# Boston & Maine Achieves Control over Railroad Performance

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Between 1977 and 1982, the Boston & Maine Railroad made extensive efforts to improve its operating performance, especially in the areas of freight service, terminal control, and freight-car utilization. Major changes were made in the organizational structure, in information systems, in the decision-making processes, and in physical facilities. As a result, significant improvements in service and costs were achieved. The railroad saved more than $3 million annually, or roughly three percent of total operating expense, which helped the B&M to achieve the first income-based reorganization in the rail industry in more than 20 years. Operations planning played a major role. The MIT service planning model was developed in order to evaluate alternative operating plans and establish origin-to-destination trip-time standards.

The Boston & Maine Railroad, which provides freight service in New England, went bankrupt along with six other northeastern railroads in 1970. Since bankrupt railroads can continue to operate, the financial situation continued to deteriorate until 1975, when the B&M lost more than $10 million on freight revenues of less than $90 million. By that time, however, a young, energetic management team headed by Alan Dustin was beginning the slow process of restructuring the railroad as a profitable operation. In addition to taking action to


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rehabilitate the railroad's major facilities and to gain control over labor expense, Mr. Dustin emphasized the need to control operating performance. As evidence of this concern, the B&M participated in three projects sponsored by the Freight Car Utilization Program (FCUP), a cooperative research-demonstration program funded jointly by the Association of American Railroads and the Federal Railroad Administration. These projects, in general, addressed the need for better control techniques to improve railroad service and equipment utilization. B&M was anxious to participate in these projects in order to enhance its management capabilities, improve its service, and reduce its costs. MIT was funded by the FCUP to work with B&M.

These research projects developed several important techniques for controlling railroad performance. In 1977, B&M adopted improved budgeting techniques for freight car expense. In 1979, the railroad implemented an operating plan developed by an interdepartmental service committee as the most effective means of resolving chronic operating and service problems [Martland, Messner, and Nowicki 1979]. The planning process was aided by the development of the MIT service planning model, which was used to analyze alternative operating strategies and to establish standards for trip times and yard times [Martland, Messner, and Rennicke 1979]. The B&M defined, for the first time on any major railroad, standards for both trip times and reliability that were explicitly related to train schedules and standards for yard-time performance [Task Force on Car Cost Allocation and Budgeting 1982]. In 1982, B&M evaluated various terminal budgeting and measurement techniques designed to provide a more explicit link between terminal performance and system performance [Martland, Marcus, and Raymond 1983]. Throughout this period, MIT staff met regularly with B&M officials and developed many procedures and analytic techniques that were tested by B&M. Carl Martland was the principal investigator for all of this research, while Hank Marcus and George Raymond developed car-cost budgets and analyzed changes in terminal and system performance.

The techniques they developed proved to be very helpful in improving performance, as noted by Mr. Dustin [1980]:

> This work, coupled with our extensive efforts to develop innovative management procedures and techniques, has yielded significant success. In 1976 average cycle time per load on the Boston & Maine was 6.9 days or 165.6 hours. By March of 1980, cycle time per load had been reduced to 5.4 days or 130.7 hours. This 21 percent reduction in cycle time has resulted in annual savings of about $1.5 million in car-hire payments alone.

By 1982, the total benefits, including further improvements in car utilization as well as improvements in other aspects of productivity, were estimated to exceed $3 million annually. Boston & Maine's experience provides a good example of the effectiveness of using analytic techniques to promote and support interdepartmental attempts to regain control over performance.

**Overview of Railroad Operations**

Railroads achieve their competitive advantage by using a single locomotive to pull a great many freight cars — that is, by running trains. To do this, they use classification yards to assemble and disassemble trains [Petracek et al. 1977]. After a freight train leaves its cars at a classification yard, switch engine crews sort these cars into groups with common characteristics. This sorting process is called classification, and each group of cars is called a block. A large yard will have 50 or more tracks devoted to classification plus other tracks for receiving and

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assembling trains. Only a few hours are needed to classify or assemble a train, but freight cars spend much closer to a day in the yard because of congestion and the infrequent (typically daily or at most twice daily) departures of appropriate outbound trains. The factors that influence yard performance include the volume of cars to be handled, the extent of peaking in train arrivals and departures, the number of switch engine crews working, and the layout and condition of the facility [Raymond 1982; Tykulsker 1981].

