A Hierarchical Task Model for Dispatching in Computer-Assisted Demand-Responsive Paratransit Operation

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ABSTRACT

This research was conducted to organize and model a comprehensive paratransit dispatching task activity in a computer-assisted control room. The dispatching task involves continuous monitoring and interaction with archived and real-time data using a dispatch software. Extensive field observations and video recordings of dispatch operations were conducted. Then, an expert dispatcher was used to generate a skeleton decision model of the dispatcher's task performance. Hierarchical Task Analysis (HTA) was used to further refine this model into a comprehensive HTA decision hierarchy (decision tree). To capture the complexity of multi-dispatcher operation, we extended this model to a simultaneous operation of two collaborative dispatchers in the same control room -- a van dispatcher and a lead dispatcher. The results of this analysis have shown that HTA can be used to model such an activity with a user-defined degree of fidelity. The sequential decision tree format of the HTA also shows promise as a training tool for entry-level dispatch personnel.

KEYWORDS

Paratransit Service, Computer Automation, Dispatch Operation, Task Analysis, Decision Tree, Dispatch Training

INTRODUCTION

Demand-responsive paratransit service is on the rise. For example, in Los Angeles County alone more than 5000 vans and 4200 cabs provide service, generating about 8 million trips per year. The current expansion of the paratransit industry was made possible by the passage of The Americans with Disabilities Act of 1990 (ADA). This act requires fixed-route transit systems to provide complementary paratransit services for disabled persons within three-quarters of a mile of a transit route. The ADA required all agencies to: (a) provide accessibility (e.g., wheelchair) to all new and renovated transit vehicles, and (b) offer complementary paratransit service to disabled individuals [Dempsey, 1991].

Due to the lack of advanced communication and tracking technologies, the early systems tended to operate as advanced reservation systems with some service providers requiring users to place a reservation at least one day in advance of their travel. As reported in the Transit Cooperative Research Program Report #18 [Lave et al, 1996], this mode of operation has been associated with much lower service productivity. In particular, the early systems failed to meet expectations due to low demand requests and deficiency in communication and computer technology to effectively manage system complexity [Lave et al, 1996]. However, the introduction of Intelligent Transportation Systems (ITS) such as automatic vehicle location (AVL) devices, geographic information system (GIS), and mobile data terminals (MDTs), has the potential to improve paratransit operations due to the automation of information processing.

An issue essential to the application of advanced information technology in paratransit services is the effectiveness of automation in improving the process of dispatching and scheduling of demand-responsive transportation. System productivity is often measured by the ability of the dispatchers to match vehicles to trips within a very short period of time. This is a much more complex problem than taxi and airport van services due to the rideshare nature of this service, which necessitates multiple origins and destinations. In this type of service, trip destinations must also be acquired by the call-takers and a more complex scheduling algorithm is needed since multiple trips must be scheduled in a logical sequence for specific vehicles.

For paratransit services, we have the added complexity of scheduling each trip according to the special needs of the disabled customer. Now, a critical question is whether ITS technologies have been implemented efficiently and productively for this level of user complexity. We now know that the technology for developing such a system is easily achievable. The questions remains whether or not the operators use and interact with such a system effectively under prolonged working periods.

Most of the research on scheduling demand responsive transit systems have focused on the algorithms, neglecting the human element. Little research has been performed to understand the task complexity of dispatchers interacting with their computer systems. To meet this objective, we developed a task analytic model of a dispatcher in a highly interactive computer-assisted scheduling process. The modeling approach was based on a detailed logical representation of task sequences, called Hierarchical Task Analysis (HTA), first introduced by Annett et al [1971] and later revised by Shepherd [1993]. HTA models are useful in designing complex human-computer systems (such as those found in dispatching operations) and developing training programs to improve the efficiency of these operations.

In order to develop the HTA model, we studied in detail the dispatching operation of a paratransit service provider in Los Angeles County. Although the developed model represents the tasks of the studied provider, it is representative of the industry in general. Also, our methodology and model development can easily be used to represent other similar systems. The remainder of the paper is organized as follows. The next two sections provide a background of generic dispatching operations and the studied agency (service provider). We then present the details of the HTA model.

BACKGROUND OF DISPATCHING OPERATIONS

Before we address the issues related to paratransit computerization, we need to explain the elements of a dispatching environment [for a detail information flow diagram see Lave et al, 1996]. The primary operation of computer dispatching involves the use of both analog and digital communication systems to connect the dispatching centers to the vehicle drivers. Incoming calls are answered by a group of call-takers as the pickup addresses (and other passenger information) are inputted into the computer databases. In an automated dispatching system, a dispatch algorithm runs in the background and determines the vehicle that should service the call (usually the vehicle closest to the pickup address in a posted zone). The information is then transmitted to the assigned vehicle (through an in-vehicle data terminal) with a precise sequence of trips assigned to this vehicle. The driver then accepts the trip and the dispatcher submits the rest of the information to the driver. The driver then proceeds to service the trips in the assigned sequence. All transactions are then kept in the computer databases for record keeping, management reporting, accounting, and performance analysis/reports.

In general, the non-scheduling aspects of paratransit operations (client certification, records and agency billing, accounting, etc.) have already been fully automated. However, the scheduling aspects of dispatching are not easily automated. Most paratransit service providers are using semi-automated or computer-assisted scheduling. In these systems, incoming calls (trip requests) are categorized into “steady” (e.g., reservations for the next day) and “ready” (e.g., real-time or within the next few hours). The call-takers check the passenger's ADA eligibility and enter the information into the main computer. Then, the scheduling tasks begin. Usually, the night before, an experienced dispatcher develops a "skeleton" route for the next day, based solely on the steady passenger trip requests. Drivers, vehicles, and passengers are grouped together for the most efficient route. General sequence of vehicles and trips are grouped according to time of day, day of week, O/D, and special passenger needs. The vehicle path is optimized for minimum time and distance subject to vehicle capacity limitations. During the day, however, additional requests are serviced on a real-time basis. These additional trips cannot simply be re-optimized without regard for those trips already scheduled and confirmed with customers. In a fully automated scheduling system, these additional trips are inserted and the schedule is re-optimized until a schedule of pick-ups and drop-offs is re-built. In a semi-automated system, this re-optimization process is accomplished using the cognitive capabilities of the dispatcher on a real-time basis. The latter was the case in our analysis documented in this paper.

In the computer-assisted system, the interaction of the dispatcher with the driver is also important in a real-time scheduling process. For example, each driver is given the skeleton route at the beginning of his/her shift. This pre-assigned sheet includes sequence, pickup times, and O/D addresses for each passenger. It also includes the estimated travel time and the minimum distance path for each trip. The use of ITS technologies has been expected to make the rest of this process more efficient and easier to use. The same pre-assigned route is used by the computer for the real-time "ready" trip insertions. The computer knows the exact route and the location of each vehicle in the fleet (using AVL technology). All new trips are inserted at the most optimum route sequence. The new schedule is communicated to the driver, who may begin a new trip, or deviate from the current trip and pickup the new passenger.

