IDENTIFICATION OF POTENTIAL HUMAN FACTORS ISSUES RELATED TO APTS: INTRODUCTION OF ENHANCED INFORMATION SYSTEMS (Work in Support of the Federal Transit Administration)

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ABSTRACT

Introduction of enhanced information systems into an operational environment requires reallocation of functions among those responsible for providing service. This study describes an effort to develop and apply a methodology to identify the types of human factors issues associated with introducing an Advanced Public Transportation Systems (APTS) type system. The focus of this study is the categories of transit employees, dispatchers, supervisors and bus operators in this application, most immediately affected by the introduction of a category of APTS known as Automatic Vehicle Location (AVL) systems. Information is obtained from the Denver Regional Transportation District (RTD) which is currently installing an AVL information system.

The methodology developed requires collection of two sets of data to record the existing transit operation, as well as transit system operation using AVL technology. The measures of the existing system provide a baseline set of data against which to identify the human factors issues expected with AVL.

Data collection focuses on documenting the communication activity between dispatchers, supervisors and bus operators, prior to, and following the introduction of an AVL system. Data is obtained from individuals as well as from transit system measures.

The analyses in this paper are based on work in progress and, as such, can only identify potential human factors issues. At this time, it is not possible to know if any of these potential issues will become operational issues. In addition, the analyses do not incorporate the results of the other improvements which the transit system is also making at this time.

Based on this preliminary analysis of work in progress, some potential human factors issues which may accompany the introduction of an AVL system are the following: task allocation between dispatcher and the automated system, differential allocation of communication after AVL implementation, changes in work roles following introduction of AVL, changes in workload, and adaptive responses to these changes.

PURPOSE

The purpose of this research effort is to understand how the introduction of a technological change into a transit system will impact transit system employees because they are a major cost and functional element in any transit system. Identification of the potential human factors issues associated with Advanced Public Transportation Systems (APTS) installations will contribute to developing features of APTS which are adapted to transit system and employee needs. This paper describes a methodology and the preliminary results of its application to identify the potential types of human factors

issues associated with APTS systems. Other transit systems, contemplating introducing such a change, may find it valuable to learn how a metropolitan bus system achieves its goal of maintaining a high level of passenger service while improving efficiency through implementation of an APTS system.

The information in this paper is based on a category of APTS known as Automatic Vehicle Location (AVL) systems. AVL systems use information, communication and navigation technologies to provide real time information to enhance the efficiency of bus operations. The transit system employees most likely to experience the increased amount and improved quality of information due to the introduction of AVL are the dispatchers, supervisors and bus operators.

The contents of this paper are based on work in progress, supported by the Federal Transit Administration (FTA), to identify the human factors issues associated with the introduction of an AVL system at the Denver Regional Transportation District (RTD).

The analyses are based on work in progress and can only identify potential human factors issues. At this time, it is not possible to know if any of these potential issues will materialize into operational issues. In addition, the analyses do not incorporate the results of the other improvements the transit system is also making at this time.

DESCRIPTION OF THE AVL SYSTEM

In March 1992, the Denver RTD made the decision to obtain a satellite based system, using AVL technology, to track its buses. This AVL system can report bus locations within 100 feet using a Global Positioning System (GPS), supplemented with dead reckoning (odometer sensing only) for areas where GPS signals are not clearly received.

The goal of this AVL system is to assist RTD to improve the operational efficiencies of the bus service by maintaining and updating scheduled headways and giving passengers more accurate information about real time operations. Information from the AVL system will give dispatchers a more efficient way to adjust on-street operations and to respond to emergencies. Real time bus location information will be used to update schedules.

Denver RTD is obtaining the "SmartTrack" AVL system from the Westinghouse Electric Corporation, who is also providing the systems integration. This AVL system has two computer screens. The Automatic Vehicle Location (AVL) screen is a geographic map which shows vehicle status. AVL will be customized to include RTD's "train card" program and head ways in addition to the geographic map with real time vehicle locations. The second screen, the Computer Aided Dispatch (CAD) screen, is the control center. It can prioritize the radio calls, handle eight "requests to talk" at once, and has "pull down" option menus.

Westinghouse will also provide transit controlheads to be installed in each bus. The controlhead's display will show the current time, schedule status, notification if off route and text messages from the dispatcher. There are twenty buttons on the transit controlhead which the bus operator can use to send precoded messages to the dispatcher. If the transit controlhead fails, the radio system reverts to radio communication using the handset.

