Analyzing Railroad Dispatchers' Strategies: A Cognitive Task Analysis of A Distributed Team Planning Task

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ABSTRACT

This paper describes a preliminary cognitive task analysis (CTA) that is being conducted to examine how experienced train dispatchers manage and schedule trains. The CTA uses ethnographic field observations and structured interview techniques. The objective is to gain insight into the cognitive demands placed on train dispatchers and the strategies they have developed in response to those demands, as an input to guide development and design of digital communication systems and advanced information displays.

The paper reports selected results of the CTA that reveal some of the complexities faced by train dispatchers and the cognitive and collaborative strategies they have developed in response to those demands. The results of the preliminary CTA reveal that dispatchers have developed a variety of strategies that smooth the way for trains to pass through territories safely and efficiently and satisfy the multiple demands placed on track use. In many cases these strategies depend on communication and coordination among individuals distributed across time and space. A core basis for coordination is the use of radio as a communication device that provides for a shared frame of reference. The ability to overhear communications directed at others that have a bearing on achievement of your own goals and to recognize when information in your possession is of relevance to others and broadcast it, are important contributors to efficient management of track use. Dispatchers' planning and scheduling is proactive, anticipatory and opportunistic – taking advantage of windows of opportunities that arise to satisfy the multiple demands that are placed on track use. The results have implications for training and the application of advanced display and communication technologies to improve train routing safety and efficiency.

INTRODUCTION

As part of it's efforts to investigate the safety implications of applying emerging technologies to railroad operations the Federal Rail Administration's Office of Research and Development is sponsoring a cognitive task analysis (CTA) of railroad dispatcher's activities. This CTA will be used to understand the implications of the adoption of "data link" type communication systems to the railroad environment. While data link has the potential to increase safety, and improve productivity and efficiency of railroad operations, it is important to clearly understand how this technology can affect human performance.

The purpose of the CTA is to examine how experienced train dispatchers manage and schedule trains in today's environment. The objective is to gain insight into the cognitive demands placed on train dispatchers and the strategies they have developed in response to those demands as input to guide the development and design of "data link" digital communication systems and advanced information displays. The intent is to identify (1) cognitive activities that could be more effectively supported through the introduction of new technology as well as (2) features of the existing environment that contribute to effective performance that should be preserved when transitioning to new technologies.

Train dispatching is an example of a distributed team planning task in that it requires communication and coordination among multiple individuals who vary in scope of responsibility, task focus, and access to information [1]. In the dispatch center we are studying there are 7 dispatchers working in parallel, each responsible for different territories, who must coordinate with each other to optimize on-time train performance.

They must also communicate and coordinate with train engineers, train masters, and track maintenance workers, each with different performance objectives and access to different information relevant to track management

decisions.

This paper reports results from a preliminary CTA that was conducted to gain an overview of dispatcher decision-making activities, sources of complexity, and the knowledge and skills that underlie dispatching expertise. The objective was to identify opportunities for improvement in performance via changes in training, practice or introduction of new technology. A particular focus was on characterizing current communication practice between train dispatchers and other personnel that impact train routing decisions (e.g., train engineers, train conductors, maintenance of way personnel, chief dispatcher) as input to development of new concepts for off-loading radio-based communication on to alternative media (e.g., computer-based data link communication).

This paper reports selected results of the CTA that reveal some of the complexities faced by train dispatchers and the cognitive and collaborative strategies they have developed in response to those demands. Specifically the paper focuses on strategies experienced dispatchers have developed to anticipate and plan for future demands on the track they control.

METHODS

The preliminary CTA used a hybrid methodology [2] that combines ethnographic field observations [3] with a structured interview technique [2,4] to build and progressively grow and refine an understanding of the demands placed on train dispatchers and the knowledge and strategies that experienced dispatchers have developed to respond to those demands.

The CTA began with two days of observations of train dispatchers as they went about their job in their actual work environment in a train dispatch center. Two observers, the first two authors, participated. Each observer sat next to a train dispatcher and observed the communications he or she engaged in, and the train routing and track management decisions made. The observer asked the dispatchers questions when invited to by the dispatcher during low workload periods. Questions were guided by a checklist of topics to be covered that was generated ahead of time. Observations were conducted across two shifts so that a total of 8 dispatchers were observed. Observations included shift turnovers.

