# INTEGRATING LOGISTICS FORECASTING TECHNIQUES, SYSTEMS, AND ADMINISTRATION: THE MULTIPLE FORECASTING SYSTEM

by

**John T. Mentzer**
*Virginia Polytechnic Institute and State University*

and

**Jon Schroeter**
*Brake Parts, Inc.*

Although forecasting system design has traditionally focused on software and forecasting techniques, development of an effective forecasting process requires integration of forecasting techniques, systems, and administration.[1] However, little research in the forecasting area has been devoted to the integration of these three aspects of the forecasting process.

The need for this integration is perhaps greatest in the area of short-term forecasting. Short-term forecasts are necessary to facilitate many logistics activities—most notably, inventory control. Unlike longer range, broader-based marketing or financial forecasts, inventory control forecasts must be at the location-item-month level, which represents a much more refined level of aggregation.

There has been significant literature that presents and evaluates alternative techniques for developing these types of forecasts.[2] These articles have typically compared alternative forecasting techniques and offered guidelines for their application. These techniques are primarily time series-based, incorporating elements of trend and seasonality. However, in today's business environment, item sales (and therefore the requisite forecasts) are strongly driven by other factors such as promotions, price changes, and competitive actions. In addition, the individual item forecasts are also influenced by broader corporate strategy and capacity decisions. Thus, effective forecasts must tap the pattern recognition capabilities of time series techniques and the relational analysis capabilities of regression analysis. Further, information and insight that are unique to the inventory control manager and to top management need to be incorporated into the forecast.

Closs, Oaks, and Wisdo argue for a forecasting process that incorporates (1) the correct use of forecasting techniques; (2) forecasting systems that effectively interact with the corporate management information system and DRP system; and (3) recognition of the impact of forecasting management philosophy upon ultimate accuracy.[3] It is the purpose of this paper to present the result of research to develop a forecasting system that accomplishes this incorporation of the three components of the forecasting process and effectively uses the best features of several different forecasting technique approaches. The result is a forecasting model termed the Multiple Forecasting System (MFS). Prior to a discussion of this model, the three components of forecasting techniques, systems, and management philosophy will be reviewed.

## FORECASTING TECHNIQUES

Forecasting techniques are typically broken into the categories of time series, regression, and subjective techniques. Each category has its own unique advantages and disadvantages. Time series techniques are based on the interrelationship of four data patterns: level, trend, seasonality, and noise. Level (or base line) is a horizontal sales history; trend is a continuing pattern of a sales increase or decrease; seasonality is a repeating pattern of sales increases and decreases; and noise is random fluctuation—that part of the sales history that a time series technique cannot explain (often also called the residual). Time series techniques analyze the data to determine which patterns exist and then project the trend and seasonality into the future from the base line. The advantage to time series analysis is that little data are required to forecast; thus, these techniques react quickly to changes in data patterns. However, time series techniques do not effectively forecast the impact upon sales of events, such as price changes, that do not happen at regular intervals.

Regression analysis is an approach to forecasting that examines relationships between sales and exogenous variables that affect sales, such as advertising, product quality, price, physical distribution service, the economy, and competitive actions. Past exogenous variables and past sales are analyzed to determine the strength of their relationship. If a strong relationship is found, the exogenous variable can then be used to forecast future sales. Regression analysis also provides a statistical value estimate of each variable. Thus, variables contributing little to the forecast can be dropped. Regression analysis has considerable accuracy potential, but requires a large amount of data. The large data demands make regression analysis slow to respond to changing conditions.

Subjective techniques are procedures that turn the opinions of experienced personnel (e.g., salespeople, corporate executives, and outside experts) into formal forecasts. An advantage to subjective techniques is that they take into account the full wealth of key personnel experience and require little formal data. They are also valuable when little or no historical data are available, such as in new product introductions or when new events impact the sales of existing products. Subjective forecasting, however, takes a considerable amount of key personnel time. Because of this drawback, subjective techniques are typically used for adjustment purposes in short-range, product forecasting.

## FORECASTING SYSTEMS

Forecasting systems include the management information system and forecasting software used to obtain and analyze the data, develop the forecast, and communicate the forecast to the relevant personnel and planning systems, such as the DRP system. The forecasting systems support the maintenance and manipulation of the data, allow consideration of external forecast factors such as the impact of promotions, strikes, price changes, product line changes, competitive activity, and economic conditions, and provide a vehicle for subjective adjustment to the forecasts.