Denver RTD is obtaining Centracom Series II Plus Radio Consoles from Motorola. This radio equipment has these new features; an intercom between the Boulder and Denver dispatchers and between consoles at the Dispatch Center, "voted" multi-channel transmitter and repeater control, the ability to patch between radio frequencies, a secure channel for supervisors and storage of the last ten bus numbers in active memory. These radio consoles have nine channels, two for data and the remainder for voice transmission, including five voice channels for buses.

The installation of the AVL components affecting dispatchers, supervisors and bus operators began in the summer of 1992. Work to support the GPS technology was performed during the summer and fall of 1992. The repeater microwave system was installed by September 1992 and the service area was mapped during the summer and fall of 1992.

In August 1992, an AVL console was placed in the Dispatch Center for test purposes. During November 1992, representatives from Motorola and Westinghouse Electric Corporation trained the dispatchers on the use of the new console and the CAD and AVL screens. Dispatchers had two training sessions in November. A Motorola representative conducted the first session to teach them how to use the new radios. At the second training session Westinghouse taught the dispatchers how to use the AVL/CAD screens, including techniques for "mouse" use to access the "pull-down" menus.

New radio equipment will be installed on the RTD buses, including contractor buses, leased by RTD to the contract carriers, and in contractor owned buses. RTD began installing equipment in buses in March 1993 and plans to install radios in five buses per day. It will require seven months to complete this installation. Buses which have had the new radios installed will be used with the AVL equipment immediately after installation.

DESCRIPTION OF DENVER RTD OPERATIONS

Table 1 summarizes the characteristics of the bus service during the fall of 1992, prior to installation of the AVL system. When AVL is implemented in 1993, bus service data will again be collected to document the service level supported by AVL.

	Baseline	AVL System Implemented
Ridership		
Revenue Service Boardings/Weekday*	150,748	TBD*
Mall Service Boardings/Weekday (no fare)	45,234	TBD
Total Boardings/Weekday	195,982	TBD
Service Coverage		
Route Miles	2,350	TBD
Number of Routes	153	TBD
Service Area (Sq. miles)	2,304	TBD
Population of District	2 million	TBD
Operations		
Employees	1,929	TBD
Total Vehicle Hours/Weekday	6,793	TBD
Revenue Service Vehicle Hours/Weekday	5,015	TBD
Total Vehicle Miles/Weekday	106,700	TBD
Revenue Service Miles/Weekday	86,292	TBD
Bus Speed in Service	17.3 M.P.H.	TBD
Overall Bus Speed	15.7 M.P.H.	TBD
Buses-A.M. Peak	629	TBD
Buses-P.M. Peak	649	TBD
Buses-Midday	320	TBD
Contractor Service %	23%	TBD
Schedule Adherence	88%	TBD
Customer Service Calls / Weekday	209	TBD
Complaints/Weekday	72	TBD

*Mean weekdays, October 92; ** To be determined after AVL system implemented

Table 1: Characteristics of Denver RTD Service

RTD serves a six county "metro area" using a 800 bus fleet and, approximately, 650 buses in peak hour service. There is a free shuttle bus service along the length of a downtown pedestrian mall which has bus terminals at each end of the mall. Contract operators provide one fifth of the bus service.

The buses operate in tightly timed network serving a large geographic area. The dispatchers make the operational decisions necessary to maintain headways and have central operational control. Dispatchers work out of the Dispatch Center at the RTD Operations Center which has two active consoles and a lead dispatch position. Supervisors are primarily vehicle based and monitor bus schedule performance and respond to field situations as directed by dispatch.

Denver RTD employs more than 800 bus operators; there is frequent hiring, due to turnover. Operators start as part-time employees.

Denver RTD maintains a management information system which gives access to system operating data. RTD departments uses this system for operational information. RTD plans to retain the format of the management information system after AVL system implementation.

IDENTIFICATION OF HUMAN FACTORS ISSUES

Methodology

The goal of this human factors analysis is to identify the potential human factors issues associated with the transit system employees by comparing employees' work activities before and after system installation. This methodology specifies the steps necessary to identify human factors issues associated with AVL implementation.