The railroad's operating plan governs the movement of cars and trains; it includes a blocking plan, train schedules, and a dispatching policy. Even for a small railroad, there are an enormous number of conceivable operation plans. The blocking plan defines what blocks are made at each yard, what traffic moves in each block, and what trains carry each block. A large yard may make over 100 blocks that move on more than 30 outbound trains. The train schedules define the origin, destination, and intermediate stops of trains, plus the scheduled arrival and departure times and work to be done at each location. The dispatching policy determines when trains actually depart, since trains in North America seldom operate strictly according to schedule and are frequently cancelled or consolidated.

In North American railroads, the operating plan is usually maintained by the transportation department with modest input from the marketing department. Major revisions to the plan are made at irregular intervals of a few months to a few years, while minor revisions are made almost daily. Daily implementation of the plan is supervised by line-operating officers, often under the direct supervision of a centralized operations control center. Extensive real-time data concerning the location and status of equipment are maintained by the larger railroads as a guide to real-time operating decisions [Missouri Pacific Railroad 1976]. [Labor/Management Task Force 1975; Savage et al. 1981].

The operating plan is perhaps the most fundamental control at the disposal of a railroad. The operating plan directly determines the number of train crews needed and the operating capacity required at each yard. It strongly influences trip times, reliability, and equipment utilization. Hence, the procedures for developing and modifying the operating plans are extremely important aspects of railroad control systems [Williamson, 1977].

**Establishing Consistent Performance Standards**

The complexity and geographical dispersion of railroads hinders the development of effective control systems. It is difficult to set standards for overall performance that can be used as guides for people involved in operations hundreds of miles apart. Hence, an understandable tendency to monitor performance on a functional and a regional basis leads to continuing difficulties in ensuring consistency among the various performance measures.

Specific problems arise in establishing consistent standards for yard, train, and system performance. The operating department's budget typically includes the labor and fuel expense associated with train and yard operations, but not the equipment expense. One result is that operating officers have a strong incentive to reduce crew expense at the cost of delaying cars. Operating budgets also tend to reflect the anticipated rather than the actual work loads, which causes problems when actual work loads are significantly higher or lower than expected and these unrealistic and inflexible budgets lose their value as effective operating controls. A third problem is that productivity standards, like gross ton-miles per train-mile or cars handled per switch-engine hour, tend to encourage operating officers to cut back operating capacity, even if the resulting congestion causes service to deteriorate. A fourth problem is that standards for yard and train reliability, for yard times, and for trip times are often developed independently, despite their clear interdependence. A fifth problem is that standards for reliability are seldom established, which makes it difficult to control reliability.

The B&M studies addressed such problems. Specifically, MIT developed the service planning model in order to create standards for trip times and reliability that were consistent both with the operating plan and with terminal standards. In order to implement such standards, B&M made substantial changes in its control system. The MIT service planning model (SPM) estimates the service and cost impacts of railroad operating plans. Inputs to the SPM fall into four major categories:

— *Network description:* Capacity, cost, and probabilistic train connection parameters for each yard; operating parameters such as length and horsepower per ton requirements for each line segment;
— *Traffic flows:* Average daily cars of a particular traffic category moving between an origin and a destination;
— *Operating plan:* Blocking policy, train schedules, number of crews operated at each yard, and number of locomotives per train; and
— *Unit costs:* Unit costs for each train or yard and also for link- and node-specific service units such as ton-miles, car-miles, car-days, locomotive-miles, cars-switched and train-miles.

The model uses these inputs to estimate yard performance, origin-to-destination, trip-time distributions, aggregate performance by user-defined traffic categories, and a wealth of cost information (appendix).

**Changes in the B&M Control System, 1977-1982**

In 1977, B&M had an extremely lean staff at headquarters, with little capacity for planning, evaluating performance, or developing better control techniques. That summer, as part of the FCUP study, B&M established an informal interdepartmental committee to work with MIT to conduct an audit of freight service and car utilization. In 1978, this informal group was replaced by an interdepartmental service committee that met at regular intervals and reported at least quarterly to Mr. Dustin and his department heads. Mr.

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Dustin asked this committee to analyze strategic operating alternatives and develop better information on service and car utilization. The committee included a midlevel manager from each major department. In order to mediate the traditionally different perspectives of the marketing and the transportation departments, the committee was chaired by an official from the executive department. The formation of this committee in early 1978 marked a significant departure from past practices, especially since the marketing department was given a much larger role in operations planning, and since the high-level commitment to service and car utilization goals broadened what had been a limited concern for reducing labor expense.