## FORECASTING MANAGEMENT PHILOSOPHY

Forecasting management philosophy considers the organizational, procedural, motivational, and personnel aspects of the forecasting function and its integration into other firm functions. Organizational includes identification of the individuals involved in the forecasting process and their corresponding roles and responsibilities. Such decisions include the department in which the forecasting function will be located (i.e., logistics, marketing, finance, or sales), the interaction of the forecasting function with the departments in which it is not located, and to what level in the organization forecasting reports. Where logistics has more information on location-item-month operations, marketing and sales have more information on future sales levels, and finance has more information on future budgetary plans. The higher in the organization to which forecasting reports, the more status and importance will be attached to the forecasting function.

Procedural means each individual has a good understanding of the relative impact of the forecasting activities, the system, and the techniques. This includes not only the individuals making the forecasts and maintaining the systems, but also the executives who are affected by the forecasts. A clear understanding of the importance and reporting relationships of forecasting relative to the rest of the organization is essential for translating forecasts into operations.

Motivational involves tying corporate reward systems to forecasting performance. For example, one company not only makes part of the performance evaluation of its product managers a function of forecasting accuracy, but also runs a yearly contest with prizes awarded to product managers whose forecasting accuracy improves the most.

Finally, personnel implies hiring forecasters with the background qualifications to fully understand forecasting techniques and systems and providing the on-going training necessary to provide these individuals with the tools to forecast intelligently. Without this final commitment of management philosophy, the forecasting function runs the risk of forecasting without understanding and, thereby, making decisions that significantly decrease forecasting accuracy.

## THE NEED FOR INTEGRATION

Although forecasting techniques, systems, and management are important, little effort has been expended in the past to integrate them into one forecasting process. Further, although it is widely recognized that the three categories of forecasting techniques (time series, regression, and subjective) have unique advantages and disadvantages, little effort has been made to develop a forecasting system that combines the three categories to develop one forecast that uses the advantages of each. In fact, most forecasting packages available today use only one technique, and that one is often obsolete and/or inappropriate for the situation in which it is applied.

These reasons provided the impetus for the research to develop the Multiple Forecasting System, a model that combines various forecasting techniques, provides flexible system integration, and is readily adaptable to different forecasting management philosophies.

## THE MULTIPLE FORECASTING SYSTEM

The Multiple Forecasting System (MFS) is designed to assist in making forecast decisions by augmenting managerial experience with record keeping and an analysis framework. Record keeping means MFS interacts with the management information system (MIS) to obtain data on past demand, forecasts, and exogenous events.

Analysis framework means MFS has the ability to perform time series and regression forecasting in tandem to provide an automatic forecast. This does not mean the manager cannot improve the forecast. MFS organizes and analyzes large amounts of data to indicate the relationships, leaving the final forecast to the judgment of the manager. In other words, managerial experience enhances MFS forecasts. MFS provides forecasts based upon the past data, but the manager can adjust this forecast based upon future events that MFS did not consider.

MFS is designed to forecast down to a level of detail equal to each stock keeping unit at each distribution location (SKUL), but forecasts can be aggregated to any level above this. A copy of all SKUL records is maintained on both the mainframe and MFS. Each forecasting period, MIS personnel prepare a data file which contains all changes to the SKUL product list and the prior month's demand history. This file is loaded into MFS by the forecasting administrator. This process also triggers MFS to reforecast all SKUL's that now have additional demand data, and create a worksheet for each SKUL, allowing the managers to see the latest demand history and forecasts available.

Once the users have finished examining the worksheets and are ready to load the final forecasts to the mainframe, the forecast administrator performs the upload operation. The file created from this upload is then passed to the DRP system. The DRP system uses this information to make reorder point and order quantity decisions for these SKUL's.

MFS is designed to be a system that interacts with the MIS and DRP systems, provides relevant analysis of historical data, and communicates the analysis to the manager in a convenient analytical environment, i.e., a worksheet. To further understand this system, it is helpful to discuss the MFS forecasting techniques, worksheets, systems, and possible administration.

## MFS Techniques

MFS uses any of up to twenty-four time series forecasting techniques to determine base line, trend, and any seasonal patterns in the data for each SKUL. The technique that produces the lowest error in forecasting the existing data for each SKUL is selected each month by MFS to produce the time series forecast. Each SKUL has its own unique worksheet where the forecast base line, trend, and seasonality are recorded separately.

The part of the data not explained by time series (the residual) is further subjected to multiple regression analysis. Data on up to 500 potential exogenous variables are stored in the regression module of MFS and each variable is compared to the residual for each SKUL. Up to ten of these variables that are significantly related to the residual of each SKUL are selected by the regression module to forecast the residual of that SKUL. Once this analysis is completed, the regression-based forecast of the residuals is also recorded in the worksheet for that particular SKUL. The base line, trend, seasonality, and regression forecast are then added together in the worksheet to present the MFS forecast.

The forecaster is now in a position to view each worksheet and analyze the MFS forecast and its four components (time series base line, trend, and seasonality, plus the regression forecast of the residual). Based upon previous experience with the company, with MFS, and knowledge of future events, the forecaster has the ability to adjust the final forecast.