The literature seems to favor increased automation in paratransit operations. Stone et al. [1994] report that the level of satisfaction with scheduling software ranges from poor to excellent with the majority of the agencies surveyed reporting good. Also, they report that operators expect their satisfaction index to increase as the service providers fine-tune and customize their new software applications.

The increase in automation has also caused a recent shift to a more on-line reservation system. In terms of more efficient scheduling routines, Dessouky and Adam [1998] developed a real-time scheduling heuristic for paratransit services. Results of a simulation analysis using data provided by paratransit service providers in Los Angeles County show that this new heuristic outperforms dispatching rules currently used by the providers in terms of improving ridesharing and on-time performance. Despite the advantages of these algorithms, dispatchers in this rapidly growing industry lack sufficient knowledge of the elements of the complex scheduling process to perform their functions effectively in real-time. The increasing number of complex dispatching software further exacerbates this problem. Most of the current packages offer hundreds of input fields that dispatchers must understand, memorize and navigate under normal and time constrained situations. For example, they may not have the skills to make an efficient recovery plan when there are delays or deviations from the original operating plan. In order to reduce errors made by dispatchers, Sheehan [1995] stresses the need for more effective training of dispatchers due to the increasingly complexity of the technology.

In general, two classes of employees are directly affected by these problems. The following is a sample of problems reported daily:

- *Dispatchers/Schedulers* – did not share trips, sent vehicles outside the desired routes, misinterpreted mobility device requirements (e.g., sending a cab that is not equipped for wheelchair access to pick up a wheelchair customer).
- *Telephone Operators (including call-takers)* – incorrectly inputted the information into the database (e.g., incorrectly identified addresses or directions to a residence).

These types of errors reduce productivity, cause late pickup and drop-off, and result in excessive deadhead in mileage. In order to support the development of effective training tools that address these problems, this research developed a hierarchical task activity model of dispatchers in dynamic scheduling of paratransit operations. First, we describe a paratransit service provider from which we derived our model.

CASE AGENCY AND SERVICE PROVIDER

This research has been coordinated with Access Services Inc. (ASI). As mandated by California State Senate Bill 826, ASI is the only designated consolidated transportation service agency for Los Angeles County (the largest of its kind in the United States). It is important to note that ADA paratransit in Los Angeles County is a coordinated effort of the cities. ASI fills in the gaps and allows individuals to travel across Los Angeles County and the surrounding counties within the service area of Los Angeles County. ASI has currently 37,000 registered clients generating around 5300 trips per day.

We conducted initial interviews with several service providers within the region. Based on these interviews and recommendation from ASI, we selected one provider with a typical computerized dispatching system. For confidentiality, the company's name will be referred to as

"ABC." ABC provides traditional taxi services as well as transit services for its disabled passengers. The business and operation are divided into three distinct operating units: taxi operations, "Dial-a-Ride," and "Access services." Dial-a-Ride is funded by local municipalities and provides intra-city transportation for general public (disabled and able-bodied). The research team made a total of about thirty hours of observations in the ABC's dispatching operations room including videotaping their dispatching operations. The subsequent discussion concerns the dispatching operations exclusively.

ABC operates on a 7-day/24-hour basis. However, the majority of requests are for rides during "daytime" hours. According to ABC, 7 a.m. to 10 a.m. and 1 p.m. to 5 p.m. are peak times. Requests for trips on "off-hours" (e.g., evenings and nights) are sparse which makes the likelihood of ridesharing very low. Additionally, the trips during off-hours are primarily assigned to outsourced drivers (i.e., taxis and leased vans), allowing ABC's company drivers to work on a "normal" shift or schedule. ABC has about 1600 total trip requests per 24 hours, with about 700 of these dispatched (the rest are pre-assigned).

Under the federal Access program, ABC is provided with buses and vans owned by the program; and ABC employs drivers (approximately 75) to operate the buses and vans. The vans and buses are specially equipped to accommodate wheelchair-bound passengers. Performance measures are usually categorized in passenger miles in addition to a number of utilization factors. Therefore, it is in ABC's interest to maximize person trip-miles combined with ridesharing (combining requested trips into a single route). Also, under the Access program, eligible passengers are transported for a nominal fee ranging from $1.50-$4.00 (up to twice the fixed route) — which is collected by the ABC-employed driver and remitted to the Access program. Additionally, ABC utilizes the leased vans and taxi fleet to provide transportation to other disabled, non-Access-eligible passengers, as well, either on a cash basis or other contractual arrangement. Other “accounts” (the Access program is considered as an account) are hospitals, insurance companies and other large organizations. At ABC, the Access program is the significant and predominant account. It is important to mention that ABC is not allowed to use Access-provided vehicles for other purposes. At the time of our study, ABC was managing both operations—Access-eligible transit and non-Access-eligible transit for the disabled (hereinafter referred to as “Access service”) in a single operation. The fleet also includes about 75 Access-provided vans. The vans can accommodate 2 wheelchairs plus three additional, ambulatory (non-wheelchair-bound) riders. Access services also utilizes approximately 15 leased vans. Finally, the taxi services part of ABC’s business includes approximately 100 taxis. Of these, approximately 40 are suitable for Access-eligible transit. As expected, taxis transporting Access-eligible passengers are allowed to rideshare, unlike traditional, commercial taxi service. According to ABC, approximately 60 percent of all Access services requests are handled by vans and the remaining 40 percent are served by taxis.

An important aspect of any transit fleet operation is the use of advanced technology for communication purposes. All ABC vans are equipped with GPS transponders, which broadcast the vans’ present position, heading, and speed. Additionally, through manual data transmission, using a Mobile Data Transmission device inside every vehicle, drivers broadcast their present status: en route to a scheduled pickup, on-site (but not yet loaded) at a scheduled pickup, loaded at a pickup, en route to a destination, and/or their idle positions. This information is fed, on a real-time basis, into a GIS system and display. This information are available (real-time) on a GPS monitor. The dispatchers have access to a complex array of GIS/GPS data on a Windows-based system.

Under the terms of its contract with the Access program, ABC is penalized (fined a monetary penalty) by the Access program if they fail to serve an eligible client. Under the definitions of the Access programs, there are three types of reservations/ requests: pre-scheduled (recurrent), one-day advance request, and five-hour advance request.

