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Modeling Dispatcher Workload to Support Service Delivery Process Re-Engineering

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ABSTRACT

Previous efforts to optimize railroad dispatching has focused on using high-tech approaches to minimize train delay and dispatcher workload. CSXT is in the process of examining and re-engineering the service delivery process, including train dispatching. This study attempts to quantify factors that contribute to train dispatcher delay in an effort to improve service reliability. A stepwise linear regression was used to isolate key factors that influence dispatcher workload. Results indicate that the major contributors to dispatcher train delay is the physical makeup of the territory rather than the traffic volume and type that the dispatcher must deal with. These findings indicate that dispatcher train delay can be minimized with a realignment of the territory.

BACKGROUND

This study focusses on the issue of railroad dispatching workload and attempts to isolate certain factors contributing to the amount of such workload. This effort differs from previous studies because the authors first try to isolate individual factors that contribute to dispatcher delay rather than concentrating on high-tech solutions to line haul delay that previous models develop, including schedule planning and analysis (Jovanović and Harker 1991). Although line haul delay has improved significantly due to these and other innovations in railroad dispatching and scheduling technology, train delay is still a major contributor of failure to meet customer expectations.

This model was developed by the authors as part of an initiative to re-engineer the dispatching process at CSX Transportation (CSXT), a Jacksonville-based rail transport company. CSXT is the second largest railroad in the United States, comprised of over 18,000 route miles and 30,000 track miles, employing more than 28,000 employees.

In 1986, CSXT centralized major corporate operations, including dispatching and operations management. At that time, the dispatching function was reduced from 480 field dispatchers to 250 active dispatchers located in Jacksonville, Florida. Today, 41 dispatcher consoles, with three around-the-clock shifts, oversee an 18,000 mile network. This consolidation improved communications and established electronic train messages, bulletins, and trainsheets. In addition, many dispatcher tasks were automated, and it increased the emphasis on what is best for CSXT and not the operating division.

There is no typical dispatcher desk (console). For instance, there is a large discrepancy in miles per territory; territories range from 150 miles to 600 miles in length. Additionally, overall traffic volume and type varies significantly, as does communication volume and overall duration of calls.

In the 1990s, increased competition amongst freight shippers, especially between railroads and the trucking industry, has forced rail transportation companies to focus more on customer requirements. CSXT has placed service reliability as a high priority, second only to safety. Recently, it has undertaken a re-engineering project which seeks to make quantum improvements in critical areas responsible for service reliability, including service design, operations management, and dispatching.

CSXT is following a four phased approach to re-engineering the service delivery process. In the mobilization phase, the core processes most critical to service delivery were identified. After choosing operations management, service design and dispatching, an assessment phase was undertaken to map out the core processes and thoroughly identify key elements and key requirements of each function. The findings of the assessment phase will be used in the process redesign phase to increase service reliability. The fourth phase of the re-engineering process will be implementation.

OBJECTIVE OF STUDY

This study is part of the assessment phase of re-engineering and was developed to identify and quantify factors contributing to railroad dispatching difficulty using train delay as a surrogate for workload. A variety of factors possibly contributing to dispatcher workload are used to develop a model describing the relationships between various aspects of a dispatcher console and dispatcher workload.

There is no single measurement of a dispatcher territory that can accurately measure workload; this is due to the complex interrelation of console characteristics, which can also be complicated by the variability of the terrain. In order to facilitate a study of dispatcher workload, CSXT created a regression model based on workload factors as a means to understand which factors have the most contribution to train delay. Delay was chosen as the best characteristic to use, based on the intuitive assumption that high workload consoles have more delays. Although it may seem trivial to use this assumption to identify high-workload desks, this study actually identifies and quantifies factors contributing to dispatcher workload.

DATA SOURCES

The study concentrated only on the 41 "trick" dispatcher consoles and disregarded supervisory consoles. All of the 41 consoles in the study work three eight hour shifts; when possible, data was collected separately for each shift.