Before discussing the worksheet itself, it is important to point out that MFS uses the advantages of both time series and regression forecasting (time series' ability to react quickly to changes in SKUL demand patterns and regression's ability to forecast the impact upon demand of irregular events) to develop a combined automatic forecast.

## MFS Worksheet

In forecasting, it is important to create an environment whereby forecasters can easily make changes to the system forecast, based upon their unique knowledge and experience. In MFS, this is accomplished by creating a worksheet for each item to be forecast. Figure 1 provides an example of such a worksheet for a particular application. The columns in the worksheet represent the forecast periods, months in this example. Each worksheet can display up to 250 periods, with part of these

FIGURE 1

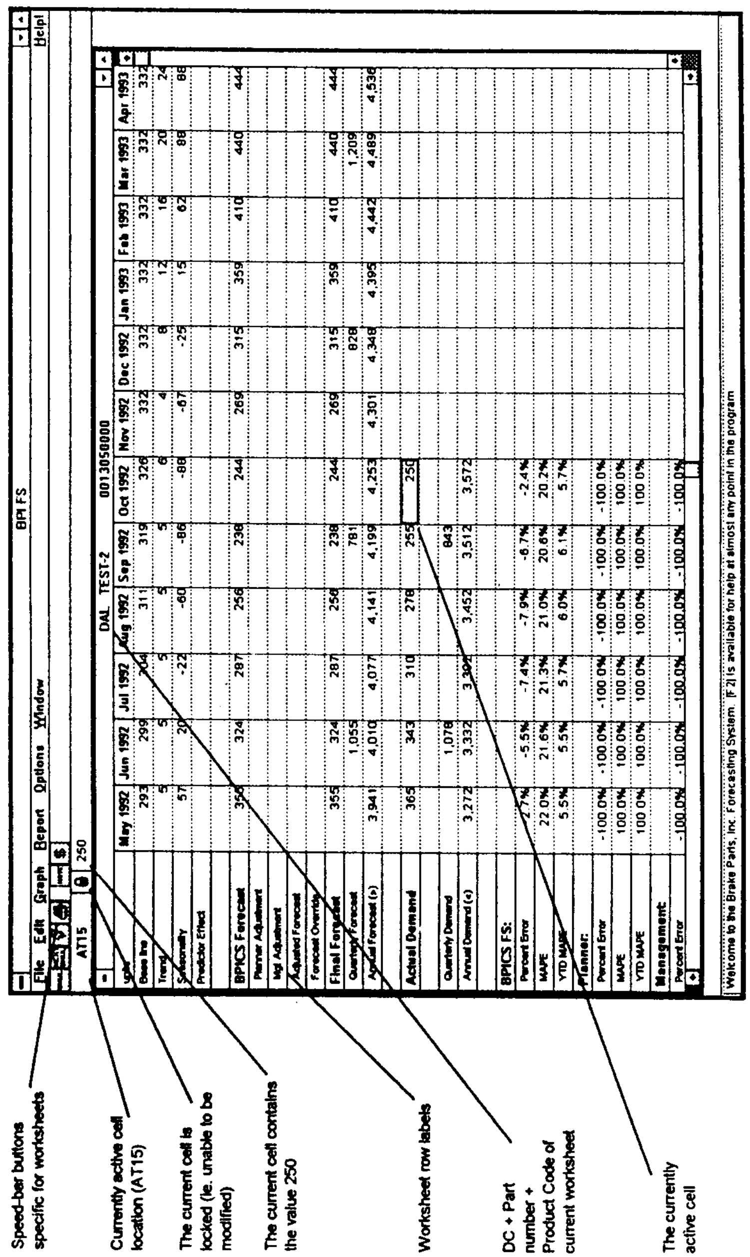
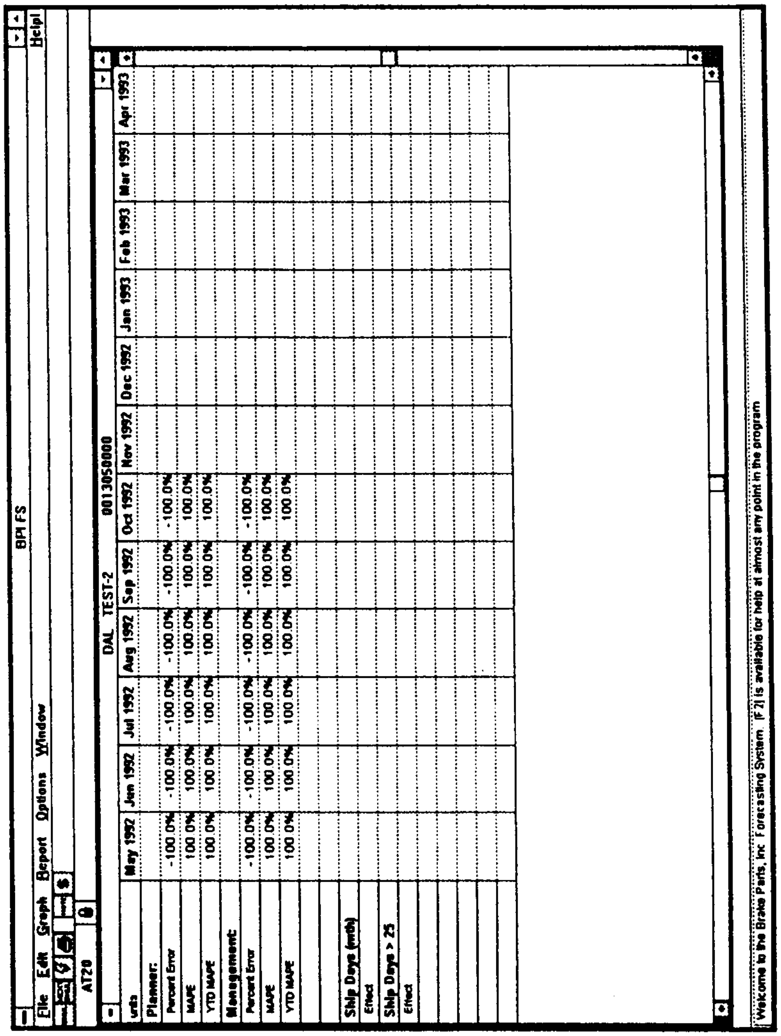