It is necessary to be familiar with the technical capabilities of the site specific AVL system to develop a plan for the research. The plan guides the field data collection, identifies what data should be collected, and how the data relates to AVL technical capabilities.

Two types of data are collected from the field, i.e., observations of and interviews with employees and systems measures of RTD's operations. The field data collection began by talking with employees and asking them to list their activities by frequency. Data was obtained from system operating measures and reports such as logs and the Dispatcher Daily Activity Record.

Data is collected about the affected employees, i.e., dispatchers, supervisors, and bus operators in terms of their activity, procedures, attitudes and ergonomic issues related to equipment use. Activity data measures communication in terms of its frequency, duration, type and intensity. Procedures data is information about staff, schedule, facilities, equipment and routine as well as non-routine practices. Employees' attitudes are recorded to understand how they view their jobs and what are their expectations for the AVL system. The ergonomics data documents how employees use AVL equipment to perform their tasks and the environmental and situational factors which affect use of equipment.

The plan also identified the need to record level of service data during the baseline as well as after AVL system implementation. Level of service data will be used to control for changes in the bus service as well to standardize dispatcher, supervisor and bus operator data for comparison purposes. This study calculates the incidence of bus operators calls to dispatch by total service hours and total miles per day.

The human factors analysis requires two data collection periods. If human factors data is only collected after the AVL system is implemented, a condition which might be identified as a human factors impact may actually be a preexisting condition. Measuring conditions prior to the introduction of an AVL system, during the "baseline," records operational levels prior to AVL implementation and gives a way to assess the human factors impacts associated with AVL implementation while controlling for factors unrelated to the AVL implementation.

The baseline data for the human factors analysis of the Denver RTD was collected in August and October 1992 before the dispatchers, supervisors and bus operators had received training on AVL equipment. "After implementation" data will be collected in fall 1993 when the entire bus fleet has had AVL equipment installed.

Although the methodology specifies data collection prior to and after AVL implementation, there may be human factors issues which arise during the transition to AVL system use. Some possible issues which might arise during a transition period are the following; what happens when the bus operation is "cut over" to AVL use, how are policy decisions and operational definitions for using AVL equipment developed, how are employees trained to use AVL and how do employees get information about AVL. Although data is not collected during the transition, the research staff is maintaining an awareness of the process.

Data

Dispatch activity creates a communication network most often involving supervisors and bus operators. The basic data measured is communication activity between dispatchers, supervisors and bus operators.

Activity data between dispatchers, supervisors, bus operators (and others) is measured in terms of frequency, time of day, type, intensity and duration. Because dispatchers must simultaneously handle numerous incidents, intensity refers to the number of incidents handled per unit of time and actions required to resolve an incident. Duration is the time required to resolve incidents and it is measured as the difference between the time of the pencil log entry and the computer log entry. This type of information is obtained from transit operator records as well as from observations of activity.

The frequency of activity on the days of the site visits for data collection and observation was compared with transit system activity measures to see if the activity on site visit days is representative of the typical activity levels. The mean weekday frequency of calls to dispatch was 224 in 1992 (January-August 20, 1992). Site visits occurred on days representative relative to system measures. Representatives of the RTD said the days selected represented "normal" operating levels.

Data is collected from organizational records as well as from individuals. Organizational data sources include RTD records such as supervisor activity logs, dispatch logs, records of calls to Customer Service and measures of the transit service such as revenue hours and revenue service hours. Data is obtained from individuals using open-ended interview questions and observation. To make efficient use of data, the data about the organization and bus operations is linked with data from individuals by coordinating date and time of individual data collection with the corresponding organizational data.

COMMUNICATION ACTIVITY-COMPARISON OF BASELINE CONDITIONS AND AVL SYSTEM CAPABILITIES

This section contrasts the current or baseline communication procedures of dispatch, supervision and bus operations with the AVL system's communication capabilities.

Baseline-Dispatch

Each of the two active dispatch positions covers one of the two bus channels. Bus sub-fleets are allocated to channels by bus number and dispatchers rotate channel coverage by shift. Dispatch positions also have radio channels for maintenance trucks and for supervisors. The one dispatch position in Boulder has a separate radio channel for their buses. To contact their buses when they are out of reach, they telephone the Dispatch Center to relay messages.