A "master" data set containing all the data used in this study was compiled from a variety of regularly maintained CSXT data sources: QBase, SPM Reports, Trainsheet, AVTEC database, and the CSXT timetables (see table 1).

TABLE 1

Representative Independent Variable Selection List

Traffic Based:

Number of train meets
Number of trains*
Total dwell time of trains*§
Total transit time of trains*
Total train* times in territory
Total train* miles
Total train* gross ton-miles
Total train* car-feet-miles
Total train* stations worked (pick ups/set offs)
Number of foreign trains

* - For each type: intermodal, unit, merchandise, local, automobile, and passenger.
§ - This is normal, scheduled dwell time at terminals.

Physical Characteristics of each console:

Number of foreign railroad crossings, grade crossings, and defect detectors.
Percentage of 'Direct Train Control' (DTC - Manually authorized blocks) and 'Train Control' (TC - Automated train control) in territory
Number of DTC blocks
Number of sidings - DTC and TC
Number of operating divisions in territory
Number of yardmasters, signal maintainers, and roadmasters in territory
Number of crew change points
Number of special restrictions and train bulletins issued
Number of miles of TC track, DTC track, industry track, yard track and total miles of territory
Signal & siding rank - this is a rating from 0.5 to 1.5 based on the type of signals and number of sidings in the territory*

*0.50 = all DTC, no sidings
0.75 = DTC with sidings
0.85 = ABS
1.00 = TC, no sidings
1.25 = TC with sidings
1.50 = Double track TC
Averaged per mile across territory and inverted

TABLE 1

Representative Independent Variable Selection List

Communication Data:
Number of phone calls in and out
Number of radio calls in and out
Total radio and phone calls in and out
Total time on hold (for inbound calls)
Total time communicating inbound
Total time communicating outbound
Total time communicating total
Total time on hold and communicating
Other Data:
Slow orders issued
Maintenance blocks issued

QBase and SPM Reports. QBase is a car cycle data base that integrates financial, marketing, and transportation information. The QBase file was created by the Operations Research (OR) group at CSXT to be a primary feeder to a multitude of models and reports. QBase contains car movement data for every piece of equipment moving on CSXT (Kraft 1991). The SPM (Service Planning Model), maintained by ALK Associates, is a regularly maintained model which is a simulation of CSXT actual operations, calibrated using QBase inputs. CSXT uses actual historical data in SPM and has a large set of rules governing the QBase to SPM interface, so it accurately reflects the traffic type and volume on the CSXT rail network (Lawrence and Shughart 1993, McCarren and Martland, 1980). Together, these data sources were used to gather traffic volume information. Six representative train types were included in this study: intermodal, unit, regular merchandise, local, automobile, and passenger trains. Train counts, dwell time, transit time, train miles, gross ton miles, car feet miles, and number of stations worked were collected from QBase/SPM for each desk and shift.

Trainsheet. Trainsheet is a train-based database used to collect information on train delay. The train delay time for this study was taken from the trainsheet database for each desk and shift.

AVTEC database. The AVTEC database collects information on the communication volume at each console. It includes type of communication (phone versus radio), direction of call (inbound or outbound), and total time on hold and communicating. This data was collected for each desk and shift.

CSXT Timetables. The physical characteristics of each console's territory was taken from up-to-date CSXT timetables. This includes all physical characteristics of the territory: including the number of miles, grade crossings, DTC miles, TC miles, industry track miles, operating divisions covered, and more than 30 other static characteristics. This data was collected for each console.

Data Limitations. Several difficulties exist in relating the more than 70 factors in the data base to train delay. First, some of the factors may be correlated to other factors (for instance, the number of intermodal train miles has a high correlation to the number of intermodal gross ton miles). Many of these collinear variables were eliminated from the model after analyzing the output from the initial runs.