BPI FS
DAL TEST-2 0013050000
Welcome to the Brake Parts, Inc. Forecasting System. [F2] is available for help at almost any point in the program
Speed-bar buttons specific for worksheets
Currently active cell location (AT15)
The current cell is locked (ie. unable to be modified)
The current cell contains the value 250
Worksheet row labels
DC + Part number + Product Code of current worksheet
The currently active cell

FIGURE 1 (Continued)




| units | May 1992 | Jun 1992 | Jul 1992 | Aug 1992 | Sep 1992 | Oct 1992 | Nov 1992 | Dec 1992 | Jan 1993 | Feb 1993 | Mar 1993 | Apr 1993 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Planner:** | | | | | | | | | | | | |
| Percent Error | -100.0% | -100.0% | -100.0% | -100.0% | -100.0% | -100.0% | | | | | | |
| MAPE | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | | | | | | |
| YTD MAPE | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | | | | | | |
| **Management:** | | | | | | | | | | | | |
| Percent Error | -100.0% | -100.0% | -100.0% | -100.0% | -100.0% | -100.0% | | | | | | |
| MAPE | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | | | | | | |
| YTD MAPE | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | | | | | | |
| **Ship Days (mth)** | | | | | | | | | | | | |
| Effect | | | | | | | | | | | | |
| **Ship Days > 25** | | | | | | | | | | | | |
| Effect | | | | | | | | | | | | |

periods representing historical records and the rest representing forecasts into the future.

The rows represent various information useful to the forecaster. The first three rows are the base line, trend, and seasonality determined by the MFS time series forecast. The predictor effect row is the summed effects that all regression (predictor) variables (shown later in the worksheets) have had on what was left of the demand history after the time series forecast was removed (the residual). All four of these rows are summed into the MFS forecast (for this particular application, called the BPICS or Brake Parts, Inc. Computer System Forecast). This is the forecast value that will be sent to the mainframe DRP system each month if no user intervention or adjustments take place.

The next area of the worksheet shows rows that either the forecaster or the forecast administrator can use to adjust or override the model forecast. The Planner Adjustment Row is a relative number that is added (or subtracted) from the model forecast. This is the typical row where forecasters (called Planners in the Figure 1 application) put numbers to adjust the model forecast. The next row, Mgt Adjustment, allows the Forecast Administrator to enter a relative number which adds (or subtracts) from the combined model and planner rows. The distinction between planner and management rows is important, since MFS keeps track of the forecast error of planner adjustments separate from the forecast error of management adjustments. These performance tracking rows are shown at the bottom of each worksheet. The next row shows the model forecast with the total of forecaster and management adjustments included.

Finally, there is a Forecast Override Row. Any value in this row is treated as an absolute forecast setting, i.e., if a value is present in this row, then it will be sent to the mainframe DRP system as the final monthly forecast, regardless of the MFS forecast or any planner or management adjustments. The final value that will be sent to the DRP system is shown in the Final Forecast Row. This value is summed quarterly and annually and placed in the Quarterly Forecast row and Annual Forecast row, respectively. The Actual Demand row shows the demand values that actually occurred up to the current month. This is also summed quarterly and annually.

