panel discussion

AUTOMATION IN DISPATCHING DEMAND-RESPONSIVE VEHICLES

Richard H. Shackson, Ford Motor Company, moderator

This discussion is about using the computer directly in the decision-making task. Haddonfield is the only application to demand-responsive transportation. A couple of large taxi fleets have taken this step. The panelists are associated with these systems both in their daily operations and the research and development that led to them.

PANELISTS

Sam Rudofsky, Ford Motor Company and representing Los Angeles Yellow Cab Company
Gordon Thompson, Canadian Marconi
Kenneth R. Roberts, Mitre Corporation
Nigel H. M. Wilson, Massachusetts Institute of Technology

ROLE OF AUTOMATION

QUESTION: What is the exact role of automation in your system?

RUDOFSKY: A few major objectives were achieved by automation: The amount of paper work in dispatching was reduced (the Los Angeles Yellow Cab Company processes approximately 15,000 orders per day); orders in the dispatch center are handled more accurately and faster; and transactions can all be passed into a history file for batch processing at some later time.

THOMPSON: The Diamond Cab Association of Montreal used automation to overcome a number of problems that are peculiar to the taxi industry and to improve the efficiency of the operation. Our main objectives were not so much related to paper problems as to discipline problems. In such a large open-channeled system, piracy (a call intended for one cab taken by another that got there first) is a serious problem. The computer acts as an interface essentially between the dispatcher and the cab operators.

ROBERTS: The computer has 5 main functions. The first one is to assign customers to vehicles—an automation of the scheduler function in Haddonfield. The scheduler was assigned a customer, and he made a specific vehicle assignment. The computer has automated that portion of the manual system completely. The second one, to monitor vehicle location, is a partial dispatcher function. The dispatcher has other functions, but one of the things he is required to know is where his vehicles are. Now the computer keeps track of that. The third is to maintain master files. In the manual system, there was 1 file that contained names of periodic customers. We now maintain 4 or 5 master files (street names and some other things). The fourth is to keep track of operating parameters. The street file contains coordinates and other calculations that are useful during congestion situations with regard to vehicle speed. Also, some other system costs that are used in the scheduling system are based on how busy the system is. And, finally, the computer is used to prepare the transaction file, based on a formalized reporting system, and produce daily reports.

WILSON: The M.I.T. system provides essentially the same working features that Roberts has described for the Haddonfield system. The computer system performs the decision-making role that is performed by the dispatcher in manual systems and is also responsible for the bookkeeping task the dispatcher would normally handle. The way the system operates is that, when the request is received, a telephone operator, seated at a teletype or similar terminal, types in the origin and destination. The computer translates these addresses into coordinates, makes the decision on the best vehicle for that particular passenger, and immediately sends back to the teletype and the telephone operator the expected pickup and delivery times. When a driver makes a stop, he informs the dispatcher, who enters the information through another input device, indicating to the computer that a stop has been made. The computer responds with the next stop for that vehicle, which is transmitted back to the driver. Other functions performed by the computer are automatic billing and allowing different classes of trips to be made at the same time with the same vehicle fleet.

JUSTIFICATION AND PERFORMANCE MEASURES

QUESTION: How was automation justified? Can you identify performance measures that can be used in the evaluation of an automation system? By these measures, has performance been satisfactory?

RUDOFSKY: Quantifying performance benefits that were anticipated and derived is difficult. The amount of paper work in the dispatch center was reduced. In fact, the normal operation has no paper work except for time orders, call-backs, and late orders. Orders are put through faster, and customers wait less. Because of accurate operations, drivers spend less time looking for bad addresses and, most important, pay-miles improved from 47 to 57 percent. (Their objective is still 60 percent, but they are extremely happy with the results so far.) Previously, customers calling in would be queued and have to wait, but now 90 percent of all telephone calls are answered within 45 seconds. The number of orders that are assigned to cabs within 15 minutes improved from 60 to 90 percent. The bottleneck in the dispatch center has been eliminated so that now, with automation and video terminals, orders move from order taker to order sender instantly instead of taking 4 minutes as previously.