A second problem is that the model in no way takes into account the level of experience of the individual dispatcher running the console. Some train delay may be caused by a lack of experience as a dispatcher or as a qualified dispatcher on that territory. The model implicitly assumes no human factor can cause train delay.

Perhaps the most significant data problem is the assumption that train delay is a measure of dispatcher workload. Both communication volume and a qualitative assessment were also considered as the dependent variable; however, both of these factors have inherent defects. Communication time is often influenced by poor line of communication or other factors that would skew the results of the model; for instance, a less busy dispatcher might be inclined to be involved in lengthier calls with no additional value -- which is not an indication of workload; in addition, the number of field personnel (such as track maintainers) would increase communication volume. A complete qualitative assessment of the individual consoles was deemed inappropriate based on the fact that no single person is knowledgeable about every console and every shift, and the small range of values (only 8, 10, and 12 for easy, medium, and hard) mathematically proved difficult to use. While factors other than delay do in some way measure dispatcher workload, train delay was selected as the best surrogate for dispatcher difficulty.

DEVELOPING THE MODEL

The model is based on the assumption that all train delay can be explained by a combination of a finite number of factors. Furthermore, the model attempts to explain those factors which contribute the most to train delay, and mathematically quantify the relative "weight" of all the factors identified as being contributing factors.

The authors estimate the model parameters using a stepwise linear regression, which is intended for this type of exploratory analysis (SAS Institute 1982). The calculations for this model are done using the SAS statistical package on an IBM system 370 mainframe.

In step one, the complete set of data was used as possible independent variables, running separate regressions using train delay, communication volume, calculated as number of calls inbound and outbound, and qualitative assessment as dependent variables. The qualitative assessment was a judge of console difficulty from interviews with dispatch chiefs using 8 for "easy", 10 for "medium", and 12 for "hard".

In step two, several of the collinear variables were identified. These variable pairs were analyzed and the best variable was retained. For instance, the database contained percent DTC and percent TC as well as DTC track miles and TC track miles. The variables containing mileage were kept, the percentages were eliminated from the study.

The first regressions showed a poor R-square for qualitative assessment as a surrogate for workload, most likely based on the small number of consoles that were judged outside the "medium" range. After further study, the authors also deemed communication volume a poor surrogate for dispatcher workload (see data limitations above).

Also noted by the authors was the fact that the model had an unusually high *y*-intercept. That is, the model was indicating that a dispatcher with no territory (i.e. no track, no traffic, etc.) would still have train delay. This is counter-intuitive. The intercept option was eliminated from the regression.

For step three, after all of the above considerations, the model was executed using a subset of the master data set, forcing the *y*-intercept to zero. Key independent variables were identified by the model (those having the most contribution to the R^2 of the regression). This run of the model included only those independent variables contributing more than 0.020 additional R^2 to the model; these factors can be seen in figure 1. The factors are listed in decreasing order by contribution to model. Contribution is determined as the F value associated with type II sums of squares; the ratio of regression mean square to the error mean square. (Hines and Montgomery). The model result is shown in figure 2.

The factors the model identified as the most significant causes of dispatcher delay were consistent with expert intuition.

The number of DTC blocks has a high contribution to workload based on the fact that these blocks must be manually authorized and released -- taking much of the dispatcher's time.

The signal rank of the territory is also consistent with this idea; the more TC territory a dispatcher has, the less his workload.

The number of industry miles is directly related to the number of manual authorizations a dispatcher must give a train crew to enter an industry siding, again requiring the full attention of the dispatcher.

The number of yard masters intuitively accounts for a higher workload index most simply because a dispatcher's time will be consumed in more planning sessions. Similarly, the number of yard masters is proportional to the number of yard and likewise to originating and departing trains, both of which demand planing time and increase workload.

The influence of the crew change points comes about with dispatchers having to be aware and make time for the train to change crew. Again, the dispatcher must be involved in a planning session, consuming time. Also, the dispatcher must watch for crews going "on the law" (a crew can only work 12 hours) which will create additional delay.