For operational reasons discussed subsequently, all transportation requests are entered into the computer database, and scheduled/dispatched, based on pickup time. In the terminology and requirements of the Access program, a calling customer is “offered” a ride. Once the offered pickup time is accepted by the customer, actual pickup must occur within a window of -5 minutes (early) or +15 minutes (late), or ABC is “fined” by the Access program. The delay fines increase with each 15-minute increment, with a maximum fine of $100 for pickup delays over one hour. Because of these performance requirements, extensive performance statistics are calculated and monitored by ABC. This is facilitated by extensive computerization of the dispatch and operations control processes, discussed subsequently.

Advance, skeleton routes for the Access-provided vans are constructed the night before, based on advance (24 hour) and recurrent, pre-scheduled trip requests in the computer database. According to ABC, typically, 900-1000 advance requests might be scheduled overnight. However, not all advance requests for the next day are scheduled overnight. About a third of these trips may require special arrangements which would be preferable if scheduled during daytime. One consequence of this is that the unscheduled requests, mostly for later in the day, have to be dealt with on a real-time basis (i.e., dispatched) by the dispatchers. However, the ABC’s training stresses the need to meet customer requirements (especially pick-up times) as a priority in both prescheduled and real-time insertions. Scheduling is performed in time-order (order of requested pickup time). The skeleton routes (scheduled pickup and drop-off times and locations) are transmitted electronically to the van drivers when they log into the system at the beginning of their work shift. Based on our observations, the construction of the skeleton routes is primarily a manual task. The primary reasons are lack of trust, software complexity (54 variables need to be adjusted for each routing algorithm) and slow computational speed. According to ABC, the primary purpose of skeleton route construction is to maximize the utilization of Access-provided vans. This is to say, the routes are "packed as densely as possible." ABC's data show that approximately 30 to 40 percent of trips are rideshared.

Again, despite ABC's extensive computer capabilities, the day-time (real-time) dispatching process is also semi-automated. In this case, lack of computational speed and lack of system flexibility appeared to be the primary reasons for manual dispatching. During the peak hours, the dispatchers were managing about 200 active or imminent trips in a short period of time. In terms of dispatching, one person was dedicated to dispatching vans (called "van dispatcher"), and another was dedicated to dispatching taxis (called "taxi dispatcher") for Access service requests only. Additionally, another dispatcher monitored and modified dispatched assignments and assisted the dispatchers in assigning unscheduled requests (called "lead dispatcher"). Figure 1 shows a schematic of the dispatching computer equipment layout.

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Figure 1 about here

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Unassigned trips (as well as assigned and "active" trips) are displayed on monitors in front of the two dispatchers, one for vans and one for paratransit taxis. Trips are displayed in order of pickup time. According to ABC, the goal is to assign unassigned ride requests to vehicles already in service at least 30 minutes before the requested pickup time. As noted before, ABC's performance in the Access program is based, in part, on utilization of the Access-provided vans. Hence, there is incentive to assign unassigned trips to these vehicles first. However, ABC also has incentive (both in terms of maintaining contingent capacity and direct business interests) in assigning trips to the paratransit taxis and leased vans. However, in discussions with our expert dispatcher, ABC attempts to distribute trips between each on some "equitable" basis. This equitable distribution of trips appears to be a part of the dispatcher training at ABC. Due to the complexity of the "real-time" dispatching operation, we know of no quantitative "rule" or "heuristic" for such distribution. Finally, the objective of dispatching also included the maximization of ridesharing, whether utilizing the Access-provided fleet or the leased vans and taxis. Again, this was observed to be attempted primarily by a "tacit" heuristic used by the dispatchers, as modeled in our Hierarchical Task Analysis section. The objective of maximizing ridesharing appeared to be greatly facilitated by the dispatchers' use of the combined (interfaced) GIS/GPS and trip management software. We now begin to explain the HTA's modeling process.

HTA MODEL

The literature contains a large number of diverse task analysis methodologies [for a description of different modeling efforts related to task analysis, see Diaper, 1989; Kirwan and Ainsworth, 1992; Olson and Olson, 1990]. We have adopted HTA due to its flexibility and its extensive use in the design and evaluation of computer interactive systems. Our way of approaching the decomposition of the dispatching task is to see them as an arrangement of less complex sub-tasks, which themselves may comprise a number of more specific elements. We were also interested in describing the dispatcher's tasks in terms of their "goals" (and then sub-goals) as they perform their assigned tasks. In this approach, we have assumed that the goal hierarchy of the dispatchers is in congruence with that of the task assigned to them.

We have approached this problem in two iterative layers. First, we observed about 30 hours of dispatching operation and recorded their critical tasks. Then, we interviewed an expert dispatcher and generated a skeleton framework for the HTA model (as described in the next section). The dispatcher's HTA was also re-described in terms of a set of goals (high level of abstraction) and subordinate goals (low level of abstraction). These subordinate goals were organized as a *plan* which governs the conditions for carrying out the constituent sub-goals [for a version of this approach applied to the design of a teach pendant, using Protocol Analysis, see Rahimi and Azevedo, 1990; for another version called Critical Decision Method, see Hoffman et al, 1998]. This plan will contain information concerning the sequence in which sub-tasks are carried out and the conditions that must exist before they are undertaken. Examination of these sub-goals highlighted the feedback that the dispatchers must monitor in order to determine how to sequence their goal-directed actions. That is, at each decision node, the dispatcher has the option of following a number of decision routes, each requiring certain cognitive (e.g., information) requirements and system responses.

The developed HTA has three distinct characteristics:

- A set of action sequences from high level of abstraction to low level of abstraction. The action sequences are also organized according to their sequences of priority from left to right.
- A set of decision nodes at which the dispatcher must respond to (cognitively) in order to proceed to the next task. The result of each decision node is a "yes" or "no" based on the plan associated with each response.

- The lowest level of abstraction in which the decision tree reaches its “termination” node. At this point, the dispatcher returns to the next higher level of the branch and continues to move to the right and down, until all the nodes are covered.

The dispatchers had two primary responsibilities: maintaining voice and data contact with their respective fleets (including responding to driver requests and inquiries), and assigning unassigned, pending trip requests (from a queue displayed on the monitor) to vehicles. As will be seen in our detailed HTA model, preference was given to insertion of trips into planned Access-vehicle routes. In most instances, the dispatchers appeared to identify candidate vehicles for trip insertions based on personal judgment and geographical knowledge. Specifically, they looked at listing of either vehicle assigned routes, or of assigned trips, which included information identifying the vehicles assigned to such trips. As indicated before, about 200 trips were being managed at each point in time by the three dispatchers. During the observed periods, much of the dispatching activity focused on the many unscheduled, imminent trips (those approaching 30 minutes of scheduled pickup time).