During the fall of 1978, the service committee met 10 times as it used the SPM to analyze three major alternative operating plans [Martland, Messner, and Rennicke 1979]. The first several meetings of the committee were structured around the information requirements of the model, while the entire fall's activities were structured around the use of the model. In effect, the availability of the analytic tool provided sufficient reason to bring people together from the various departments to debate issues of importance to the entire railroad. For the first time, representatives of both marketing and transportation, as well as the other major departments, designed and investigated serious alternatives to the existing operating plan. As is often the case, using the model meant developing information that should have been but, in fact, was not readily available: all the details of the existing plan, average yard and origin-to-destination trip times, and accurate estimates of traffic flows. More important, the group discussions brought out fundamental questions concerning marketing priorities, labor relations, and performance measurement that had earlier been dealt with inadequately. Many of these discussions went far beyond the scope of the SPM, but it was the SPM and the need for operating analysis that brought the group together.

On December 6, 1978, senior management approved the service committee's basic recommendations, which called for some specific operating changes as well as some general recommendations. The general recommendations fell into four categories:

(1) *The operating plan:* Adopt priorities and guidelines for handling the major classes of traffic including some specific goals for train frequency and service.

(2) *Empty car distribution:* Establish a separate car utilization department with responsibility for empty car distribution; use Lowell rather than East Deerfield for the distribution of empty cars in the eastern portion of the railroad.

(3) *Facilities:* Rehabilitate the major yards, especially East Deerfield and Lowell, so that classification can be concentrated and the minor yards can be closed.

(4) *Organization and control:* Make a greater effort to operate according to the plan; monitor yard and trip time performance relative to standards derived from the service planning model; continue the meetings of the service committee.

The specific recommendations called for establishing regular high-frequency service between the Hudson River and the state of Maine, introducing new through service between Maine and Southern New England, closing the yard at White River Junction, Vermont, and joining the Clearinghouse (an industry-wide program for reducing the movement of empty cars by relaxing the restrictions on loading empty cars belonging to member rail-