Based on the results of the preliminary field observations a set of questions were prepared to guide more in-depth structured interviews. Three dispatchers were interviewed one at a time using a structured interview form. The two observers who conducted the field observations participated in the interviews. Interview topics covered included:

- Complicating factors that made track management and train routing difficult;
- The strategies that they have developed to facilitate performance and maintain the big picture;
- The communication systems and how they used them;
- Issues in training new dispatchers
- Suggestions for improved communication systems and/or computerized support systems.

The interviews lasted approximately two hours and were audio-taped.

In addition to field observations and interviews of train dispatchers, an interview was conducted with a commuter train engineer. The interview was conducted in the engine cab during a scheduled run. The objective was to examine the radio communication and train routing decision from the perspective of the train engineer to look for convergence and/or divergence of beliefs and opinions.

RESULTS

The Train Dispatching Environment

The dispatch center we observed handles a mixture of long distance passenger trains, local commuter trains, freight traffic and special trains (e.g., private trains).

The dispatch center has 7 dispatchers working in parallel, each responsible for different adjoining territories. The dispatchers each sit at their own workstation in one large room. Dispatchers can talk directly with those immediately around them (i.e., the dispatcher next to them, in front or back). They can also talk with any dispatcher in the room using an intercom system that they can access through their phone handset.

Each dispatcher has four video display terminals at his own workstation. One is devoted to display of radio and phone communication information. Three are devoted to display of train information. Two of these are used to show schematics of portions of the track. They are typically used to display portions of the territory being controlled by the dispatcher. The third is devoted to tabular/textual displays of information related to train statuses. There is also a PC at each desk used for administrative tasks.

There is also a large wall projected overview display that displays a schematic of the entire set of railroad tracks

being controlled from that dispatch center. All the dispatchers can see the wall panel overview display from their own workstation to get an overview of track usage and train activity throughout the rail system being controlled by that dispatch center.

Dispatchers' primary means of monitoring activity and communicating with people in the field (i.e., train engineers, maintenance of way personnel, train masters) is via a radio system. Dispatchers continuously monitor the road channel that covers communication in their territory and broadcast messages over the radio. They also have available a phone that they occasionally use for one-to-one conversation with people in the field (e.g., maintenance of way foremen, train masters.)

What Makes Train Dispatching Difficult?

Routing trains that arrive on schedule is not hard. The tracks to be used, and the meets (the time and place when two trains will meet) are predefined and routing decisions are routine.

What makes dispatching hard is dealing with *unplanned demands* on track usage, and the need for dynamic *re-planning* in response to train delays, and track outages.

One source of complication is the need to satisfy the multiple demands placed on track usage introduced by unanticipated requests for track use while still insuring that scheduled trains are not delayed. Unplanned (and thus unpredictable) demands on track usage include:

- maintenance of way (MOW) personnel requesting time to inspect and maintain tracks;
- Freight trains that do not have precise schedules;
- Special trains (e.g., private trains).

Dispatchers must estimate the time required by these unplanned activities and the time available before the track will be required for a scheduled train. Often the demands placed on track use are greater than can be satisfied at given point in time, requiring the dispatcher to prioritize and perform triage (determine which activities/trains will be delayed).

A second source of complexity is that trains are often delayed and/or tracks are taken out of service making the preplanned routes and meets obsolete, and necessitating dynamic re-computation of feasible train routes and meets.

A third source of complexity is heavy attention and communication demands, particularly over the radio. One dispatcher estimated 178 communications in one 8 hour shift (i.e., more than one every three minutes). Communications include the need to:

- Answer requests for, and issue train movement and track usage authorization to train engineers, MOW staff, etc.;
- Inform train engineers whether there are any updates to speed bulletins or other messages;
- Find out the status of trains – where they are, why they are delayed;
- Exchange information regarding rail conditions (e.g., broken rail; malfunctioning signals; obstacles on the track; trespassers);
- Coordinate with train masters and yard masters;
- Coordinate with emergency response personnel (e.g., police, fire, ambulance) in accident situations.

Typically, while the dispatcher is attending to one request, multiple other calls will come in on the radio. Per necessity, these calls get delayed in being answered.

A fourth source of complexity is the physical constraints that determine under what conditions a train may proceed. The make up of the train and physical characteristics of the track (i.e. track characteristics that determine allowable speed, height of bridges over track that determines maximum car height, hazardous materials in the rail car that may travel through heavily populated areas) interact to affect the conditions under which a train may move over specified sections of track. The dispatcher must possess knowledge about the track that remains relatively stable and information about the make-up of the train consist which may change constantly as the train proceeds on its journey.