We next describe in detail, the cognitive activities of the expert van dispatcher, as the focus of our HTA development. We also examined and added the van dispatcher’s cooperation with the lead dispatcher, as both dispatchers became heavily interactive during peak demand periods. The HTA decision network was created as a chronological hierarchy. That is, the actions at the bottom of the tree follow the top and the actions on the right nodes follow the left. Figures 2 and 3 define the symbols and abbreviated codes used in the HTA model, respectively.

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Figures 2 and 3 about here

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Van Dispatcher's Node Description

Each van dispatcher needs a few minutes of time at the start of the shift to mentally prepare for the current workload, current trip assignments in the network, and potential difficulties encountered by the previous dispatcher. The new dispatcher is primarily interested in three aspects of the operation: 1) trip insertions, 2) problem entries and 3) delayed trips. Therefore, we have modeled the cognitive interactions of the van dispatchers with their computer system according to these three elements. Figure 4 shows the top level of the HTA for the van dispatcher and Figure 5 shows the expansion of node 6 (at the bottom of Figure 4) to show further detail in this process. We note that the complete HTA model has well over two hundred nodes [not shown here; a complete report can be obtained from the Metrans Research Center, Rahimi et al, 2000]. Note also that the HTA decision network generated here captures only a "typical" or "generic" set of activities, based on dispatcher training routines at ABC. Other variations on this network are possible, due to the complexity of the human judgements and human-computer interactions.

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Figure 4 and 5 about here

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Trip Insertions. According to the characteristics coded in the trip information database, either the van dispatcher (V) (for both the ambulatory and wheelchair van requests) or the taxi dispatcher (T) (for the cash and taxi trips) initiate the trip insertion process (see Figure 4, box 1. or equivalently 2nd row, 1st box). In simple terms, the V is constantly checking for the unassigned trips, and becomes mentally aware of the requested pickup time (or Estimated Time to Arrival) as well as the origin and destination points. This is an intense cognitive operation, which requires total visual and mental attention at all times. Under heavy load (or non-routine trips), they consult the lead dispatcher (L) located between the two dispatchers. The lead dispatcher consults a Windows-based GIS display indicating vehicle positions. Thus, the lead dispatcher is expected to have a more pictorial and comprehensive access to the critically needed information, and support the van dispatcher's decision process. Additionally, the lead dispatcher performs the function of improving assigned (planned) routings. This task appears to be performed on a "time available" basis. The software also allowed the lead dispatcher to construct tentative trips, if needed (or if requested by the other two dispatchers). The display of assigned and pending/unassigned trips also indicated pickups that were late, i.e., the assigned pickup time had passed and the driver had not yet arrived. When these were identified, they were handled on a priority basis by the dispatcher(s) and lead dispatcher working together.

When a van driver (N) has either finished the route or has a significant time gap, he/she informs the dispatch center of his/her current location requesting a new trip. V then tries to assign N to a trip –or if possible multiple ridesharing trips- with origins close to N's actual location and destination close to N's next origin. Priority is given to the employees van drivers. If V finds one or more trips that fit the above-mentioned criteria, he/she assigns the specific trip to the van number selected, from his/her rideshare screen (S). Unless the driver does not acknowledge receiving and accepting the specific trip, V assigns the specific trip to the route of the specific van, and moves on to the next trip assignment activity.

V can also assign a trip to a van by using the S screen for any non-assigned trips (trips that their "Van #" field is blank). From all the non-assigned trips, V chooses the ones that their ETA is equal or a little greater than 30 minutes from the actual time. (This 30-minute window is important to keep the unassigned trips within the scheduled set.) V then asks (through the voice intercommunication system) for vans wishing to do the specific trip. The vans interested in the specific trip(s) send a voice request message to the center. V calls back the van showing interest based on the time sequence of the received messages. Main criteria for this selection are:

- Distance separating the van’s current location with the origin point of the trip,
- Distance separating the destination of the trip(s) from the origin of the van’s next trip (when N is serving another pre-assigned route
- Ability to assign multiple trips at the same van (rideshare)
- Type of contract with the van driver

The trip has to meet the above criteria based on the judgement of V, under the current circumstances. If it does, then V performs the following: moves to the S screen, inputs the van’s number in the trip’s “Van #” field, informs N by voice for the number of trips N has at any point in time. After this point, the driver has to acknowledge receiving the specific trip, using the MDT. Only then, N is able to access the information of the specific trip (address, name of client etc.) from the van’s monitor. After V has contacted each van bidding for a specific trip and after a specific trip’s assignment has been completed (by seeing the status code of S changing from A to D), V erases N’s voice call-request from the problem screen (P) (by inputting the action’s number). If for any reason, N does not acknowledge receiving the trip (which is done by pressing the acknowledge button on the monitor, which changes the status code from A to D), V has to contact the driver (by voice) asking for acknowledgement. If this is not possible, V repeats the trip assignment procedure.

In the case that the van dispatcher cannot locate any vehicle matching the distance criteria, the assignment algorithm of the system will take over. This is designed into the system using the rule of the pickup time being less than 30 minutes. The system either assigns the trip to a vehicle that according to the software is the most appropriate to serve the specific trip, or leaves it unmatched. There is also the possibility that even if the system assigns the trip, the driver may not accept the trip.

Problem entries. The van dispatcher checks the problem screen for any problem entries that have not already been answered by the previous van dispatcher (see Figure 4 , box 2. or equivalently, 2nd row, 2nd box). Usually, there are multiple messages appearing on the screen. Some of them have high priority; the van dispatcher ignores what he/she believes to be low and medium priority. The low priority messages are the ones that are usually produced by the software itself, e.g., "late meter on." The decision rule is that the messages that do not apply to the current operating conditions are left for later consideration.

Another item that creates the need for real-time trip management is the issue of "cancellation." Planned schedules and routes are adjusted on a real-time basis due to cancellations. A trip is considered a "cancellation" if the passenger cancelled a previously requested trip more than 45 minutes before the pickup time. If the passenger called to cancel a scheduled trip less than 45 minutes before the scheduled pickup time, it is considered a "no show." Each cancellation or no-show needs to be carefully documented in the passenger information sheet for future audit and analysis by Access and the management. Among all the problem messages, the highest priority goes to the "No Show" message since it may not leave adequate time for the dispatcher to inform the van driver who might be at the pickup location anyway (see Figure 4, box 2.1 or equivalently, 3rd row, 2nd box). This is due to the fact that the driver declares to the dispatcher that either the passenger (who ordered the trip) is not at the pickup location or the passenger is not ready for the actual pickup. Obviously, a passenger no-show is a serious problem because of its potential impact on all the subsequent trips in a specific vehicle route. Therefore, the van dispatcher has to do a sequence of actions to check if the "No Show" is factual and begins to gather information to respond accordingly (see Figure 5; also for details related to this activity, see Rahimi et al, 2000).