There are several gauges of the performance of the MFS model, the planner adjustment, and the management adjustment. These measures give the forecaster a feeling for how much reliance can be placed on the MFS model, if the model is improving over time, and how the forecaster should be adjusting the model to improve accuracy.

Three measures of accuracy are used. The first is the Percent Error (PE) and is defined as the difference between forecast and actual demand divided by demand. This measure is plotted over time in several graphs and is a good managerial tool for tracking the error over time. PE is calculated such that a value tells how much the forecast was off in any given period and whether the forecast was high or low. For example, if the forecast was 110 units and the actual turned out to be 100, the PE would be 10%. This indicates the forecast was off by 10% and the positive sign indicates the forecast was high. If the forecast had been 85 units and the actual turned out to be 100, the PE would be -15%, which indicates the forecast was 15% low. Patterns of PE over time help the user to adjust forecasts. For instance, if PE's over time are consistently -5%, this tells the forecaster to adjust the MFS forecast up 5% to be more accurate.

The Mean Absolute Percent Error (abbreviated to MAPE) is calculated by summing the absolute value of a range of percent errors, then dividing this by the number of percent errors summed. The MAPE values for the model are calculated from the beginning of the worksheet. MAPE is simply all the PE's to date, with the signs dropped so they do not cancel each other, added together, and divided by the number of PE's. This indicates, on the average, how well the forecast is performing. For example, a MAPE of 4% indicates that, on the average, the forecast has been off by 4%. However, the forecaster needs to look at past PE's to see if the forecast has been high or low.

One problem with MAPE is that old errors never leave the calculation. Suppose, for instance, that in the early stages of forecasting, some PE's were as high as 200%, but recently the forecast has never been off by more than 5%. The 200% early errors would always be in the MAPE calculation and, thus, MAPE would always make present forecasts look worse than they are. A solution to this problem is to also calculate a year-to-date MAPE (YTD MAPE). This calculation wipes the slate clean at the end of each year and starts recalculating MAPE in each January, using only that year's PE's. Thus, it is a more recent and accurate indication of forecasting error.

The next rows in the worksheet are occupied by up to 10 regression variables and their associated predictor effects. These are the data that are used by the regression analysis to forecast the time series residual. The summed effect across all predictor variables is placed in the predictor effect row near the top of the worksheet.

Since each SKUL has a fully functional worksheet within a Windows environment, all features that an experienced user would expect to find in a spreadsheet are available. However, several additional features are provided that are important to forecasting.

*The Notepad.* This is a simple word processor used to keep notes on why forecast adjustments or changes have been made to a particular worksheet. Each worksheet has a unique notepad attached that can contain up to thirty pages of text.

*Graphs.* A number of graphs are available to assist the forecaster in analyzing forecasting performance. Figure 2 provides an example of one possible graph. Figure 3 provides a complete list of the available graphs, where FS stands for the forecast of the forecast system (i.e., MFS).

As a feature to make adjusting forecasts easier, the FS vs. Demand graph has the ability to allow the forecaster to "pull" the forecast. In other words, rather than having to enter forecast adjustments in each future period of the worksheet, the forecaster can use the cursor with this graph to reshape the forecast into a line that the forecaster believes is more accurate. When this process is completed, MFS calculates the actual values from the new line and enters them in the Forecast Override row of the worksheet. In this manner, the forecaster can enter adjustments directly into the worksheet or enter values that visually seem more accurate.

*Reports.* MFS can be customized to have any number of reports on forecasting performance. An illustrative list for one application is provided in Figure 4. The General Purpose report can be customized at the user's discretion and is primarily used for preparing presentations and measuring system activity. The Regression Variable Assignment report details which regression variables were assigned to specific SKUL's. Planner Usage documents which worksheets were accessed by forecasters in any given period—it is a measure of forecaster analysis activity. New Part Number Models describes new products that have recently been introduced and the forecasting approaches presently used to forecast them. The MAPE Counter report lists SKUL's in descending order by the MAPE's that have been achieved.