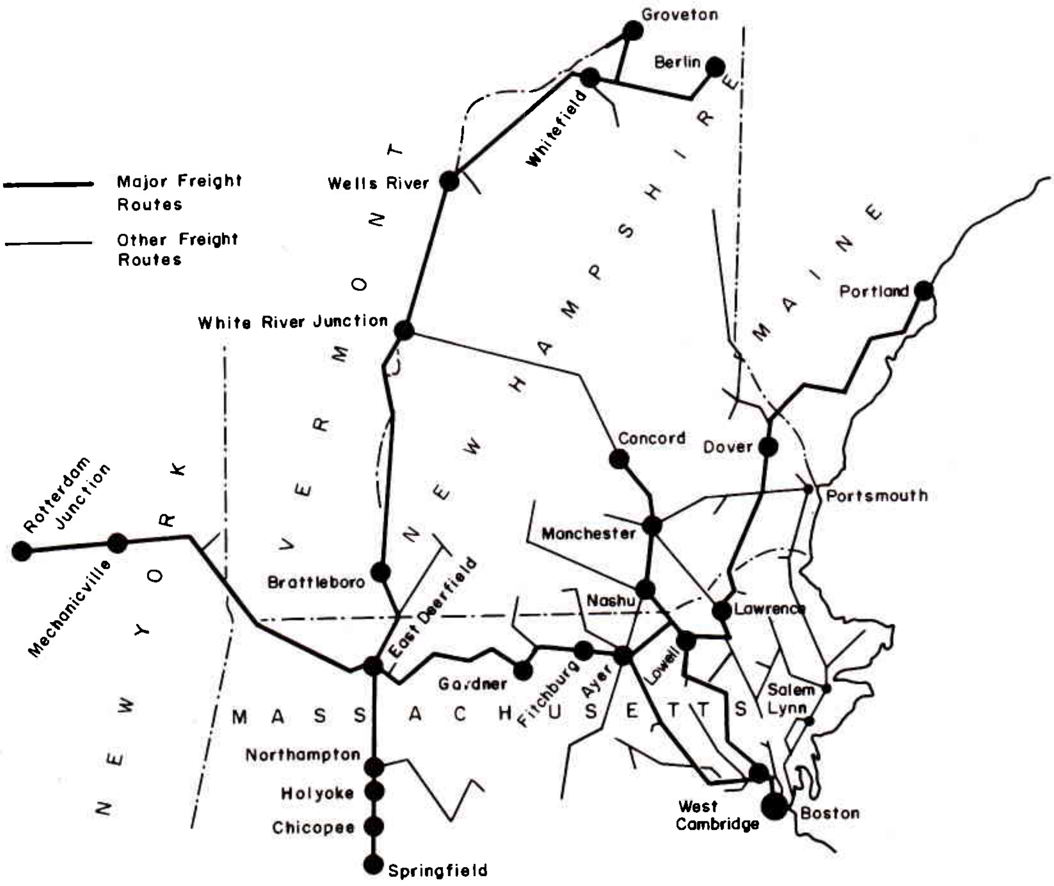


**Figure 1: The freight routes of the Boston & Maine Railroad as of 1980.**

roads). The service committee met nine more times over the next six months to coordinate the implementation of these specific changes, using the SPM to ensure that the changes were likely to achieve the intended improvements while avoiding degradation in the service provided to other traffic. These changes were coordinated with a rehabilitation program that upgraded much of the B&M's mainline in 1979 and 1980 and rebuilt East Deerfield yard in 1981 (Figure 1). With strategic operating objectives clarified, B&M was able to concentrate rehabilitation efforts where they were most needed.

B&M also developed new reports to ensure that service objectives were consistently met. From a control perspective, the most important of these was the operating/service plan report, which monitored yard performance and origin-to-destination trip times relative to standards derived from the SPM. Critical information from this and other reports was summarized, beginning in 1980, in a brief weekly car-utilization report. This report was used by senior management to check the performance of key trains and traffic flows, to monitor car costs relative to budget, and to compare average trip times to the average SPM standard.

Significant changes were next made in measuring yard performance, which was originally viewed exclusively in terms of crews worked and labor expense, with no consideration for the reliability of train connections or for average yard times. These changes focused on East Deerfield, the B&M's largest yard. By mid-1982, yard time was monitored on a daily and weekly basis relative to a standard derived from the SPM. In addition, weekly budget reports were prepared by yard and headquarters staff using microcomputers; these reports showed car time relative to standard, crews worked relative to a volume-variable standard, and total costs compared to a volume-variable budget. The standard for the number of yard crews was based upon a regression analysis that linked crews worked to cars handled at East Deerfield, in effect allowing a base number of crews for the yard plus an additional few switching minutes for each car handled.

With better facilities, more complete information, and a stronger organization, the B&M was better able to control operating performance in 1982 than in 1977. In daily decisions, much more concern was shown for train reliability and train connection performance. In the weekly review of operating performance, a new emphasis was placed on average trip times, both at the system level and for the highest priority traffic flows. Whenever major changes in service were contemplated, the transportation planning group and the service committee used the SPM to help develop new train schedules and blocking policy. A spirit of cooperation and confidence grew and a tangible air of excitement developed within the B&M's headquarters.

**Improvements in System Performance, 1977 to 1982**

B&M made substantial improvements in overall service and car utilization between 1977 and 1982. The service improvements showed up as a five to 10 percent decrease in average trip times for loaded cars and a 15-20 percent improvement for

| | Loads | Empties | Average |
|---|---|---|---|
| 1977 (September only) | 42.3 | 41.0 | 41.7 |
| 1978 (June, September and December) | 41.1 | 40.0 | 40.6 |
| 1979 | 41.8 | 42.9 | 42.3 |
| 1980 (January-May) | 38.7 | 38.9 | 38.8 |
| 1981 | 38.9 | 34.5 | 36.7 |
| 1982 | 40.4 | 35.1 | 37.7 |

**Table 1: The average origin-to-destination trip times on the Boston & Maine Railroad in hours showing the figures for loaded cars, empty cars, and the average for the two.**

empties (Table 1). The faster trip times for loads were concentrated in the most important corridors. These corridors were monitored on a weekly basis, and they dominated the concerns of the service committee. Trip times dropped more for empties than for loads because a railroad is able to determine which empties are used and which empties are returned to their owners. The freight car utilization department was able to distribute empties much more efficiently, thereby reducing both the time that empties spent on the railroad and the distances that they traveled.

The specific changes recommended by the service committee in 1978 were, in general, successful (Table 2). The committee audited performance during 1979 and documented weekly benefits of close to $40,000, which project to $2 million annually. The yard at White River Junction was closed without hurting service or car utilization. The new, direct service between Rigby and Springfield had begun to attract additional traffic, and the regular, high-frequency train operations on the major east-west corridor allowed B&M to reduce terminal detention time for its locomotives while providing more reliable train service. These facility and schedule changes, however, had much less impact than the improved management of empty cars which accounted for more than 75 percent of the net benefits.