In terms of the lower priority problem entries, we characterize entries based on the following requests from the van driver:

- Free and available for a trip,
- Cannot find the pickup address,
- Cannot locate the passenger,
- To be relieved of a pre-assigned trip and
- Additional trip while serving one currently.

The van dispatcher answers the calls based on the sequence that they were received (First-In-First-Out). The dispatcher enters the problem number that corresponds to the driver request and then calls him/her on the voice channel for detailed information (see Figure 4, box 2.2 or equivalently, 3rd row, 3rd box). For each of the above requests, the dispatcher is expected to perform a series of actions to respond to the specifics of the situation [again, see Rahimi et al, for details of these lower priority calls].

Delayed trips. The last stage of the van dispatcher's activity is to check for the delayed trips on the rideshare screen (see Figure 4, box 3. or equivalently, 2nd row, 3rd box). Potential for a late trip is a serious problem for efficient dispatching operation. A major component of the HTA has been assigned to this portion of the dispatching activity. All dispatchers and drivers know that late trips carry a significant penalty (up to $100 per trip). As mentioned before, a large number of variables contribute to late arrivals. During the peak demand times, the van dispatcher normally does not have the opportunity to deal with severely delayed trips. Thus, the van dispatcher constantly monitors the rideshare screen to identify delayed trips (see Figure 4, box 3.1 or equivalently, 3rd row, 4th box). Once identified, the van dispatcher requests the lead dispatcher to take control of these trips (see Figure 4, box 3.2 or equivalently, 3rd row, 5th box). The following section describes the lead dispatcher's attempts to handle this type of request.

Lead Dispatcher's Node Description

Like any other dispatcher, the lead dispatcher's shift begins with a few minutes of familiarization, checking the existing trip request conditions and tracing the potential problems. Figure 6 shows the HTA model for the lead dispatcher's top-level decision hierarchy. From the time he/she sits down and starts the shift, he/she is continuously monitoring both the rideshare screen and the GPS screen looking for vans running late from their pre-assigned pickups. The main function is to inform the van dispatcher of potential problems, rather than taking independent actions. For example, experience may tell the van dispatcher that, according to the current traffic conditions (reported by other van drivers), an assigned van may not have adequate time to reach his/her next pickup location on time. The van dispatcher then asks the lead dispatcher to take care of this situation, while he/she is attending to other requests. The lead dispatcher then locates the trip at the rideshare screen in order to see the pickup time and location and also any details that may indicate passenger flexibility in pickup time (see Figure 6, box 1. or equivalently, 2nd row, 1st box). If, for example, the passenger has to go to a hospital or an airport, the passenger may not have the flexibility for a delayed pickup. This situation requires an immediate and concentrated attention of the lead dispatcher.

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Figure 6 about here

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In such a case, the lead dispatcher locates the late van at the GPS screen, and develops a mental estimate of the time the driver needs to reach the pickup location (see Figure 6, box 2. or equivalently, 2nd row, 2nd box). If he/she sees that the van has reached the previous pickup location and he/she is already moving toward the drop-off location, then the driver has forgotten to "load" the trip, or the main system was not updated, showing the van still on the way to the pickup location (see Figure 6, box 2.1 or equivalently, 3rd row, 1st box). In this situation, the lead dispatcher is using the message window from the rideshare screen to send a message to the van driver to load the trip. The driver has to perform this task once to let the system know that he/she has reached the pickup location, and then again, to actually board the passenger. If the van driver follows the lead dispatcher's request, then the symbol at the "status" field of the rideshare screen will change from N (indicating "vehicle on site") to L (indicating "passenger picked up") which is a logical conclusion for the lead dispatcher. Then he/she informs the van dispatcher verbally that the delayed trip problem has been solved and the passenger was picked up.

If, on the other hand, the lead dispatcher checks the GPS screen and he/she finds the van dispatcher at the pickup location (perhaps sitting idle), it means that the van driver forgot to load the trip and the main system was not updated (see Figure 6, box 2.2 or equivalently, 3rd row, 2nd box). The lead dispatcher follows the same procedure as mentioned before. The only exception is that the lead dispatcher waits to see the change of the status (indicating that the passenger has been picked up) in order to consider this request completed. Then he/she informs the van dispatcher verbally that the van driver has picked up the passenger.

In the worst scenario, however, the lead dispatcher (by checking the GPS screen) finds that the van is not close to the pickup location (see Figure 6, box 2.3 or equivalently, 3rd row, 3rd box). In this case, he/she uses the message function of the rideshare screen to send a message to the van driver requesting the estimated time to arrival at the pickup address. Then he/she informs the van dispatcher of the van's current location and distance from the pickup address, and informs them that he/she is waiting for a response from the van driver. If the van driver replies that the estimated time of arrival at his/her next pickup location is less than 10 minutes, then the lead dispatcher allows the van driver to proceed to his/her pickup location and he/she continues to monitor the delay situation. This continuous monitoring is necessary to ensure that there will be no additional delays for this trip. If the van driver replies that the estimated time of arrival is more than 10 minutes, the company's regulation does not allow them to take any further action. However, he/she has to inform the van dispatcher of this situation. The van dispatcher is now responsible to handle the situation accordingly.

CONCLUSIONS

The modeling question that we were concerned with in this research was how to capture the dispatcher's human-computer interactions in a complex dispatch operation? This question was raised because of the issues such as difficulty in training the dispatchers and their high error rates due to excessive workload and stress. In order to approach these questions, one needs to know how users of these systems respond to a large array of system requirements and component interactions. Our use of HTA was a step forward in this direction.

Our observations showed that the dispatching process (and its associated sub-processes) required an extremely complex and interactive human-computer cognitive behavior. The dispatchers at ABC appeared to be operating at or near human capacity during most of the day, and especially during the peak hours. This is evident, according to ABC, by the high turnover and "burn out" rates in this job. The aspect of the job function that was most striking was the observed and apparent need to simultaneously communicate, interface, and coordinate with multiple system interfaces, drivers, and other dispatch personnel. Moreover, a keen memory appears to be a must prerequisite for this job (capable of remembering the locations of many vehicles, vehicle routes, pending and assigned trips, as well as other data presented by the software and other personnel).

The most practical application of this research is the use of the dispatcher's decision model for training purposes. We believe that the model format and language is simple yet powerful enough for training the incoming dispatchers with any level of formal education. However, in order to implement this system in a technologically complex environment, we need to view this similar to the current developments in "supply chain management" software development. By this we mean that the paratransit companies need to provide detail information about their specific operational needs and requirements to the software developers, and visa-versa. Also, both need to communicate their system development strategies with their local and regional service providers. Two problems have prevented this from happening in this particular industry. One is the way software has been introduced into the paratransit operation: essentially grew out of the traditional taxi and emergency vehicle dispatch operation, and slowly "force-fitted" into the paratransit and dial-a-ride operations. We believe that this approach leads to system inefficiency and user training problems. It is interesting to note that in the last stage of our research, the company management decided to split the van and taxi services into two separate operational control units with independent software control systems.