FIGURE 2

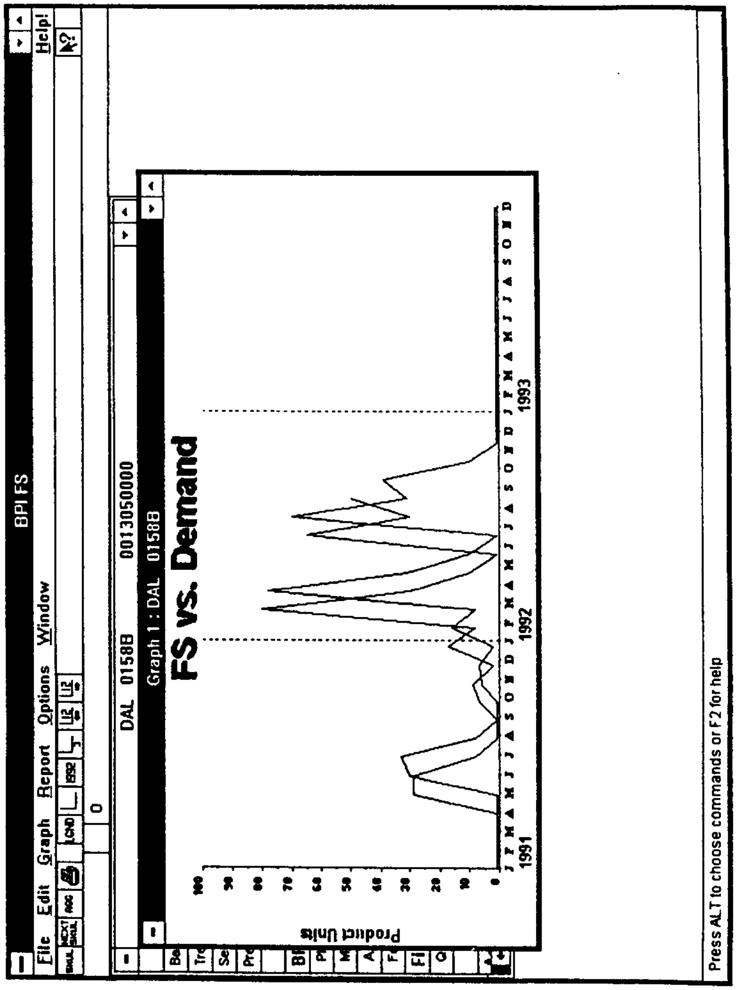

BPI FS
File Edit Graph Report Options Window Help!
DAL 0158B 0013050000
Graph 1 : DAL 0158B
FS vs. Demand
Product Units
1991
1992
1993
Press ALT to choose commands or F2 for help

**FIGURE 3**

**LIST OF AVAILABLE GRAPHS**

| Graph | |
|---|---|
| 1:Planner vs Demand | Alt+1 |
| 2:FS vs Demand | Alt+2 |
| 3:Management vs Demand | Alt+3 |
| 4:Planner vs FS | Alt+4 |
| 5:Planner vs Management | Alt+5 |
| 6:Demand | Alt+6 |
| 7:Planner, FS and Demand | Alt+7 |
| 8:Forecast, Business Plan and Demand | Alt+8 |
| 9:Percent Errors | Alt+9 |
| A:MAPE | Alt+A |
| B:YTD MAPE | Alt+B |

**FIGURE 4**

**REPORTS ON FORECASTING PERFORMANCE**

| Reports |
|---|
| General Purpose... |
| Regression Variable Assignment... |
| Planner Usage... |
| New Part Number Models... |
| MAPE Counter... |

## MFS Systems

Figure 5 illustrates the interaction of corporate systems necessary to operate MFS. The historical information is drawn each forecast period from the corporate MIS (typically held on the mainframe, but it can be on any computer system). MFS automatically makes the time series and regression forecasts and updates the spreadsheets for each forecast item. Forecasters can then access each spreadsheet and make adjustments to the MFS forecasts or simply not access a spreadsheet and accept the MFS automatic forecast. Reports and graphs can be viewed and printed and management can adjust any forecasts deemed appropriate. When this process is completed, the final forecast is uploaded to the corporate MIS, primarily to the DRP system.

The MFS system can consist of a single personal computer performing all forecasts or a network of computers connected by a local area network with each computer having certain forecast items assigned to them. In total, this forecasting system allows for historical data storage on the mainframe and within MFS, allows personal computers to be used for what they do best (analysis), and provides a coordinated forecasting system with specific data maintenance, forecasting, and reporting assignments well defined within the organization.