THOMPSON: Our main objectives were to improve discipline in 2 main areas: piracy, which causes a lot of trouble, complaints, and dissension among the cab drivers, and favoritism, wherein the dispatcher has a favorite that he always uses on selected driver jobs. These were overcome almost completely with the aid of the computer. Piracy was eliminated by giving the message only to the driver for whom it was intended. And, because the computer assigns the cab to the dispatcher for dispatching, this resolves the matter of favoritism. Because of the number of cabs involved, frequency congestion was another problem that was solved by computer-aided dispatching; the total register dispatch cycle is now down to 12 seconds per cab. Efficiency in loading, a secondary consideration, has improved, measured by the fact that the income of the drivers is up an average of 20 percent with the computer dispatch system.

ROBERTS: Automation was justified, but whether manpower was reduced is not pertinent with respect to our objectives in Haddonfield. We addressed the questions of what is the maximum capability of a manual system and how big should a system be before computer control is needed. We examined wait-and-ride times from 2 points of view: first, with a wide-open computer system to determine whether they would be greater than with the manual system, and, second, with computer controls so that wait-and-ride times were guaranteed by refusing customers if they could not be given a guaranteed time or by bringing more vehicles into service. Computer control provides the capability both to measure and guarantee service, and thus productivity is increased. If a vehicle is going to be out of service downtown for half an hour for a lunch break, with the computer system we can start building up what we call tours or we can accept customers and assign them to that vehicle so that, when the driver reports back in, a load is ready. We also think that the assignment operation gives us higher productivity because of better customer-vehicle assignments when the system is busy. We have, of course, a central-control capability with management control that is a little superior to that under the manual system. And then, the final area that I think we wanted to address was the problem of merging a scatter-gather system with a many-to-many system. In a straight scatter-gather situation, a manual-control system is probably reasonable. A computer-control system is needed for a large, many-to-many, share-cab system, or whatever it may be called. The challenge is to merge these two types of capabilities into a transit system that uses the capabilities when it needs them. That would probably require some type of automatic control.

WILSON: Automation can be justified for the above reasons, which can be summarized as follows: Automation can increase the system productivity, both the passengers carried per vehicle-hour and the passenger-miles per vehicle-mile. It can provide more reliable passenger service through using and closely monitoring guarantees and constraints on service. It can extend the feasible size of the system that can be implemented. You can implement large systems if you have a control center with automated decision-making. For the computer system that uses voice communications between control center and vehicles, manpower reductions are minimal. Some of the decision-making responsibilities are removed from the dispatcher, but the dispatcher must still relay messages to the drivers. With the computer and digital communications, manpower savings will occur when the number of dispatchers is eliminated or reduced. Service measures are important: wait times and travel times. As a result of the increase in reliability we hope to see an increase in ridership. System productivity must also be measured. We are also interested in things relating to the automated function itself, such as times between failure for the computer system, both hardware and software.

QUESTION: What cost-benefit ratio can be attached to automated vehicle monitoring?

RUDOFSKY: The automatic vehicle monitoring system (AVM) will result in better management control of cabs and could improve efficiency. Automation covers only about 50 percent of the operation—receiving customer calls and then dispatching them to cabs. The other part of the operation involves the drivers' picking up customers at hotels and on the streets. So, the cab companies rely to a great extent on the individual cab record to determine how efficiently the cab operates. When I reviewed performances of individual cabs, revenues varied significantly; individual driver earnings ranged from $125 a week to $300 a week. So, I think AVM could serve as a management tool for providing better control over cabs, especially since a major portion of the cab activity does not originate in the dispatch center.

WILSON: We have done simulation experiments on automatic vehicle monitoring. It improves vehicle productivity about 5 or 10 percent; it decreases costs about 5 to 10 percent, excluding the cost of the AVM system itself. Whether it is worth using depends on the cost of the system.