The negative coefficient of the number of DTC sidings and TC sidings is consistent with intuition. The more sidings a dispatcher has to work with, the easier his job becomes as there is more opportunities to meet and pass trains.

Local trains are significant delay contributors because of their variability in switching time (CSX Local Train Review 1992). Switching time in local industry is very difficult to plan for, and hence the dispatcher must often delay a train due to bad timing. In addition, communication volume between the dispatcher and local trains is usually heavier than the volume between the dispatcher and other train types.

Figures 1 and 2

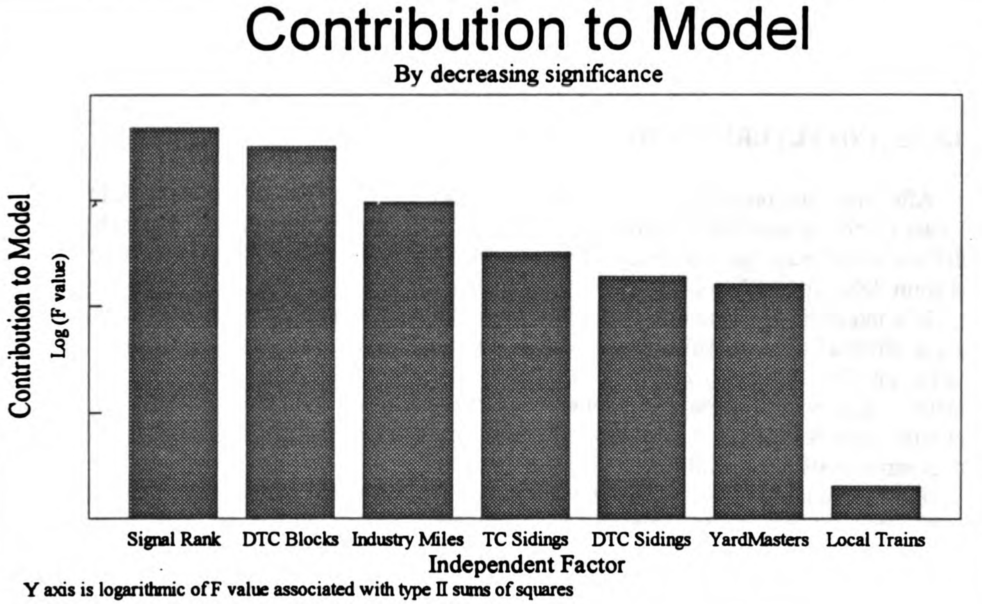

Figure 1 - Contribution to Model

Dispatcher Model Final Results:

Train Delay (in minutes) =

$$15.038\alpha + 0.426\beta + 0.309\chi + -0.147\delta + -0.239\varphi + 0.602\phi + 0.046\gamma$$

Where

α = Signal Rank
β = DTC Blocks
χ = Industry Miles
δ = TC Sidings
φ = DTC Sidings
ϕ = Yard Masters
γ = Local Trains

Figure 2 - Final Model Results

A few outliers were apparent after this execution of the model. One console in particular had twice as much train delay as any other single console on all three shifts. After careful consideration, a total of 10 of the 123 shifts were eliminated from the study. Seven of the ten shifts, from three consoles, had excessive train delay, more than 150% over any other shift. The remaining three shifts, all on one console, had excessive missing data. The model accounts for 92% of the variation among desks as measured by the R^2 factor.

RESULTS AND FUTURE STUDY

After the final rendering of the model, the coefficients of the independent factors were multiplied by the appropriate variables (refer to figure 2) for each of the 113 dispatcher shifts to calculate an estimate for train delay. The model estimates for train delay were plotted against actual train delay for each console on each shift (figure 3).