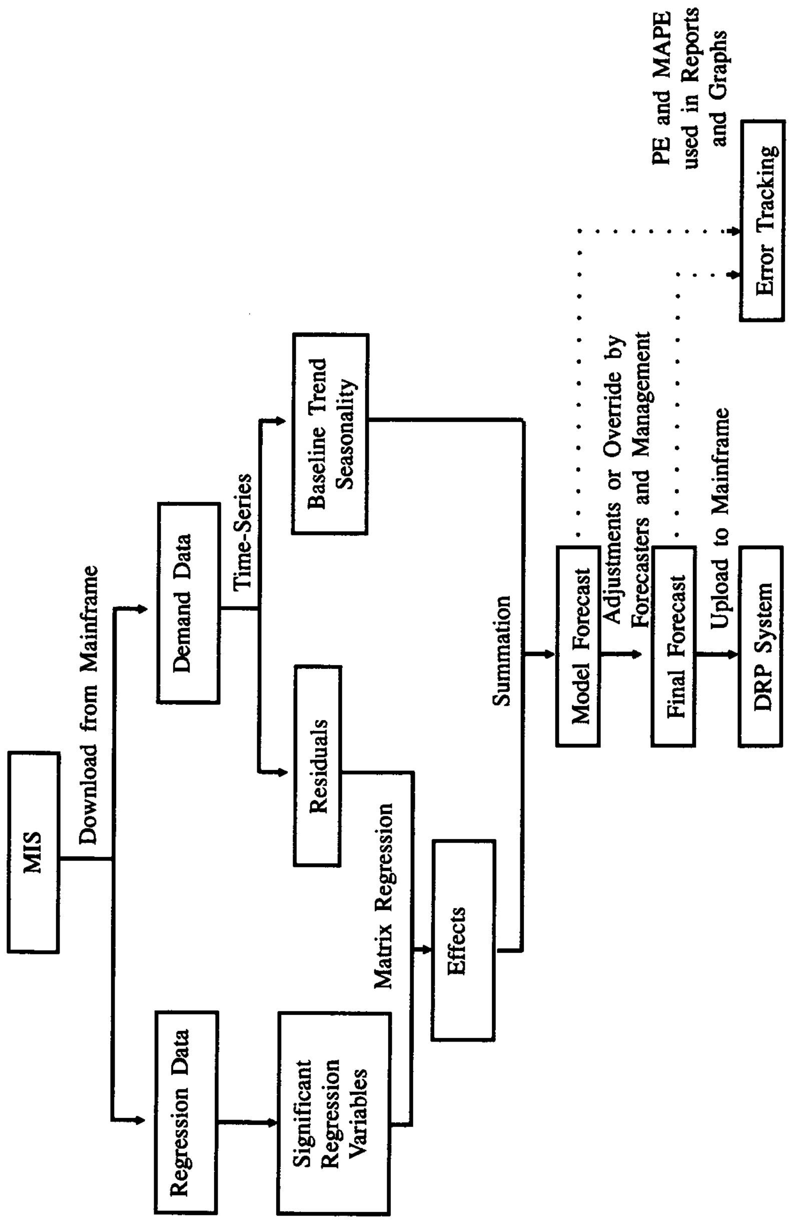
## MFS Administration

MFS allows for a wide variety of forecasting administration structures. For instance, Planters LifeSavers Company uses MFS, with responsibility for forecasting housed in the marketing department. Each month, sixteen marketing product managers develop forecasts for the SKU's under their responsibility (over 1000 SKU's in total) and develop a report for the vice president of marketing. The vice president meets with her counterparts in finance, sales, and distribution to reach a consensus forecast. Any adjustments suggested by this management group are entered by the product managers as management adjustments and the final forecast is sent to the DRP system, which breaks the SKU forecasts down to the SKUL level. Thus, MFS tracks over time the accuracy of the MFS forecasts, the product managers' adjustments to this forecast, and the management group's adjustment to this forecast. Over time, each group learns where their adjustments improve or worsen the forecasts.

The Centralized Inventory and Distribution System (CIDS) of the Internal Revenue Service also uses MFS to forecast demand for IRS forms, but with a

FIGURE 5

MFS SYSTEM FLOW



different administrative structure. In the CIDS structure, distribution is entirely responsible for the forecasting of over 10,000 SKUL's. MIS provides the historical information, MFS makes its automatic forecasts, and the distribution managers make their adjustments and send back to the DRP system their final forecasts.

Finally, Brake Parts, Inc. (BPI) uses MFS within an entirely different forecasting administrative structure. The BPI situation will be discussed at greater length in the next section.

## FORECASTING AT BPI

Brake Parts, Inc. is a basic manufacturer of replacement parts for domestic and import automotive and light truck braking systems. Their products are sold to the North American aftermarket through eight channels of distribution, encompassing forty brand names. With nine manufacturing plants and seven distribution centers throughout the U.S. and Canada, BPI has approximately 250,000 SKUL's for forecasting, planning, scheduling, and distribution.

Responsibility for forecasting the 250,000 SKUL's in BPI rests with the inventory planning group within distribution. Input is solicited from marketing, sales, production, and finance and these groups meet together once a month to provide management adjustments to the forecasts. However, the responsibility for developing and finalizing the forecasts rests with the twelve inventory planners. Thus, BPI faced a situation of having a limited staff, with each inventory planner responsible for making approximately 20,000 forecasting decisions each month. What was needed was a forecasting system that allowed the inventory planner to quickly analyze and adjust the forecasts of the important SKUL's and allowed the system to automatically forecast the less important SKUL's.