Furthermore, the HTA model is easily adapted for use as a computer interface evaluation tool. This can be accomplished by mapping the dispatchers decision paths and define their "over-used" or "under-used" cognitive resources. For example, we have noticed that the displays using the DOS-based format have the advantage of information simplicity and speed of information retrieval. However, they lack screen design consistency and generate long scanning and navigation times. One the other hand, the displays using Windows-based format (i.e., GIS/GPS) have the advantage of spatial and iconic representation, well-designed popup menus and cursor sensitive information display. The most important disadvantage of this design was a very long system lag time (refresh rate). In addition to the abovementioned HCI application, our HTA can be used as a simulation model of dispatcher's performance system. That is, the HTA model can be easily simplified into a smaller performance-based simulation model (using any general-purpose simulation software) and analyzed based on the available company data.

Finally, we attempted to capture only the high level hierarchical progression of rules and decisions that the dispatchers are following in a generic dispatching process. However, capturing the tacit rules and heuristics, and the "fuzzy" decision criteria of the dispatchers requires extensive cognitive analysis tools and was beyond the scope of this study. Moreover, the dispatchers decisions clearly were aimed at certain obvious and sometimes tacit objectives, including those noted previously. But, it was equally obvious that other constraints and requirements (such as limits imposed by the Access program on ridesharing) did not appear to be considered in the computer-assisted process. Further research in these areas will be beneficial to both the software developers and the user community.

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FIGURE CAPTION SHEET

Figure 1. A schematic diagram of the dispatch operation room and their computer monitor locations.

Figure 2. Symbols and descriptions for the HTA decision model.

Figure 3. Legend and code attributes used in the HTA model development. These codes are used extensively to reduce the apparent size of the decision tree.

Figure 4. The first (top) level of the HTA model showing the decision nodes for the van dispatcher. The "Plans" are the conditions that need to be met in order for the decision to move the next (lower) level. The action sequences follow what the dispatchers "should" be doing based on the design of the current system.

Figure 5. Further expansion of the node 6 shown in Figure 4. In this sequence of decisions, van dispatcher deals with the difficult decision of what to do when the passenger is not present at the pick up location.

Figure 6. A new branch of the HTA model was created for the lead dispatcher, due to its high degree of interaction with the (Access) van dispatcher. The first layer begins with the lead dispatcher responding to the van dispatcher to locate a late vehicle and help assign another vehicle to service this trip.

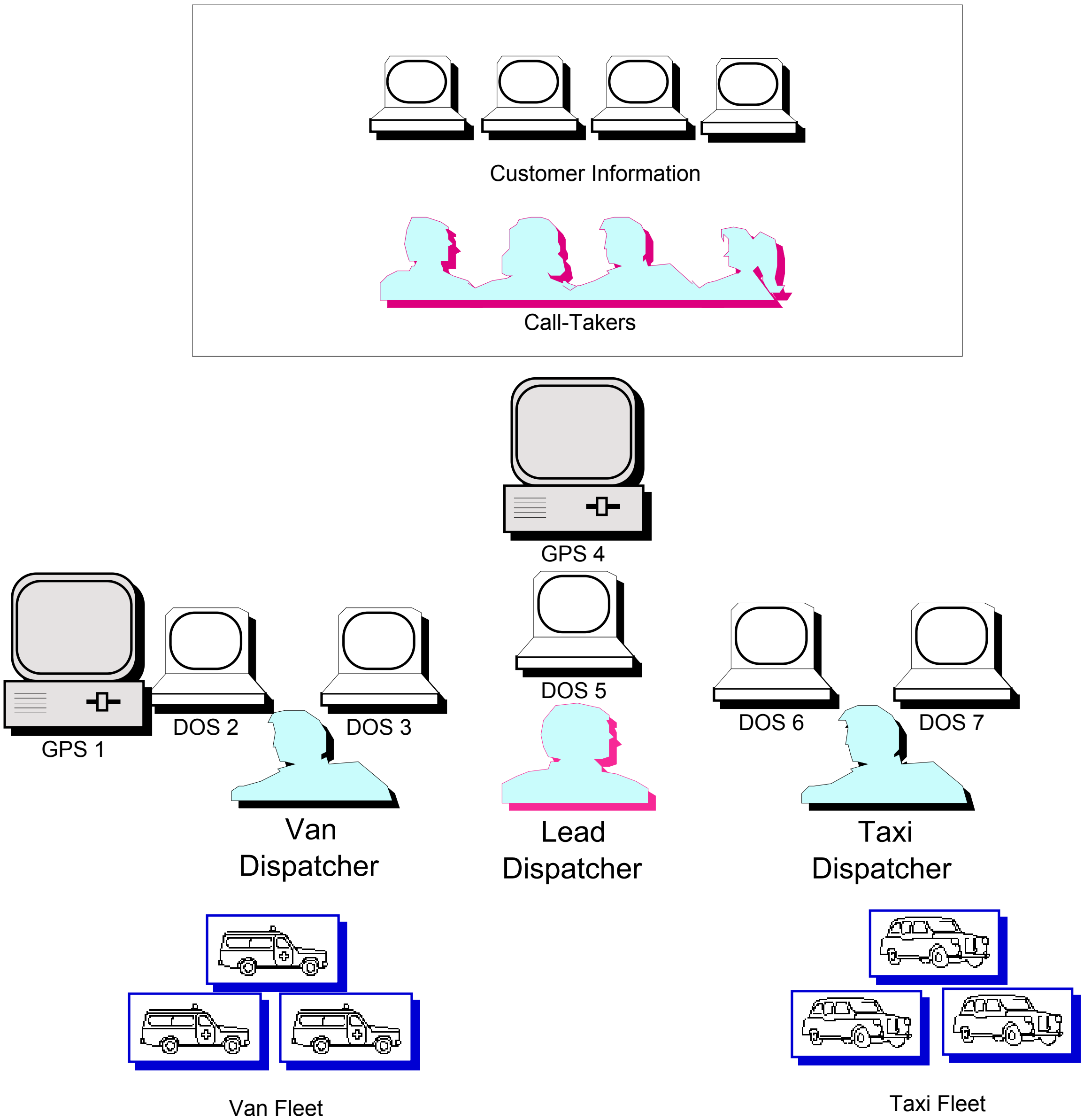
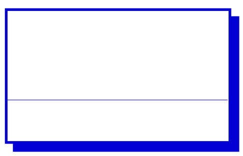


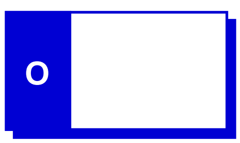
Figure 1. A schematic diagram of the dispatch operation room and their computer monitor locations.