The attention paid to car utilization also led to general improvements in performance. Car utilization is normally measured in terms of the car cycle, which is the average number of car-hours per load handled. From initial levels of more than 150 hours, the average on-line cycle fell to 133 hours for the first five months of 1980 (Table 3). After this period, the car cycle

| | Close White River Junction | Direct Rigby-Springfield Train Service | High Frequency Rigby-Hudson River Train Service | Improved Empty Car Distribution | Total |
|---|---|---|---|---|---|
| Train Operations | $(1,160) | $(3,840) | $2,400 | $14,600 | $12,000 |
| Yard Operations | 4,160 | — | — | — | 4,160 |
| Car Utilization | — | 1,700 | (1,640) | 19,500 | 19,500 |
| Power Utilization | — | — | 4,800 | — | — |
| Market Impact | — | 1,700 | — | — | — |
| Administration | — | — | — | (3,000) | (3,000) |
| Total | $3,000 | $(440) | $5,560 | $31,100 | $39,220 |

**Table 2: The weekly benefits resulting from the service committee's specific recommendations, comparing 1979 to 1978. Parentheses signify deficits.**

| | Estimated cycle time | Loading/ unloading time | Foreign car hours per load received |
|---|---|---|---|
| 1977 | 154 | 123 | 191 |
| 1978 | 152 | 95 | 201 |
| 1979 | 142 | 95 | 177 |
| 1980 | 133 | 88 | 166 |
| 1981 | 155 | 125 | 150 |
| 1982 | 147 | 111 | 155 |

**Table 3: Car utilization performance: The 1977 and 1978 cycle times are based upon B&M estimates of foreign car days per load and an assumption that 72 percent of all loads were in foreign cars, as observed in 1978. The loading and unloading time is based upon a random sample of 183 loadings and unloadings in September 1977. In 1981 and 1982, loading time was assumed equal to the average unloading time, which was distorted by the effects of car surpluses. Private cars, which are controlled by shippers, receive compensation only on a mileage basis and were excluded from the study.**

was distorted by events beyond the control of B&M. Beginning in 1980, the entire rail industry suffered a dramatic cutback in traffic volume that created tremendous surpluses of freight cars. Consequently, the need to move empty cars was greatly diminished, and in fact, B&M's empty cars sat idle for long periods before they could be reloaded. B&M encouraged shippers to use cars for storage, and essentially all of the railroads offered car-hire discounts for reloading their cars rather than sending them home empty. Because of the cutback, empty cars tended to spend an extra day or two in terminals and the car cycle returned to about 150 hours in 1981 and 1982.

Since the effects of the car surpluses distorted the meaning of the car-cycle measures after 1980, B&M's car utilization department developed a measure more closely tied to car-hire payments, namely foreign car-hours per load received. In the rail industry, a railroad must pay to use foreign cars (cars owned by other railroads) on both an hourly and a per mile basis, with the exact car-hire rate depending upon the age and original cost of the car. During the study period, for example, the average car-hire rate was about $0.40 per hour and $0.04 per mile. In order to minimize car-hire payments, a railroad may try to minimize the time that foreign cars spend on-line. B&M was in fact able to reduce the foreign car-hours per load received from roughly 200 hours at the start of the period to about 150 hours by 1981 (Table 3).

Between 1977 and 1982, B&M also made substantial improvements in financial performance. The B&M, which entered bankruptcy in 1970, lost over $6.6 million in 1977. Yet over the next three years, B&M actually became profitable, earning $3.8 million in 1980. A continued strong recovery enabled B&M to emerge from bankruptcy in 1983; it also made B&M attractive enough to be acquired by Timothy Mellon and to be included in Guilford Transportation Industries.

Most of the improvement in B&M's financial situation was directly related to the benefits gained from better service and better utilization of equipment. In 1979, for example, the B&M's car-hire payments exceeded $15 million, which was more than 15 percent of total operating expenses. However, if car utilization had not improved over the 1978 levels, car-hire payments would have been $2.9 million higher. In addition, B&M's own cars spent more of their time on other railroads (58 percent in 1979 versus 49 percent in the previous year), thereby earning another $1.3 million in car-hire revenue. The total car-utilization savings of $4.2 million, which were sustained throughout the study period, accounted for roughly 40 percent of the railroad's increase in profitability and were certainly one of the major reasons for its financial recovery.

**Improvements in Performance at East Deerfield, 1977 to 1982**

East Deerfield, the largest and initially the most congested B&M yard, was the target of many of the changes initiated by the Service Committee. In 1977, at the start of the study, the East Deerfield yard handled about 560 cars per day; the average daily work load dropped to about 500 cars by 1980 as a result of an overall decline in B&M traffic. When new operating plans were implemented in 1979 and 1980, a great deal of traffic was rerouted around East Deerfield. As a result, the average number of cars handled per day dropped dramatically from 500 to about 350, easing the congestion that had previously plagued the yard.