It is interesting to note that six of the seven most contributing factors to dispatcher train delay are physical characteristics of the territory and are not a function of the volume or type of traffic on that line. This implies that train delay can be controlled by realigning the territories. Also note that the single most contributing factor to train delay is the signal and siding rank of the territory. This validated previous efforts that promote the benefit of Advanced Train Control Systems (ATCS) technology. (Resor 1993)

The model accuracy graph isolates dispatcher shifts that fall outside an acceptable range of model error. A distribution of model error (figure 4) shows that almost 50% of dispatcher shifts fell within ±20% of the model estimates, and 79% of the shifts fell within ±40% of the model estimates.

Seven shifts have at least 40% more actual train delay than computed; 17 shifts have at least 40% less actual train delay than computed (illustrated in figure 4). In addition, 6 shifts have a significant absolute value deviation from the model prediction (over 14 minutes variance -- see figure 5).

Observations below the center line on the chart in figure three and figure five have more actual train delay than computed train delay. Reasons for this difference could be the experience level of the person working that desk, or some unique local factor that makes this desk more difficult than the model estimated. This unexplained train delay may also be one indicator of dispatcher difficulty. For example, difficulty may result from a combination of factors that are not captured by this model. If total delay is a measure of difficulty, as mentioned before, then observations with unexplained delay and high actual delay are likely the most difficult.

Likewise, observations above the line have less train delay than the model predicts. This can be attributed to excellent performance by the dispatcher. All of the outlier observations are being researched further.

One idea being considered for further study is matching dispatcher quality to desk workload. In this scenario, dispatchers would be qualified as "apprentice", "journeyman", or "master" level workers. Apprentice dispatchers could only bid jobs on easy desks. Master level dispatchers would not only get paid more, but also be assigned to difficult desks where their experience would have the most benefit.