COSTS

QUESTION: What did your installation cost in terms of both time and money?

RUDOFSKY: The equipment was delivered to the Los Angeles Yellow Cab Company January 1971; the major part of the software and hardware debugging was done at the factory prior to delivery. Not until November 1971, approximately 10 months later, was the programming complete and the company on the air for a few hours a day. Three months later, February 1972, the company was on line approximately 90 percent of the time. Even then numerous shortcomings were recognized, and a program rework was undertaken. That took another 4 months; by May 1972, the system was operating relatively reliably and satisfactorily. The Los Angeles Yellow Cab Company intended to pay for the system by monthly rentals after the equipment was delivered, debugged, and accepted. National Cash Register was the successful bidder. The whole system, both software and hardware, was provided by a single vendor.

The cost is $6,000 a month rental for the real-time system (there is a separate system used for batch processing and performance analysis). The telephone system is a key part of the operation, and an Automatic Call Distribution System is rented from the Bell Telephone Company for $1,700 a month.

THOMPSON: We purchased the computer, but we did the complete job otherwise as far as the software, radio, and interface are concerned. However, from the time that we finally came to an agreement, it took 1 year until we had operating hardware—slightly more than a year because the end of 1 year occurred during the Christmas period, and that is not a good time to interrupt taxi operations. A large part of the debugging was done throughout the design. The program writing was going on in parallel with design; and about 2 months after the installation, the major part of the debugging was complete. However, we learned that taxi drivers are quite ingenious when it comes to beating a system, and they found ways that showed up as much as 10 months after the system was in operation (for which we had to alter the program and system). The project was financed by the Canadian Marconi Company on a rental-purchase arrangement. The automation part cost something on the order of $100,000.

ROBERTS: Haddonfield is a federally funded experiment with some state participation. The experiment is funded to the extent that we can operate the system at no fare for the duration and still not spend the money. The state of New Jersey is the local sponsor and purchased the vehicles. The local bus company supplies the drivers, and Mitre Corporation is an UMTA consultant and is implementing the computer control, which is the second phase of the experiment. We use a 2500 minicomputer with a substantial amount of software and have implemented primarily the M.I.T. concept in machine language. A team of 5 people worked a year on implementation, and the system is now turned on for a substantial amount of time. Software implementation is being done by Mitre, but the experiment as a whole has several groups involved. We have, of course, used a substantial amount of vendor-supplied software, which also was worked into the system during that time period. We have had a normal amount of computer downtime. Debugging is an ongoing effort. The basic computer rental price is about $2,500 a month, plus $5,000 for a maintenance contract, which I heartily recommend.

WILSON: If we look at the research and development effort that took place at M.I.T., we can identify 3 distinct phases that led to the development of the real-time control system. First was the development of the assignment and control algorithms. The second was the development of the simulation model capability within which these assignment algorithms could be tested and the overall economic feasibility of the system investigated. The third was the development from that simulation model of a real-time control system. Bear in mind that this was part of a much larger research and development effort on dial-a-ride going on at M.I.T. The overall time to complete all 3 phases was about 3 years, and the total amount of effort put into them was about 7 man-years: 1 man-year on the development of the assignment or control algorithms; 3 man-years on the simulation model development, testing, and debugging; and 3 man-years on the development, testing, and debugging of the real-time control system. We developed a couple of different real-time control systems that operated on different machines and different operating systems. We made the decision to go to a real-time control system from the simulation model; this enables us to develop a system quite rapidly and inexpensively. We were able to use existing operating systems. We used high-level programming languages, and this again was intentional to give us the flexibility when the system was used to modify the assignment algorithms and to modify the real-time control system rapidly as the demonstration was proceeding.