Partly because the work load diminished and partly because of the greater concern for service, average yard times and connection reliability improved markedly between 1977 and 1982. Prior to 1979, no consistent attempts were made to monitor average yard times at B&M yards, although special studies had highlighted poor performance at East Deerfield. During 1979, the first year that performance reports were routinely available, average yard times hovered around 30 hours; they dropped below 27 hours only for the month of August, when the average time was still 24 hours or 20 percent above the standard of 20 hours. In 1981 and 1982, however, average yard times at East Deerfield seldom exceeded the 20-hour standard.

The improved management of empty cars accounted for more than 75 percent of the net benefits.

The number of switch engines working at East Deerfield was also sharply reduced between 1977 and 1982. During the first part of this period, the yard was plagued by congestion and the average weekly number of switchers (switch engines) rose from about 46 to just over 50 in 1979. As the work load dropped, however, B&M cut back to 45 crews per week in mid-1981 and to 40 per week in early 1982. The completion of the yard rehabilitation project in late 1981 allowed crews to be more productive and aided this reduction. In fact, with 40 crews per week, B&M had the capacity to handle substantial additional traffic, as demonstrated when an agreement with the Delaware & Hudson railroad increased the workload by 25 percent without any increase in average yard times or in crews.

Combining the yard-volume and switch-engine statistics gives a common productivity measure, namely cars handled per switch-engine hour. This measure fell from about 10 in 1977 to about 6.5 in mid-1981, indicating that the work load was declining more rapidly than the work force. By 1982, after the work load increased, the cars handled per switch-engine hour rose to about nine, or still about 10 percent below the level at the outset of the study.

The volume-variable budget that was used at East Deerfield from 1980 to 1982 provided a means of evaluating overall performance during comparable periods in 1980 and 1982. The periods chosen avoid the winter, when the weather sometimes dominates yard performance, as well as major holidays, when yard-time operations are severely curtailed. Over this two-year period, cars handled daily declined 17 percent to 444, yard crews dropped 21 percent to 40.3 per week, and average yard times declined 11 percent to 19.2 hours (Table 4). The number of yard crews was eight percent below the standard allowed by the volume-variable budget in 1980, but 20 percent below in 1982; the average yard time was eight percent over the 20-hour standard in 1980, but four percent below in 1982. In 1980, the actual expenses were slightly over budget, as the savings in crew costs were offset by added costs related to car time, but in 1982, actual expenses were well below budget (Table 4). As a result of inflation in unit costs, the average costs per car rose from 1980 to 1982. However, productivity improvements and the reduction in volume (most of which was the conscious result of new operating plans) enabled B&M to avoid any increase in total costs (Table 4). In short, after B&M upgraded its operations planning and measurement techniques, terminal performance at East Deerfield was indeed brought under control.

**Conclusions**

Can the performance improvements achieved be related to particular aspects of the strategies followed by B&M or the analytic techniques used in the study?

| | 1980 | | 1982 | |
|---|---|---|---|---|
| Volume and productivity factors | Actual | Standard | Actual | Standard |
| Cars handled per day | 529.0 | NA | 444.0 | NA |
| Crews/week | 51.0 | 55.1 | 40.3 | 50.2 |
| Average yard time | 21.6 | 20.0 | 19.2 | 20.0 |
| Expenses | | | | |
| Total per week | $65,052.00 | $64,609.00 | $64,362.00 | $71,882.00 |
| Average per car | $17.57 | $17.45 | $20.69 | $23.10 |

| Relationship between 1980 and 1982 expenses | |
|---|---|
| Base expense, 1980 | $65,052 |
| Adjustment for higher unit costs | $18,931 |
| Total projected expense, 1982 costs and 1980 volume | $83,983 |
| Adjustment for lower volume | (7,881) |
| Adjustment for productivity improvement | (10,745) |
| Adjustment for all other factors | (995) |
| Actual expenses, 1982 | $64,362 |

**Table 4: A comparison of transportation performance and expenses at East Deerfield for a six-week period from mid-April to late May, 1980 and 1982.**

This question is difficult to answer conclusively. The single most important step was the 1977 decision to address the fundamental problems of operations control, congestion at East Deerfield and empty car distribution. Senior management made this decision after reviewing analyses that documented poor performance and demonstrated that investments in yard rehabilitation and in more frequent train operations could be justified by the potential reductions in car costs. Hence, basic analysis, without sophisticated models or analytic techniques was all that was needed to arouse senior management.