When a dispatcher receives radio calls from a bus, a print out is made of the time and bus number and the process makes a noise similar to a teletype. The digital console in front of the dispatcher displays the vehicle number of the bus calling. Using the printer noise as a cue, the dispatcher looks at the bus number on the console and types it on a computer keyboard. A computer screens displays the bus's scheduled assignment ("train card") and operator. Because the bus number and the operator assigned may differ from the computer information which uses the schedule created as a result of the "vote", the dispatcher asks for verbal confirmation of the operator's identity, work and location.

To communicate with the bus operator, the dispatcher pushes down on a foot pedal and speaks into a microphone asking "bus calling, come in." The dispatcher enters the call at the same time on the paper log. The dispatcher transcribes these logs into the computer log, as soon as possible, and codes log entries by RTD's problem codes.

A dispatcher can talk to from one to four buses at once or to the whole fleet. If a dispatcher needs to notify all buses on a route of a detour, for example, the dispatcher must announce it to the entire bus fleet.

Dispatchers relay messages between supervisors and bus operators. RTD dispatchers communicate directly with the operators of contractor buses and relay messages between these operators and the contractor operators' dispatchers and supervisors. RTD dispatchers and supervisors can over-ride contractor operators' dispatchers and supervisors' decisions.

RTD provides 50 dispatch hours per weekday to handle an average of 245 calls. The frequency of calls to dispatch is only a partial representation of dispatch activity. Frequency

of dispatch contacts with parties (bus operator, maintenance truck, police, etc.) are 36% more than the calls in the computer log and two thirds of these 333 contacts are with bus operators.

Dispatchers respond in many ways to the calls received. Dispatchers make radio calls not recorded in the computer log which can be calls back to an initiator as well as radio and telephone calls to other sources of help or information. Other dispatch activities include entering log data, making telephone calls, checking for availability and recording use of extra service and conferring with other dispatchers.

The frequency and duration of recorded radio calls, as well as radio calls not recorded, computer log entry activity and telephone calls was observed for peak and off peak operations for six and one half hours. For one call recorded in the computer log, it is estimated that there are, on average, five dispatcher actions. The mean duration of a dispatcher activity is 47 seconds which suggests that dispatchers are involved in some action for two out of three minutes during a twenty four hour day. On average, 44 minutes elapse between when a call is received and when it is recorded in the computer log. During the afternoon peak hours, elapsed time averages 61 minutes before entry into the computer log.

AVL System Capabilities-Dispatch

The AVL system has routine transmission buttons which should reduce the frequency of voice communications and expand the capability to serve. When an operator presses the "request to talk" button, the AVL screen will show his location. The dispatcher selects the top priority on the CAD screen which show multiple "requests to talk" and the dispatcher handles these requests by keyboard.

The dispatcher, looking at the CAD screen, will select incidents shown on the screen by priority and respond by key board.The dispatcher also watches the AVL screen for a graphic display of incidents, for example, a bus's on-time performance will be color-coded.

Dispatchers will be able to talk with each other using an intercom. Dispatchers will be able to patch calls between supervisors and bus operators which may reduce the number of calls dispatchers make relaying information. When a bus leaves the garage, the AVL system opens a log with the bus number and the operator number. The operational log is in the AVL system.

There will be three dispatch positions at the Dispatch Center, one more than presently exists, as well an AVL equipped dispatch position in the maintenance area. Table 2 compares dispatch procedures to report schedule performance and bus location, to communicate and to report capacity passenger loads in the baseline with changes following AVL system use.

Baseline	AVL System Implemented
Schedule Maintenance	
on time performance- -field checks by supervisors -operators initiate radio call to dispatch to report schedule adherance	on time performance- -off schedule buses flagged
on route performance- -operator initiates radio call to dispatch to report off route -supervisor may observe and report to dispatch -supervisor may contact bus	on route performance- -off route buses flagged, location shown
Communication	
security problem- -operator initiates radio call to dispatch -operator calls "mayday," if life threatening -operator gives location, describes problem verbally	security problem -operator presses transit control head button,activates covert microphone, if life threatening -call prioritized to top of list, flashing red bus gives location. Covert microphone opens
accident -operator initiates radio call to dispatch, -operator gives location, describes problem verbally	accident -operator presses "priority request to talk" button, transit control head -call is top priority, AVL screen shows location
maintenance problem -operator initiates radio call to dispatch -call in queue, answered in order received -dispatcher contacts maintenance truck by radio if in field, by telephone, if at garage	maintenance problem -operator presses "maintenance, in or out of service" button, transit control head -call prioritized on screen, dispatcher response depends on priorities. AVL screen shows maintenance truck location -dispatcher contacts maintenance truck by radio if in field, telephone if at garage.
Bus Location	
bus missing- -dispatcher tries to contact by radio -dispatcher calls supervisor to search -dispatcher calls police to search	bus missing- -screen message if bus off route including number and location
Capacity Passenger Load	
-operator makes radio call to dispatch -dispatch calls up "train card" on screen for numbers of other buses scheduled on route -dispatch makes radio calls to find bus to help	-operator uses transit control head button to report capacity load -screen locates bus -information given to buses on route with one command