Expert Strategies to Meet the Multiple Demands on Track Use

Dispatchers have developed a number of strategies that smooth the way for trains to pass through territories more efficiently, and satisfy the multiple demands that are placed on track use. Experienced dispatchers have developed strategies that allow them to anticipate requirements for changes to schedules and planned meets early so as to have time to take compensatory action. They monitor the wall panel display, consult with other dispatchers, and 'listen for' information on the radio that will allow them to track progress of train movement and get early indication of need for re-planning.

Anticipate and Plan Ahead

Dispatchers have developed strategies to extract information from radio communication and/or actively

seek information to allow them to anticipate delays and plan ahead. They actively monitor how the trains that are headed their way are running. If a train is one hour late out of the Boston terminal, they want to know right away. They also take into account whether there is any slack in the train's schedule to estimate whether the train is likely to make up any of the delay before it reaches their territory. In the words of one dispatcher the ability to anticipate and plan ahead is critical "otherwise you start getting trains late and things start to get out of sync."

Taking Advantage of the Radio "Party Line" Feature to Anticipate and Plan Ahead

Dispatchers routinely "listen for" information on the radio channel that is not directly addressed to them but provides important clues to potential delays, problems or need for assistance. As one dispatcher put it "after a while you kind of fine tune your ear to pick up certain key things". Examples include:

- *Identifying when a train has left a station*: The train conductor will generally tell the engineer "OK out of New London", by comparing the time to the scheduled departure you can compute the delay.
- *Identifying equipment problems:* By overhearing conversation between a train engineer and the mechanical department, the dispatcher gets early notice of malfunctioning train engines that will need to be replaced. In one recent case there was a train with 500 or 600 people on it and a malfunctioning engine. The dispatcher had overheard the Engineer call the mechanical department and so began thinking about his options and anticipated the need to hold another train back for two minutes in order to minimize the delay of the train with malfunctioning engine.
- *Listening for/heading off potential interactions and conflicts:* Dispatchers listen for commitments made by others that may impact activity in their territory. As example a train may request approval from the dispatcher of an abutting territory to go toward his territory, while the dispatcher may have already given someone else approval to move on the same track in the opposite direction. It's important for the dispatcher to catch that. In the words of one dispatcher "I have to make sure that I remember each thing – because if I send one guy toward the yard and another out – now you have two trains looking at each other and they can't move – You can get yourself stuck – so it is important to listen ahead."

  The ability to listen ahead allows dispatchers to nip potential conflicts before they arise. In one case a dispatcher overheard a request made by a train to a tower to come out of the yard. In his words "I know when someone is talking to South Bay tower, I know that sure enough South Bay is going to talk to me and I'm going to have to do something about it. So it is anticipation. Getting ready ahead of time. Who can go when? Do I want to let him go now? Can the terminal dispatcher handle him now?" He checked with the terminal dispatcher, who was unable to take the train. He then called the tower to ask them to delay the train – all without ever having explicitly been asked.
- *Listening for mistakes.* An experienced train dispatcher will pick up key information that may signal a misunderstanding, confusion, or error. A case in point is a situation where a MOW person is working on the wrong track. On the rail, it is easy for a MOW person, especially an inexperienced one to get disoriented and think they are working on one track when they are working on another. In one case a dispatcher overheard a flagman talking to his crew say "OK to come out of the lot at Endels". Endels was across the other side of live track, it was not the track the MOW flagman had requested to be blocked off and protected. The dispatcher immediately put signals to stop and called the MOW person to alert him.

Thinking Ahead/Cooperative Planning to Facilitate Train Movement Across Territories

Dispatchers have developed cooperative strategies to provide each other with look ahead, and facilitate routing beyond their own territory. They provide each other with status updates to support anticipation, they consult with each other when there are alternative routing options that may differentially impact the abutting dispatcher's territory, and they try to accommodate each other. Dispatchers will:

- inform the adjoining dispatcher what track he is sending a train on (or will ask which track he/she wants it on) so that the dispatcher knows which track to expect a train on and therefore what signal switching will be needed (e.g., when going from two tracks to one track).
- alert abutting territory dispatchers that there will be a change in the order in which trains will come into their territory (which may trigger re-planning of routes and meets); or in cases where there is a choice, will ask the dispatcher of the abutting territory which he/she wants first. If one train will need to turn around right away, the dispatcher will want that train first.