The overall initial development effort was funded by the Urban Mass Transportation Administration. The total project cost was $1.4 million and included many other aspects over and above the assignment algorithms, simulation model, and real-time control systems. The cost of the assignment algorithms, simulation model development and testing, and real-time control system development and testing was approximately $400,000. Additional efforts would be required to get from where we are now with our real-time control system to actually using it in a given environment. Those efforts would be principally related to tailoring the system to the individual service area and to the individual hardware configuration and software configuration under which it would be operating. The entire system was developed by M.I.T. with a minimum of full-time research staff. On the software development, we had one full-time researcher, and the remainder of the staff was composed of faculty members and graduate students working part time.

QUESTION: What is the marginal cost for computer automation? If the first system has been installed, has the second one also? How much additional cost and effort are required to tailor this technique to other specific applications?

RUDOFSKY: Unless the second system is almost an exact duplicate, a major portion of the costs are going to be repeated, e.g., street files of specific cities. Hardware need not change if one is willing to copy someone else's operating system. The problem is that, after the first system is completed, debugged, and operating, many new devices become interesting and tempting for the succeeding implementation. I also doubt that 2 cab management groups would set up the same target for an automation program.

ROBERTS: We would only have to redo the street name file to move the Haddonfield system to another location.

WILSON: I think about 80 percent of the costs would be nonrecurring from one system to another, but some significant things would have to be done. One involves the street network coding, as Roberts mentioned. Another involves travel time prediction, which may be specific to a given service area. A third involves paying attention to and persuading the dispatching staff and the drivers so that the system responds to what they want it to do. That may require making changes in the input and output messages and degree of control given the dispatcher and possibly the driver in certain situations. It is more than just relaying messages; additional capabilities may be needed in a given situation. The fourth involves the computer system in the second area, which is probably different from the system that the software was designed for. Software changes may be necessary to accommodate the machine.

RUDOFSKY: The Yellow Cab Company would like to expand its system and to automate the process of assigning orders to the cabs. However, the company finds itself in a rather awkward position; the computer is totally saturated. To expand would require a totally new computer. Of course, a lot of the software and a lot of the programming are already done and would be transferable. (The entire street file is in the computer, and the address of every order is checked to determine whether it is valid.)

STAFF AND USER ATTITUDES

QUESTION: How are people taken into consideration? For those systems that have operating experience, what has been the reaction of both staff and users to the employment of automation?

RUDOFSKY: The Los Angeles Yellow Cab Company has used automation more in the interest of customer-dispatch center relations than of dispatch center-cab driver relations. The drivers hardly realize that an automatic system exists, and that is of little concern to the company since there is a 295 percent turnover of drivers per year. Automation did have a great impact on the dispatch center. There was no resistance, just skepticism. That disappeared after the system had been in use for about 18 months. The amount of manpower saved in the dispatch center almost paid for the system. The customers are also quite happy with it. Phone calls are answered promptly, and cabs arrive at their doors in much better time. Training, too, is easier. The order takers have video terminals and keyboards and type in the addresses. The order senders interface directly with the cab drivers, and their operation has become much simpler. Previously it took months to train a very efficient and effective order sender, but now they are up to maximum efficiency in about a month.

THOMPSON: I think there are 3 groups that have different reactions: the cab drivers, the dispatchers, and management. The cab driver was faced with an entirely different situation because he was used to hearing everything on his particular channel so that he got to the point where he did not hear anything except what was directed to him. As a matter of fact, he could not initiate anything except his own car identification and address; he could not pick up the mike and talk to anybody. Inititially, there was some adverse reaction to this quiet condition. Although the computer sends back an acknowledgment, he worried that he might have missed it, that he was being ignored, or that his radio was not working. The drivers have now developed initial confidence in the system, and their problems seem to be over. The dispatchers are the ones that benefit most. They had a rough job with an open-channel situation in which everyone was clammering for a call. This is an orderly operation for the dispatcher. The computer stores the incoming calls from the taxi waiting to be registered. The dispatcher tells the driver what address to go to, and all he ever hears is the voice of a cab driver who has to ask for information. Management, of course, benefits from having better working conditions and management information.