Table 2: Comparison of Dispatch Procedures: Baseline and AVL System Implemented

Baseline-Supervision

The coordination between dispatchers and supervisors is allocated such that supervisors are responsible for the immediate problem they see and are responsible for making the decisions at the scene. Dispatchers "should have the last word over operations" and they are responsible to assign support such as extra service, maintenance trucks, etc.

Supervisors are assigned to vehicles except for the two supervisors assigned to the Mall. The supervisor's radio monitors four channels: the supervisor's channel, two bus channels and a channel for the maintenance truck. Supervisors communicate using the supervisor channel which is set on priority and can override bus channels. Supervisors tend to listen to the bus channels.

Supervisors' vehicles carry a variety of equipment including an adjustable lamp attached to the dash board, notebooks listing "headways" and names of operators by route to help with the "checking" placed opened on the front passenger seat. They carry items to assist them to keep buses

in service such as a tool kit to unjam fareboxes, chains, sign material to make portable signs, water, shovel, etc. Supervisors also carry the many forms they must complete as well as a camera to document accidents.

Supervisors are assigned to geographic areas and keep area coverage until late at night when the on-duty supervisors cover the downtown area. Supervisors perform an average of 22 activities and drive 69 miles per weekday. Almost four fifths of the supervisor activities are route and time checks of buses and contacts with operators.

AVL System Capabilities-Supervision

The actual number and responsibilities of supervisors has not yet been fully specified. Supervisors will have lap top computers as data terminals and will use them to log on. Supervisors will use keyboards to enter data such as location. These computers will display vehicle information text with real time data on the current status of buses. Supervisors will access the RTD train card to see scheduled times. The supervisors' radios will be controlled by the Motorola radio system. Supervisor vehicles will appear on the dispatcher's AVL screen.

Baseline-Bus Operation

Each bus has a radio which works on one of the two bus channels. A bus operator keys up the "mike" on the console and calls dispatch using the bus number. Buses do not have emergency alarms. Operators call in the emergency and, if it is life threatening, call "mayday."

Bus operators, including contract operators, make an average of 223 calls to dispatch per weekday. The largest number of bus calls to dispatch report that the bus is running late. One quarter of the bus calls to dispatch are to report they are running late or to request schedule information. Contract operators initiate more calls to report running late or request schedule information.

AVL System Capabilities-Bus Operation

To speak with a dispatcher, the bus operator will press a button on the controlhead labeled either "request to talk" or "priority request to talk" if there is an urgent need to speak. For easily categorized problems, the bus operator pushes one of the labeled buttons. The dispatcher will respond to highest priority call in the queue.

The AVL system provides an emergency alarm which, when pressed, the AVL screen shows the bus's location to the dispatcher and a covert microphone opens. AVL system features include the following; the computer will assign a bus to a voice channel, bus operators will not need to call dispatch for radio checks and Boulder buses could be dispatched from the RTD Operations Center using the AVL/CAD capabilities. If the computer fails, the AVL system reverts to voice communication as existed prior to AVL. The AVL system has a telephone or radio to use if the computer is down. Each console has an emergency power generator.

POTENTIAL HUMAN FACTORS ISSUES RELATED TO AVL

The following potential human factors issues have been identified from work in progress. They are based on data analyses as well as interviews, observations and comments offered. They represent a preliminary effort to identify the types of potential human factors issues which might be expected with implementation of an AVL system. The value of such preliminary identification of potential issues is that it offers a awareness and the possibility of addressing such issues during the implementation process should the need develop.

Potential Human Factors Issues-Dispatch

Based on a review of the baseline dispatch procedures and the changes anticipated with AVL system implementation, the following potential human factors issues may arise.