Figures 3 and 4

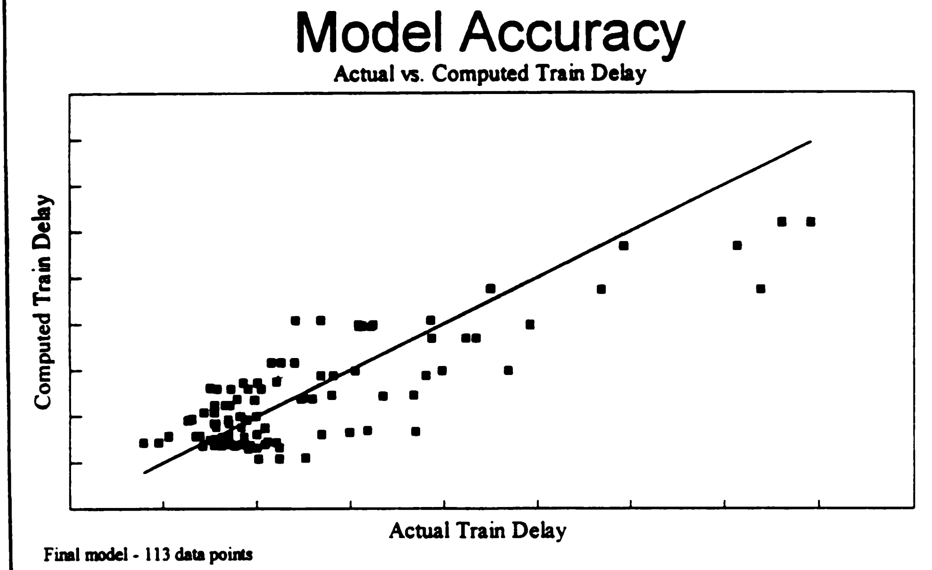

Figure 3 - Model Accuracy

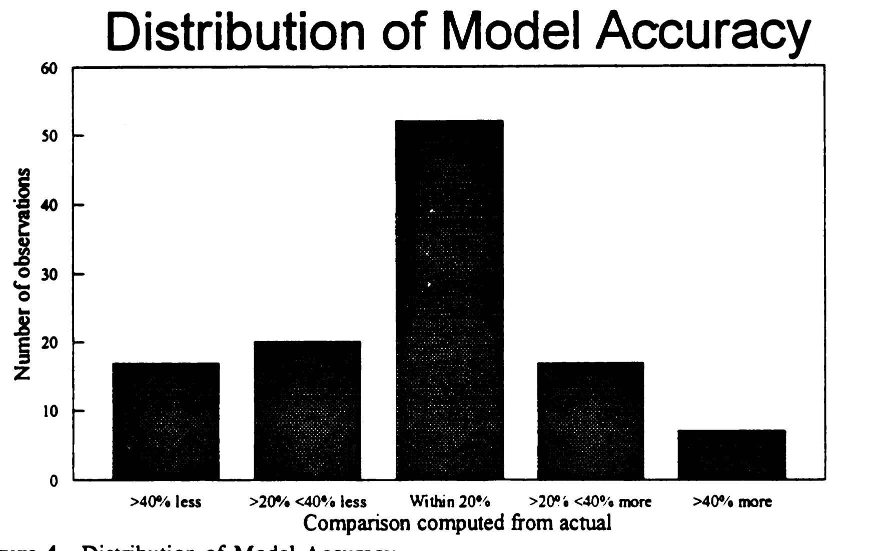

Figure 4 - Distribution of Model Accuracy

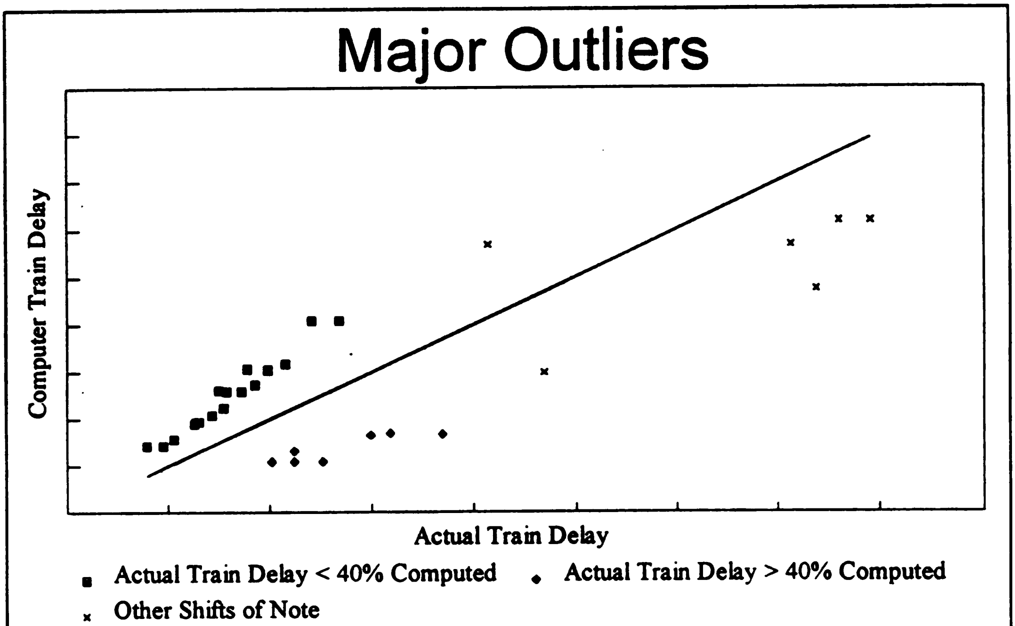

Figure 5 - Major Outliers

A second approach would be to perform an analysis of the coefficients of the factors involved in dispatcher workload. Geographical territories would be realigned using the delay model to balance the workload in an attempt to minimize train delay.

In summary, while past research has focussed on developing tools to help dispatchers make better decisions, this model is unique in that it attempts to quantify the factors contributing to the difficulty. Process re-engineering is helping CSXT understand how to re-design work in a way that eliminates steps and minimizes opportunities for failure. This model was a useful tool in that effort.

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ENDNOTE

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