ROBERTS: The users in the computer control system are required to furnish fairly complete origin and destination information for many-to-many service. For scatter service, users do not call but merely board a vehicle and the driver arranges the drop-off location. This is a result of the particular control strategy that assigns the customer to a vehicle confined in a central location. We discourage boarding by people who have not called (except in the case of scatter service). The drivers have had to adapt to the computer control system in central areas. They now have less advance knowledge; they are given only their next stop or perhaps their next few stops. It is not advantageous to give drivers too many stops ahead because they will be modified or reshuffled by the computer up to the last minute. We discourage reshuffling of stops on the street by the driver because we are going on a synchronization procedure to update pickup and drop-off times. The impact on the control staff has been minimal. They recognize that when we reach a high level of activity they would not be able to manage a manual system.

WILSON: Users are primarily interested in the service they receive. If a manual control system has options that a computer system does not have, such as flagging a vehicle down, extra people getting on at a stop, or not having to call in at a main activity center when they board a vehicle, then users will perceive the computer system as effectively restricting their options. If, on the other hand, they receive more reliable service, low wait times, and lower travel times, then they would obviously be more in favor of computerization. Both the Mitre and the M.I.T. systems transfer full decision-making responsibility to the computer. Other systems give partial control and decision-making power to the driver or the dispatcher in certain instances. There is a need for exploring these options as well as the full computerized control system. For instance, the computer in general will not have current detailed knowledge of the street system or congestion on the street system; the driver will have that information, and the dispatcher also will have that information to some extent. Where several stops are quite close together the driver, knowing the local street pattern and the local situation with respect to congestion, is in a better position to decide on the optimal sequence of making those stops. I think a mix of computer and manual control techniques is desirable.

QUESTION: Under full computer control, what procedure is followed to modify a vehicle tour if the driver picks up passengers who have not called in? Explain scatter-gather and its operation difficulties under automation.

ROBERTS: We use the term scatter for the one-to-many situation, such as from an activity center or a transfer point from another transportation facility. For example, at the Lindenwold station, vehicles with zone numbers on them pull into the station and are boarded by customers who do not need to call in but can look on a map at the station to find the zone they are in. The driver has a preprinted map on which he marks their stops and somehow works out a drop-off sequence. We worked these into the computer system by putting a customer in called Mr. Dispatch who starts at the station and is dropped off somewhere near the far limits of that zone. The gather, of course, is the opposite situation. That is, the driver picks up regular customers in the morning and takes them to the station. He is given a list of the predetermined pickups. Because the gather tours are early in the morning, the probability that they will need to be merged with the many-to-many tours is minimal because we can, in most cases, let a vehicle work a pickup tour first and then put it under computer-controlled many-to-many service because people tend to go to work before other people do most other things. In the afternoon, scatter tours from the station, say, have to be handled in conjunction with regular many-to-many passengers. The difficulty in computer controlling scatter tours is that people who get off the train want to go as quickly as possible and not be delayed by a sorting sequence. The second difficulty is that the algorithm was not designed for this situation. Further, there is no guarantee that if this service were put into the algorithm it would be improved. Handling these tours manually saves the imposition on the control center and saves all the communication. It does mean, of course, that these transactions are not in the system. Those who want many-to-many service should all call in so there is a full record. That has to be established as a policy. The problem then is how to identify people who did not call. This is no problem at a home address, but there is one at an activity center. The driver cannot separate those who have called from those who have not because everybody will say they called.

QUESTION: What actually happens when the vehicle pulls up at a shopping center stop and there are 3 people who placed orders and 3 others who did not? Does the driver allow them all to get on?