Once the railroad decided to establish standards for service and car utilization, analytic techniques became critical. Without a network model, it would not have been possible to analyze alternative operating strategies as thoroughly or so quickly as was done in 1978. Furthermore, it would have been extremely expensive to create even simple trip-time standards manually. It would have required roughly 15 minutes for each of more than 200 origin-to-destination movements. With the MIT service planning model, consistent standards for yard times, trip times and reliability were created automatically with each run. This sophisticated analytic technique made possible a realistic and complete set of performance standards, which were then used routinely to ensure thorough reviews of operating performance. Without the model, senior management's initial concern for service could not easily have been sustained, because "improved service" would not have been a readily quantifiable corporate objective.

Some might still question the relative importance of improving control systems and upgrading the facilities. It may be that investment and rehabilitation decisions are the key, not performance standards and operating plans. For example, at East Deerfield, the work load dropped dramatically, the yard was rehabilitated, and average performance improved markedly over the study period. The reduction in average yard times from about 30 hours to about 20 hours might therefore be attributed simply to a reduction in congestion rather than to improvements in the control system. However, roughly 70 percent of the reduction in the yard's work load related to changes in the operating plan, that is, to conscious decisions to route traffic around East Deerfield. Furthermore, the reductions in average yard times were evident in early 1980, well before the yard was rehabilitated.

**The operating plan is perhaps the most fundamental control at the disposal of a railroad.**

This study showed that improvements in a company's control system can lead to major improvements in performance. In addition, it demonstrated that sophisticated analytic techniques can be used to move an organization in a new direction, to initiate new decision-making processes, and to make new goals seem legitimate. The SPM was accepted by B&M management as a valuable tool for evaluating changes in operating plans because it was able to predict trip times, yard times, and system performance. Senior management therefore accepted the use of the model to create performance standards and also to conduct more thorough analyses of operating performance.

B&M continued to use the SPM to investigate alternative operating plans and set service standards even after the completion of the FCUP studies. For example, the company used the model to plan for coordinating operations with the Maine Central and the Delaware & Hudson railroads when the three railroads were acquired by Guilford Transporation Company in the early 1980s. Because of the success of the B&M case study, the FCUP supported the further development of the SPM. An upgraded, microcomputer version of the model was subsequently transferred to 14 North American railroads, who formed a users group that guided its continued evolution [Martland and Van Dyke, 1981]. In 1985, for example, an automated blocking module was added and an automated train-scheduling module was designed.

## APPENDIX

### Overview of the MIT Service Planning Model

The SPM works with one O-D (origin-to-destination) pair at a time and uses the operating plan to allocate traffic blocks, trains, and yards. The arrival time at the origin is given by an arrival time distribution, which may be specified for the yard in general or for a particular traffic class. The basic traffic segment is defined to be $T(O,D,j,t)$ where $O$ is the origin, $D$ is the destination, $j$ is the traffic class, and $t$ is the arrival time. The potential outbound blocks for this traffic can be determined from the blocking definitions for this yard. Each block is defined by its outbound train, its destination, and the traffic classes and destinations that it may include (entered into the computer as vectors of zeros and ones, where the $n$th element of the vector indicates whether or not that traffic class or destination is included in this block). There will be at least one and perhaps several candidate blocks for each traffic segment $T$; each block is associated with a train that has a scheduled departure time. The SPM allocates traffic on a probabilistic basis to the candidate outbound blocks using PMAKE analysis. Basically, a PMAKE function (which is defined for each yard and which may be modified to reflect the priority of the traffic class, the inbound train, or the outbound train) gives the probability of making a connection as a function of the time available to make that connection [Martland 1982]. Traffic that does not make the first available connection may make the second, third, or subsequent connections (the user defines a maximum time, say of 72 hours, in order to limit the analysis required). Hence, the SPM determines the estimated fraction of $T(O,D,j,t)$ departing in each appropriate outbound block. This allows the model to update the traffic volume for these blocks and trains, the traffic volume for this yard and traffic class, and the yard time distribution for this yard. The analysis proceeds through subsequent yards, with the greatest computational effort devoted to the PMAKE analysis and the maintenance of the trip-time distribution.