Changes in Workload

Dispatchers say they expect their workload will become heavier and more demanding because they will have more information to monitor. This concerns them for two reasons; they fear losing their ten hour shifts because their work may become too tiring and they worry about being able to provide the same level of service during the transition to full use of the new AVL equipment.

It is likely that the quality of a dispatcher's work will become more intense because bus operators can dispose of routine calls by using the transit controlhead. Bus operators will have more information displayed on their transit controlhead and will use it to obtain information about their performance. The volume of voice communication from bus operators ought to be fewer in number but more demanding. The dispatcher's work pace will be less frequently interrupted by routine calls which interrupt the intensity of their work flow.

Because the information available to dispatch with AVL is more complete and centralized, dispatch will be more isolated and yet will consolidate its central operational control. In the baseline, dispatch relied on a network of inputs to develop a partial understanding of a real time incident. Using AVL, the dispatcher will have a more complete picture and yet will not have the richness of the ancillary commentary from the field network. The reduced sense of team inputs and the enhanced and centralized information may increase the workload felt by dispatchers.

Availability of Redundant Information

Baseline dispatch procedures, i.e., teletype's paper tape, pencil log, computer entry, have overlapping information and this redundant information helps to maintain a high level of service. Dispatchers have been observed referring to the paper tape or the pencil log to check the status of something. When dispatchers are not able to enter bus numbers, they use binders containing printed headway schedules placed near the dispatch position.

Because dispatchers deploy supporting service they need to know the exact availability of equipment. They check completed paper logs to determine the availability of equipment to support service, i.e., the availability of a bus for extra service.

Dispatchers may expect to use some form of hard copy to refer to past actions or to use in case of system downtime. The dispatchers have said they want to access paper logs even after the AVL system implementation.

Excessive Workload Demands

In the baseline period, when workload shifts becomes excessive, usually due to exogenous events, there are two customary response modes. The lead dispatcher may assist the dispatcher by coming to the active position to handle the less pressing matters or the dispatch job is split into radio communication and data entering and telephone contacts. The latter response is employed when there is a snow emergency which can double the workload. In a snow emergency the dispatch task is divided by separating the radio, report entering and telephone tasks and using auxiliary staff to provide richer information by monitoring sand trucks, location of stuck buses. Procedures need to be developed to respond to edge of the envelope workload demands when AVL equipment is used.

Handling Unresolved Incidents

Many calls to dispatch require the dispatcher to gather information and identify resources to assist which can require extended communication, as, for example, when a RTD dispatcher must relay calls from contractor bus operators to contractor dispatchers and back. Dispatchers have evolved procedures to highlight unresolved incidents using such things as colored marks on the pencil logs. AVL may shorten the chain of calls necessary to diagnose the problem and mobilize resources so that these devices are less necessary.

In the baseline condition, many calls to the dispatcher remain unresolved for a length of time. A dispatcher may handle four or five incidents at the same time which require a series of communication. With AVL, a call shows on the screen and the second call will eliminate the first call unless the dispatcher "parks" the previous call so that it can be pulled up later or search for using the bus number. Dispatchers have said they want a way to retain the preceding call visually and would like a printed record of the computer logged entries in AVL to assist them. They have asked about attaching a real time printer.

Heterogeneous Contacts

Two thirds of the dispatchers' radio calls in the baseline are from buses and, with AVL, many of these communications may be transmitted through the controlhead. One fifth of the calls are from contractor dispatch, police and emergency personnel and maintenance truck drivers. These parties also will need to learn procedures to use the new AVL communication channels and procedures. If their calling procedures vary between them this could cause an additional workload for dispatchers.

It was unclear during these training sessions what procedures the street supervisors would use to sign on and off. This is one of several policy issues regards use of AVL requiring operational decisions.

Adaptation to New Equipment

The dispatchers say they do not anticipate that adapting to the new consoles will be a problem because "they ... (are) familiar with buttons." They are concerned about people coming in and "looking at people in a 'fishbowl.'"

Dispatchers commented on the physical location of the new AVL consoles compared with their previous arrangements which were "side by side" and helped because they comment that they often work together. The dispatchers disliked the height of the new consoles because it prevented them from seeing one another to notice whether, for example, another dispatcher is using the telephone. Dispatchers would like the AVL consoles to be placed closer together so they can both see and hear each other's activity. For example, the same information on the bus ID number is shown on both consoles but they can't see it because their positions are separated.