ROBERTS: The driver will then call the control center—in effect, make the call for the people. We try to discourage the driver's having to act as an intermediary between the customers and the control center to schedule trips. The driver has to make a distinction between a situation when the vehicle is operating on the many-to-many mode where there is a requirement that people call and a situation when the vehicle is operating in the scatter-gather, many-to-one, or one-to-many mode where there is no requirement. And, one thing you cannot do is say to the person, Are you a many-to-many or a many-to-one?

EXTENT OF AUTOMATION AND BACKUP SYSTEM

QUESTION: What do you do when the computer fails? What backup is provided for the primary automation? How does this affect the choice of hardware?

RUDOFSKY: When the computer crashes, the system resorts to the original situation. The dispatch center still has the old telephone operator's patchboard and phones, still has a conveyor belt that distributes handwritten orders, and still has the order takers and dispatchers to operate the system manually. Because we reduced personnel in the dispatch center when we automated, the problem is having enough people when the backup system is needed. Another shortcoming is that transactions are not placed in the automated history file. Because this is an important part of the total system, the handwritten orders are punched and replaced in the history file later. Back-up memory is included in the system to retrieve all back orders during the transition. The old equipment formerly used for the manual system is intact and is being retained for the backup mode.

THOMPSON: We did not provide for any backup for the automated function. It was difficult to sell the system to the customer, and it would have been more difficult if we had discussed the problems in reverting to the manual system for short periods of time because of breakdown or maintenance. We have a system for switching to manual operation in the event of failure, but we do lose the information that is stored in the computer as far as the registration of vehicles in particular locations and, of course, the costs of the transactions that take place at that time.

WILSON: In the event of a computer failure, the current state of all vehicles is punched out by the machine, and the dispatcher sequences the stop for each vehicle and sets up the current and projected activity for each vehicle as a sequence of punched cards. The telephone operator moves from teletype to card punch and continues to take requests and punch them on cards that are handed to the dispatcher for decisions. At any point in time, there is a current set of assignments that have been made by the dispatcher. When the computer starts again the cards are read into the machine. Obviously the level of service is degraded in manual backup. I would not want to see the system restricted to the capacity of a manual system operating under computer control. We have to be able to handle more people by computer to justify it, and we have to acknowledge that when the system fails we must go to less reliable service and perhaps reject some requests during that period of time.

QUESTION: What happens to files of dispatches during a failure?
RUDOFSKY: We have a backup memory for the pending file, which is under the control of another computer. When the computer fails, we can pull out the active files and go to the manual system. However, there is always a common link somewhere; and if the common link is not available, we lose the orders.
ROBERTS: We have a restart capability that automatically takes care of the power situation. The problem is that, when the machine stops, we never know how long the downtime will be, so we initiate the manual backup immediately. If the system starts in 5 minutes, we have not lost much.

FUTURE PLANS

QUESTION: What are your plans for the future?
WILSON: Our approach at M.I.T. is to try to define what functions the computer control system should perform, what functions the driver should perform, and what functions the dispatcher should perform. In this sort of environment, the type of computer control system we think should be implemented is one with a high-level language, i.e., something like FORTRAN under existing operating systems that can be easily modified at low costs. When we have a feel for what the optimal or effective characteristics of the computer control system should be, we can then move to a customized low-cost control system with a simpler language, e.g., a second-generation computer control system.
RUDOFSKY: The cab companies are anticipating some funds from the U.S. Department of Transportation. The Los Angeles Yellow Cab Company is hoping for an allocation of about $200,000, but has some future plans in case the funding is not forthcoming. The company is looking at a dial-a-ride application for cabs, especially in the off-peak hours. The cab companies are also looking at Automatic Vehicle Monitoring to better control cabs. They also are considering the applicability of data communications between the cab and the dispatch center.
WILSON: I think one obvious area of future development is the implementation of a computer-digital system. We might then see what manpower savings are achievable by using a more fully automated system than the computer voice system. In the research and development stages of dial-a-ride, we conceived of a computer voice system coming before computer digital systems. It turns out that the first automated system is a manual digital system, which is not entirely what we would have expected 4 or 5 years ago.