worth the expense.

Information kiosks might better serve the riding population if placed only in certain areas along certain routes. It was noted that in sections of the route where the bus population was mostly Hispanic, fewer questions were asked. Bus drivers confirmed that Hispanic riders ask fewer questions, and assume this is because of difficulties in communicating in English. An information system in Spanish thus might better serve that population. However, it certainly would not lower DWPP values, and therefore not improve quantitative aspects of bus driver effectiveness, as currently dwell times are already low since few if any questions are asked.

Total Length of Run.   The total length of run and the driver hours ratio were not discussed in the results section because OCTA doesn't capture a driver's check-out time. However, in thinking about how ITS might improve effectiveness in this area, we turn our attention to the handling of emergency and breakdown situations. Currently, when a driver pulls a silent alarm, radio dispatch must guess at the location of the bus on its route by observing the current time and comparing it to the bus schedule and map of the run. He must form this estimate of bus location because OCTA's current information system does not provide real-time location information. ITS technologies like GPS could place the bus exactly, thereby providing faster emergency support. Likewise, such technologies could directly provide dispatchers with location information on buses that have broken down. As dispatchers must currently get such information via radio dispatch operators, a direct link should reduce decision-making time and thereby improve the speed with which breakdown calls are handled. Overall, the length of run in these extreme situations should be reduced. For more normal situations in which no emergency or breakdown occurs, ITS might again improve the driver hours ratio by improving coordination of buses in decisions of whether or not to hold connecting buses.

What About Qualitative Measures?

It was clear from observations on the ride-alongs that bus drivers provided a social function in their interaction with many of the passengers. One driver we interviewed noted that he has many regular passengers whose connecting stops he has learned. Another was observed to inquire what book a passenger was reading now, then sharing her opinion on other books both had recently read. Drivers were unhurried and polite in their conversations with passengers. Some passengers came to know the driver well over time; they would stand near the front and relate their weekend activities, family sagas, work stories, etc. None of these interactions were observed to detract from quantitative measures of the driver's effectiveness, as many of the conversations occurred either while the bus was moving or while it stood still at a major stop. They were, instead, key indicators of how bus service improves the quality of life for riders. Many passengers clearly viewed the bus driver as a fixture in their community, much like a regular postman. Engaging in conversation with the driver constituted a pleasing daily ritual for them, and lent a pervasive air of congeniality to the bus ride. This phenomena was more distinct when the bus had fewer passengers, but the air of community-oriented service often persisted even when the bus became more crowded.

ITS might improve the quality of life for passengers if it was used to provide information about shops, parks, and other places of interest along routes. However, it would clearly detract from quality of life if it was implemented with accompanying policies forbidding discussion with the driver, or if drivers were instructed to direct passenger queries to the system rather than responding in-person.

Beyond Drivers: How ITS Might Have a Systems Impact

The above discussions focused on how ITS might improve effectiveness at the local level of the bus driver. In this section, we briefly consider insights gained for how ITS might improve effectiveness at a larger systems level. In this realm, we note that ITS technology could completely remove the most frequent radio communication: calls for passenger transfers. OCTA data shows 54.7 percent of riders

request a transfer. (Only 38.2% of the riders in our sample requested a transfer; there is no ready explanation for the discrepancy.) Currently, if the bus is not too crowded, drivers ask passengers who request transfers which bus they plan to catch next. They then radio this information to the control room so that the drivers of the connecting buses can be notified to wait. An ITS with an on-board entry panel for the driver would allow the driver to enter the connecting bus numbers directly into an information system. The data could be summarized and dispatched to other drivers, telling them how many passengers to expect from which lines and how long the expected wait would be. Then, decisions regarding whether or not buses should wait for transferring passengers could be made in one of three ways: (1) locally, by bus drivers themselves acting on the information they have received, (2) globally, by the information system itself via a set of expert system-like rules with possible radio dispatch override, or (3) globally, by radio dispatchers themselves, who could view passenger transfer information for all buses. In any of these cases, the handling of transfer requests should be quicker, and decisions regarding them should improve overall measures of stop lateness. Under options (1) and (2), there is the added possibility of improving labor productivity measures by reducing the number of radio dispatchers required to run the system. While these global measures might improve, some disadvantages may exist for individual drivers. First, although system-wide measures of stop lateness might improve, values might rise for individual bus drivers. In addition, the ITS-enhanced transfer procedure might increase individual dwell times. Although current transfer procedures do not have an impact on dwell time per passenger, nor do they predict overall dwell time, much of the communication of information regarding requested transfers is conducted while the bus is in motion. Under the suggested procedure, the information would be gained and transmitted during boarding, and thus runs the risk of increasing dwell times. Under these scenarios, the ITS might cause mismatches between individual incentives and system-wide goals which would need to be addressed, most likely through changes in evaluation and reward policies.

6.0 Conclusion

Overall, the findings of this report suggest that while ITS may have a small potential for improving certain measures of driver effectiveness, current practices among drivers and passengers alike are likely to limit actual gains. Gains are also limited simply because so many events that occur in the course of driving a bus over a run are beyond the control of an individual driver (e.g. traffic, wheelchair boarding, etc.) regardless of the amount of information he or she receives. Specifically,

- ITS is not expected to have much impact on pull-out lateness measures, especially for bus lines with considerable slack.

- ITS does have potential for reducing stop lateness by alerting drivers to upcoming large groups or wheelchair/disabled passengers. However, other, less expensive options, such as telephone call-boxes, could provide this service instead.

- Although ITS could provide information that would enable drivers to better pace their buses over their runs, it is not clear that they would do so. Many seem to enjoy long breaks at major stops. Thus, although there is great potential for the use of ITS to improve the pacing of buses over their routes, that potential can only be realized with changes in work rules and their enforcement. For example, currently it is a violation of OCTA work rules if a driver fails to pace the bus over the route. However, because timed check-points exist only at major stops (i.e. there is no monitoring of pace across minor stops), and because no penalties are awarded for *arriving* at a major stop early (only for leaving early) there is in effect no enforcement of the pacing rule.

- When passengers ask questions, boarding times are raised, which increases dwell times. However, it is not clear if ITS can remedy the problem by providing automated information. For a number of reasons, passengers may continue to prefer having their questions directly answered by a human driver.

- Calls regarding transferring passengers, which currently constitute the most frequent cause for radio communication, can be handled directly and efficiently through ITS, with the possibility of improving a number of system-wide measures of effectiveness. However, there is the chance of simultaneously diminishing individual driver effectiveness measures, thereby setting up mismatches between driver incentives and system goals.

In our future work, we intend to examine the impact of ITS on bus driver effectiveness based on observations of in-place ITS systems. Specifically, we plan to observe changes in bus driver and system-wide effectiveness measures after GPS technologies are introduced on a number of OCTA buses. We will compare the results of that study with the predictions of this one.

Acknowledgment

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