Insert node indicates that an activity needs to continue somewhere else in the network, possibly due to a lack of space or is being duplicated with an Exit Node with the same number (see below)

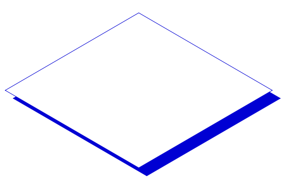
Exit node indicates that an activity is being followed (or duplicated) from another point on the network. Note: there must be at least one Insert Node with the same number as the one on this Exit Node.



Termination node indicates that the procedure (following depth first rule) has been completed at this point.



Either-Or node indicates that at this level (point in time) only one node can be chosen and followed.



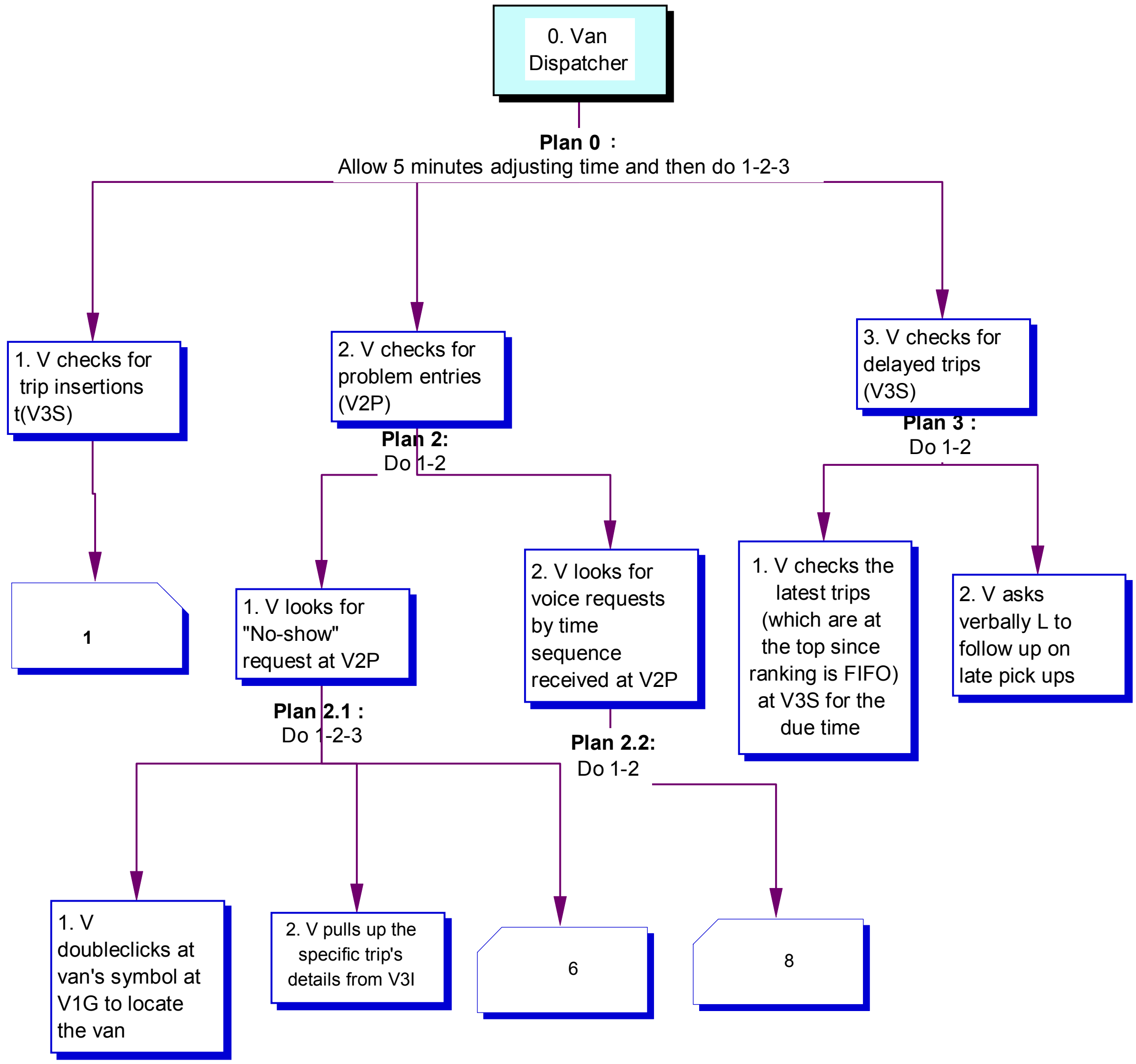
If-Then node indicates that the path will be chosen depended on the answer to a question included in the node. The selection in this node is either Yes or No.

Figure 2. Symbols and descriptions for the HTA decision model.

LEGEND:
Code attributes: <PERSON, DEVICE, SCREEN>

PERSON	DEVICE	SCREEN
V : Van Dispatcher	1: Van's GPS Monitor	S : Share-ride screen
T : Taxi Dispatcher	2: Van's left DOS	P : Problem screen
L : Lead Dispatcher	3: Van's right DOS	I : Trip detail
N: Van Driver	4: Lead's GPS Monitor	J : Trip summary
X : Taxi Driver	5: Lead's DOS	O : Order-taker screen
	6: Taxi's left DOS	R : Routing screen
	7: Taxi's right DOS	G : GPS screen
		M : Message screen

Figure 3. Legend and code attributes used in the HTA model development. These codes are used extensively to reduce the apparent size of the decision tree.