Dispatchers' duties do not always require a stationary position in front of a console. Some dispatchers have other duties which may take them away from their position. They may need a sound cue similar to what the teletype provided.

Potential Human Factors Issues-Supervision

Changes in Workload

The supervisor's job must be redefined because a major portion of the supervisor's job, route checking and monitoring schedule adherence, will be performed by AVL. These checking activities occupy a significant portion of a supervisor's time but they can be deferred if an emergency arose. Even if some supervisors remain in the field, their coordination with

dispatch will change because dispatch will have more information about the field and about their location and activity.

Access to the "Party Line"

Although they only need to listen to the supervisor channel, supervisors listen to the bus channels on their radio. They put the supervisor channel on priority but have the other channels constantly on. They say that "listening to dispatch enables (them) to stay on top of things, ...(they) can anticipate where... (they will be) needed." Because they are usually alone in their vehicle for ten hour shifts, listening to the radio links them to the RTD operation.

When the supervisor puts the scanner on, it locks onto a frequency which allows them to monitor the active bus channel. When AVL equipment is installed, the supervisor will have a scanner but the bus frequency changes depending on the computer assigned frequency, making it difficult to monitor a communication sequence.

Adaptation to New Equipment

The lighting in the street supervisors' vehicles varies by time of day and weather condition, including glare. Their vehicles have adjustable lights clamped onto the dashboard and they use them frequently. The AVL equipment will have to be used in these varying conditions.

Supervisor's vehicles tend to be crowded because they carry a lot of equipment and forms. Supervisors use the front passenger seat like a desk top for their reference material and completing forms. The remaining supervisors will have to adapt to the physical layout of the AVL equipment in a physically tight environment.

Potential Human Factors Issues-Bus Operation

Changes in Workload

Bus operators' workload may increase because they will have to use more judgement in categorizing their call to dispatch. They need to make operational decisions about what transit controlhead button to use and anticipate that the response may be transmitted to the display with a variable response time.

Reinforcement of Training

In the baseline bus operators do not call dispatch often. Slightly less than one in 20 bus operators per work shift (based on .03 per 10 total vehicle hours which is approximately the length of a bus operator's shift) or 9% of the operators in the pm peak made a call to dispatch. If this rate continues when AVL is installed, bus operators may have difficulty remembering how to use the AVL equipment effectively. Bus operators, with relatively high turnover must learn how to use, on an infrequent basis, technologically advanced equipment.

Change in Procedures

With the CAD screen, dispatchers can take non-priority calls at their own pace. Bus operators may experience more variability in response time to their call to dispatch because calls will be prioritized. This uncertainty may cause some uncertainty and bus operators may revise the expected operating procedures to acquire the information they need as quickly as they hope to receive it.

Adaptation to New Mental Models

Initially bus operators will continue to employ their baseline mental models of communication with dispatch. In the baseline model observation showed that bus operators receive reassurance and support as well as information. It is expected that bus operators may make different types of calls to dispatch using the AVL equipment because more information on operations, schedule adherence and route maintenance is provided to operators on the transit controlhead.

PRELIMINARY CONCLUSIONS

The potential human factors issues described in this paper have been formulated in relation to the AVL implementation at Denver RTD. It is possible to extend this work to generalize about potential human factors issues which may be associated with the introduction of AVL systems. However, the potential human factors issues identified should be considered preliminary because RTD's AVL system is currently being installed and this analysis does not incorporate the effects of other transit system improvements being introduced at the same time. In addition, other transit systems may differ in terms of their organization as well as their employees' experience.

Based on this preliminary analysis of on-going research, the following types of potential human factors issues may be considered in relation to AVL installations.

- job redefinitions of supervisors and consequent effects on dispatch and bus operations due to communication network characteristics of baseline operations.
- decreased richness of information and "party line" participation for the remaining field operations monitors.
- increased performance level expected from bus operators who must diagnose problems to communicate with dispatch.
- how dispatch adapts its need for redundancy and easily retrievable information sources.

- how the team work supporting dispatch operations is realigned.
- how the dispatch activity develops responses to significant changes in workload, i.e., as with major storms.
- possibility of more intense workloads for dispatch and how stress reduction is obtained; i.e., more frequent breaks to maintain attentiveness.

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