Increasing Communication Efficiency: Cooperative Strategies Between Dispatchers and Engineers

Dispatchers and train engineers also act cooperatively and proactively to increase communication efficiency between them, and facilitate train movement. As example, train engineers are required to check with the dispatcher for messages before leaving a train station. If a dispatcher has the time, he will call the train engineer before he reaches the station to let him know that there are no messages, and that he can leave the station whenever he is ready. This will allow the train engineer to start the trip back in the other direction more quickly.

In turn, train engineers will sometimes act proactively to save the dispatcher time. For example, if a dispatcher sends a message over the radio directed at one train engineer, but it is also relevant to others, the others will call in over the radio acknowledging receipt of the message (e.g., "This is 601, I copied that"). This eliminates the need for the dispatchers to call them individually.

Strategies to Take Advantage of Windows of Opportunity

- Dispatchers will act pro-actively to take advantage of windows of opportunity that open up. For example, if a dispatcher knows that a MOW person needs some foul time (time during which track is taken out of service for use by MOW workers), and he sees a window of opportunity, he will call the maintenance of way person and offer some time. In one case, as a second example, a passenger train was delayed (held up in the adjacent territory). The dispatcher used the opportunity to tell a freight train that he could pass through, given that the window of opportunity had opened up.

Strategies to Level Workload

Dispatchers work under externally-paced, high attention demand conditions. Dispatchers have developed strategies to shift workload when possible from high demand periods to lower workload periods. As example they have learned to begin paper-work and book-keeping duties during low workload period so as to avoid introducing workload bottlenecks later. Examples include:

- *pre-naming a train* (i.e., entering it into the computer) before it enters the system to save time later. (Note - if there is a change in the expected order trains are inserted this will create more work rather than less)

- *Clearing routes/setting blocks in anticipation of needs.* As example, a dispatcher anticipated that a track car working on a stretch of rail would need to request a an adjacent segment of track to be blocked off next, so the dispatcher put in the block before getting the call from the track car. As with other anticipatory strategies it can result in delays if unanticipated conditions arise (e.g., trains/track cars come through in a different order than anticipated).

- *Giving 'provisional authority'*. When someone comes in requesting a stretch of track to be blocked and the dispatcher determines that authority cannot be provided at that point in time but can be provided once certain conditions are met (e.g., a train gets through), the dispatcher can give provisional authority --- authority that goes into effect once specific conditions are met. He can begin the paper work on his side and have the train engineer do the same, leaving the time the authorization is to go into effect blank. Later when the conditions for the authorization have been met, the dispatcher can call the person back and indicate that the authorization is now in effect. This saves time, and serves to level the workload since much of the paper-work is done at a time when workload is not too heavy, rather than later when it could be heavier.

Other related strategies to cope with high workload include:

- giving MOW foremen as much track as can be afforded all at once rather than in stages to avoid having to issue repeated track use authorization forms.
- Giving authorization for track usage "until further notice" rather than for a fixed length of time, so that if the MOW needs more time than anticipated and the time is available (e.g., there is no train that needs the track) the MOW can use the extra time without

requiring additional paper work.

DISCUSSION

The selected results of the CTA presented in this paper reveal that dispatchers have developed a variety of strategies that smooth the way for trains to pass through territories safely and efficiently and satisfy the multiple demands placed on track use. These strategies depend heavily on communication and coordination among individuals distributed across time and space. One basis for coordination is the use of radio as a communication device that provides for a shared frame of reference. The ability to "listen in" on communications directed at others that have a bearing on achievement of your own goals and to recognize when information in your possession is of relevance to others and broadcast it, are important contributors to efficient management of track use. Dispatchers' planning and scheduling is proactive, anticipatory and opportunistic – taking advantage of windows of opportunities that arise to satisfy the multiple demands that are placed on track use.

The results have a number of implications for selection and training of dispatchers and the application of technologies such as advanced computer displays, decision support systems, and data link communication to improve train routing safety and efficiency [5, 6]. The results emphasize the skills that dispatchers have developed that allow them to anticipate demands on track use and act proactively; plan cooperatively across territory boundaries; and manage workload. These are important cognitive skills that need extensive practice to develop. The results also reveal the importance of the "broadcast/party line" aspect of radio communication that provides a shared frame of reference and allows dispatchers and others working on the railroad anticipate situations and act proactively. Careful attention should be paid to preserving this critical feature of radio communication in attempts to off-load radio communication to other media [7, 8].

The results also contribute to the broader understanding of team cognition in complex dynamic tasks that require communication and coordination among multiple individuals distributed in time and space [9].

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