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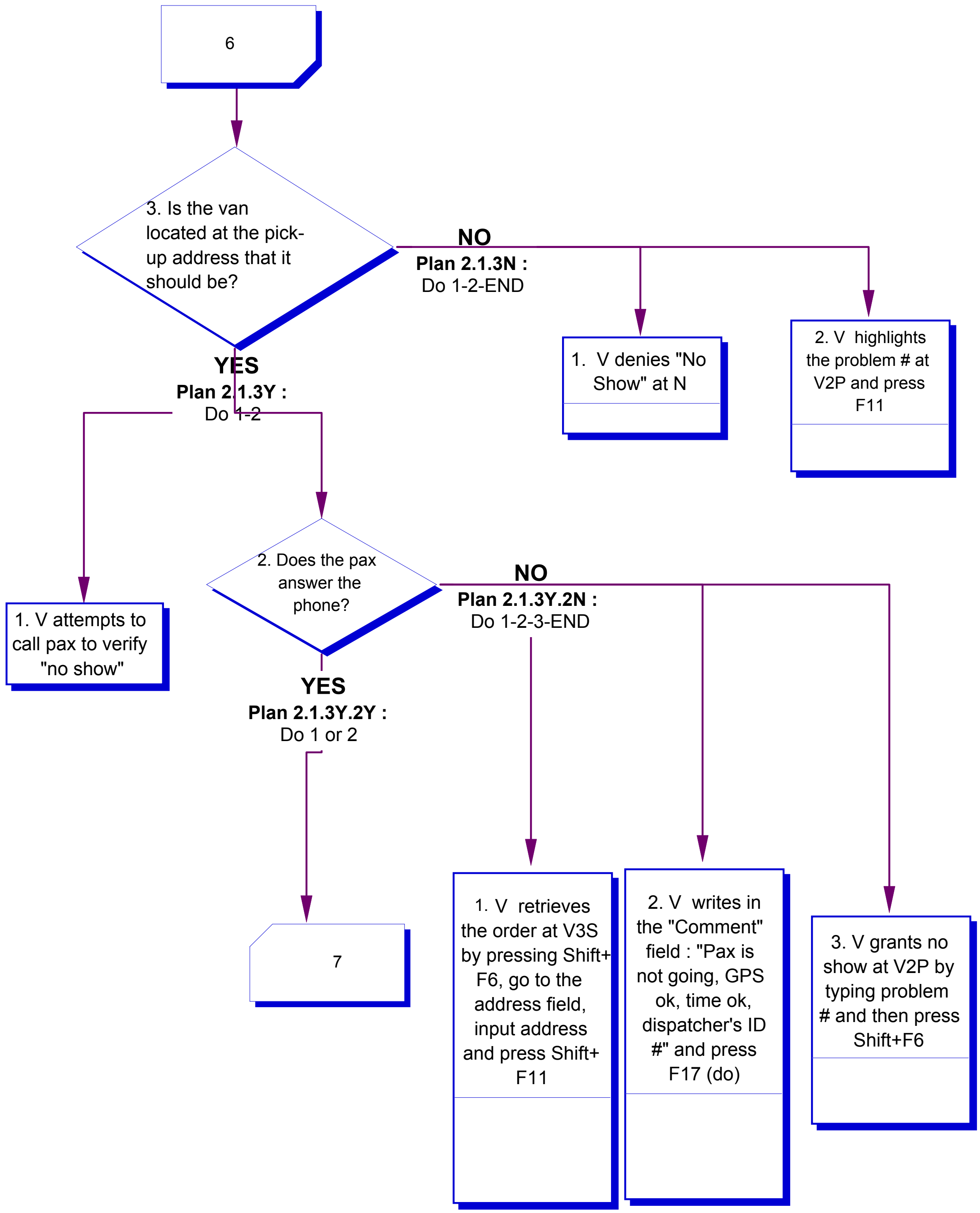

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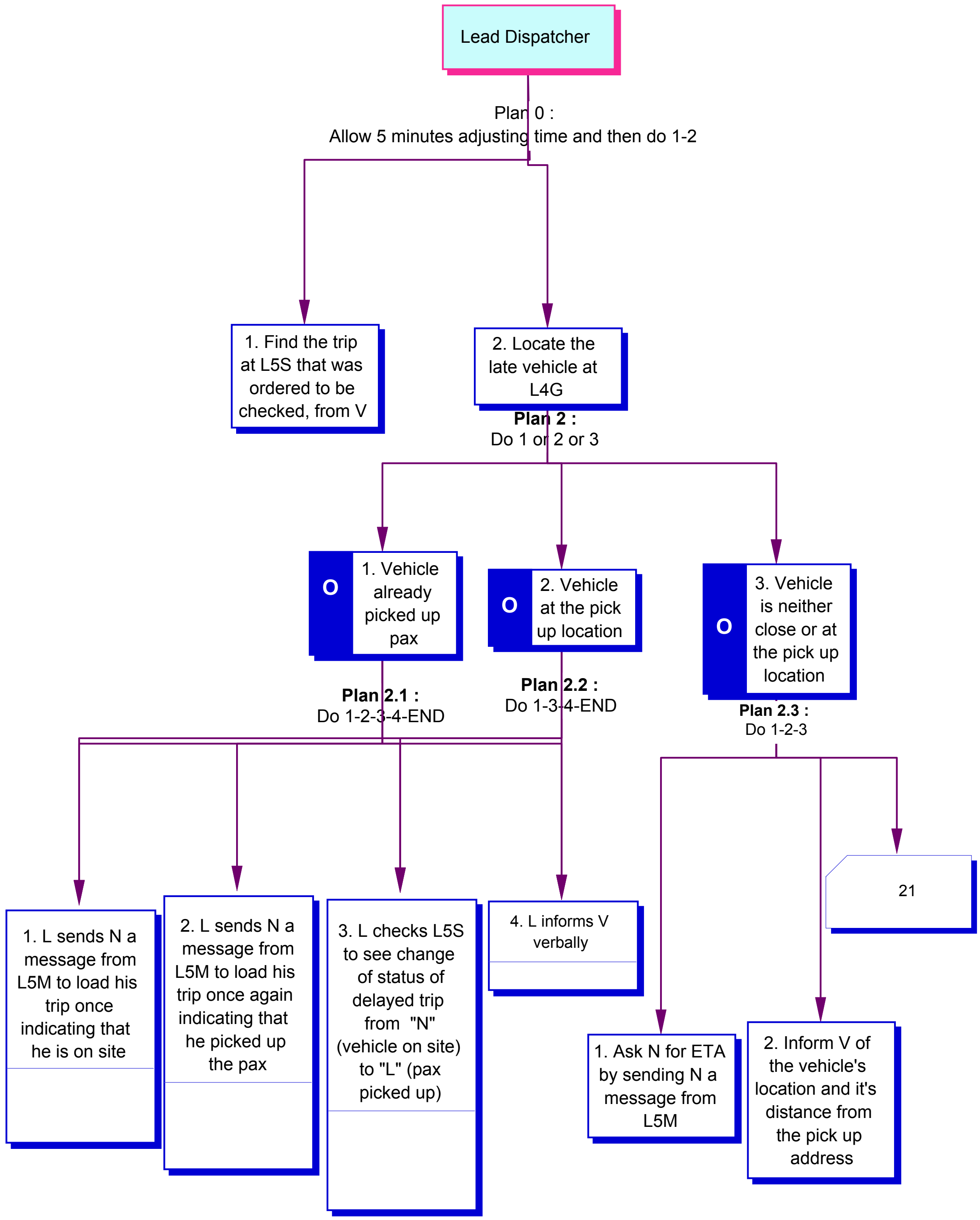

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