When all traffic segments have been handled, the SPM can produce several dozen reports showing the estimated yard, train and block volumes, the trip-time distributions, the yard-time distributions, and many other statistics. The model also computes service units on both a disaggregate and aggregate basis. Service units include gross ton miles, car-miles, locomotive miles, cars handled at yards, and switch-engine minutes, all of

| | Predicted by SPM | Actual January 1980 | Best month 1979 |
|---|---|---|---|
| Average trip time | | | |
| All loads | 39 hours | 37 hours | 36 hours |
| Major types of moves (not including customer time) | | | |
| Overhead (interchange-interchange) | 34 | 34 | 33 |
| Received (interchange-consignee) | 49 | 45 | 45 |
| Forwarded (consignor-interchange) | 27 | 28 | 31 |
| Local (consignee-consignor) | 18 | 18 | 16 |
| Major O-D movements | | | |
| Mechanicville-Rigby | 31 hours | 35 hours | 34 hours |
| Rigby-Mechanicville | 32 | 28 | 24 |
| Rotterdam-Rigby | 28 | 38 | 30 |
| Rigby-Rotterdam | 42 | 37 | 30 |
| Springfield-Wells River | 29 | 38 | 30 |
| Wells River-Springfield | 20 | 20 | 11 |
| Springfield-White River Junction | 26 | 23 | 21 |
| White River Junction-Springfield | 14 | 12 | 10 |
| Rigby-Springfield | 46 | 36 | 36 |
| Springfield-Rigby | 53 | 45 | 30 |
| Average yard time | | | |
| Mechanicville | 20 hours | 22 hours | 22 hours |
| East Deerfield | 24 | 21 | 25 |
| Rigby | 15 | 14 | 13 |
| Springfield | 18 | 15 | 14 |
| Missed connections (yard time 27 hours) | | | |
| Mechanicville | 22% | 26% | 25% |
| East Deerfield | 26% | 25% | 32% |
| Rigby | 4% | 7% | 4% |
| Springfield | 8% | 5% | 5% |

**Table 5: Comparison of predicted and actual performance.**

which are commonly used in railroad budgeting. The user can provide fixed and variable costs for each class of service unit, thereby simulating the budget process.

The O-D trip times and the yard times produced by the SPM can be used as standards in periodic performance reports. These standards are automatically consistent with one another because they resulted from the same run of the SPM. Furthermore, these standards are consistent with the PMAKE functions used in the study. PMAKE functions can be related directly to performance measures for the major yard activities [Tykulsker 1981], including

— Train arrival variability,
— Classification time,
— Train assembly time,
— Train departure variability,
— Train capacity, and
— Mechanical reliability (that is, the probability of delays necessitated by equipment failure).

Hence, it is possible to have mutually consistent performance measures for these activities as well as for train, yard, and system performance.

Table 5 compares SPM predictions to

actual B&M performance during a period when these predictions were used as performance standards. Average trip times are generally close to the SPM predictions, for individual origin-to-destination movements as well as for large groups of moves. Average yard times are also close to the SPM predictions, while the data under missed connections shows that the model provides reasonable estimates of reliability. To calibrate the model, the PMAKE functions are adjusted to obtain reasonable estimates of yard performance; once this is done, the model will give good estimates of O-D performance for a particular operating plan.

The service planning model can be used to evaluate alternative operating strategies. Its primary advantages are its abilities to produce realistic estimates of yard and origin-to-destination trip times and reliability and to simulate typical railroad costing procedures. It can therefore be used to evaluate cost/service trade-offs or to estimate the service and cost impacts of proposed changes to the operating plan.

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**A letter from** Alan Dustin, Vice-President and General Manager, NJ Transit Rail Operations, 1160 Raymond Boulevard, Newark, New Jersey states that "I can certainly verify that the financial benefits to the Boston & Maine as outlined in your paper are accurate, even though on the conservative side, and certainly don't do justice to the corollary benefits.

One additional benefit which I clearly recall was the organization changes which we instituted in order to permit this process to move forward at a more rapid pace and the team work which was generated and participated in, especially as we were able to observe and take advantage of the financial benefits."

David A. Fink, Chairman and Chief Executive Officer, Boston & Maine Corporation, Delaware & Hudson Railway Company, Maine Central Railroad Company affirms that during the period 1977-1982 "the B&M used the MIT service planning model, interdepartmental planning techniques, and improved MIS to gain control of car utilization and freight service. As a result, B&M saved millions of dollars annually in car costs, which was a critical factor in the railroad's dramatic financial turnaround in the early 1980s."

Peter W. French, Freight Equipment Management Research-Demonstration Program, Association of American Railroads, 50 F Street, N.W., Washington, D.C., writes "The operations planning and control activities of the US railroad industry are vastly more sophisticated today than they were 10 years ago. I believe that the MIT/B&M work made a significant contribution toward that end, through concepts gleaned and put into practice by the task force members, through the numerous reports that came out of the program, and through the benefits to the B&M itself.

The most visible legacy of the effort is the MIT service planning model which, as mentioned in the paper, has been transferred to 14 major railroads. Some of these railroads have made this model the foundation of their operations planning efforts. Five of them continue to fund a user's group that maintains and enhances this model. The program also continues to fund major enhancements to this model."