This was accomplished with MFS through the vehicle of a forecasting management by exception report. Each SKUL has an acceptable MAPE defined by management. Inventory planners are provided with a report that lists those SKUL's that are within acceptable MAPE limits and those that are not. In addition, the report lists those SKUL's that are sufficiently important to management that the planner is to analyze them regardless of the existing MAPE. Inventory planners are required to analyze and adjust all SKUL's that are outside acceptable MAPE limits. Thus, their time is devoted primarily to the important SKUL's and to SKUL's that MFS is not automatically forecasting well.

This configuration provides a forecasting environment where the appropriate time series, regression, and subjective forecasting techniques are used to forecast each SKUL; the MIS, forecasting, and DRP systems interact in a manner that is appropriate for BPI; and the entire forecasting process has been customized to the unique administrative situation at BPI. Thus, MFS provides a vehicle for accomplishing all the components of the forecasting process advocated by Closs, Oaks, and Wisdo.[4]

Prior to installation of MFS, BPI had a forecasting situation typical of many corporations. The forecasting system was housed on the mainframe, provided only the most simplistic moving average forecasts, with little reporting capability and no graphic capability. It is significant to note that in evaluating the improvement in forecasting performance from the installation of MFS, management did not know what the MAPE was under the old forecasting system. However, in the first month of use after MFS was installed, forecasting error for the A and B class products was 10.1 percent. This performance at the monthly SKUL level compares very favorably with previous surveys of forecasting accuracy, which have reported an average error of 16 percent over a number of companies.[5] Corporate management estimates that the savings from this improved accuracy exceeds $6 million per month in sales (and associated general and administrative costs) not lost due to stockouts alone. Further, it is expected that forecast accuracy will increase as inventory planners become accustomed to using MFS.

## ACCURACY PERFORMANCE OF MFS AGAINST THE M-COMPETITION

Although the BPI example provides dramatic positive results of MFS performance, it is desirable to provide broader evidence of MFS comparative accuracy performance. To provide this evidence, the time series component of MFS was used to forecast the 111 data series from the M-Competition.

The M-Competition is the title given to the 111 data series from various sources put together by Makridakis, et al. for the purpose of providing a broad base of data from numerous organizations for testing the accuracy of time series forecasting techniques.[6] It was the intention of the founders of the M-Competition that the 111 data series would be available so that new techniques and packages could be tested against the 24 forecasting techniques originally tested by Makridakis, et al. However, since the M-Competition represents only time series data, only the time series component of MFS could be tested. Thus, performance in reality (with the regression and subjective components utilized as well) should be more accurate than the results presented here.

To provide a comparison with the 24 forecasting techniques originally used in the M-Competition, Table 1 lists the MAPE achieved over the 111 data series by each of the 24 M-Competition techniques and MFS for various forecasting horizons. In every time horizon, MFS provided superior accuracy (i.e., lower error) than any other technique. Thus, although the BPI example provides actual corporate evidence of the overall results obtained when forecasting techniques, systems, and administration are integrated, the M-Competition results provide broader evidence of MFS technique accuracy.

## CONCLUSIONS

The state of logistics forecasting to date has largely involved the development and application of forecasting techniques and systems in an isolated fashion. Most forecasting packages that exist today use only one or a few forecasting techniques and have limited ability to adjust to different organizations' information systems and/or administrative structures. MFS is the result of a research effort involving a number of organizations to overcome these deficiencies.

MFS provides a forecasting environment that can adjust to different corporate information systems and administration and provides the unique feature of combining the advantages of the three primary approaches to forecasting techniques: time series, regression, and subjective techniques. It also provides a reasonable forecasting turn-around time (forecasting 110,000 SKUL's with MFS on a 486 personal computer takes less than five hours). It is not intended as a panacea for forecasting applications, but merely an example of how the various components of the forecasting process can be combined to maximize achieved accuracy.

The managerial implications of such a system are improved record keeping of historical demand and forecasts, an environment in which subjective adjustments can be readily input to otherwise automatic forecasts, and the improved operating performance that should accompany more accurate forecasts. Only with continued application of forecasting models such as MFS can the logistics discipline document

**TABLE 1**

**MAPE FOR ALL 111 DATA SERIES**

| | AVERAGE OF FORECASTING HORIZONS | | | | | |
|---|---|---|---|---|---|---|
| | 1-4 | 1-6 | 1-8 | 1-12 | 1-15 | 1-18 |
| NAIVE 1 | 17.3 | 19.2 | 20.7 | 19.9 | 20.9 | 22.3 |
| MOV. AVERAGE | 17.3 | 19.1 | 20.1 | 18.9 | 19.7 | 20.8 |
| SINGLE EXP | 15.5 | 17.5 | 18.5 | 17.8 | 18.8 | 20.1 |
| ARR EXP | 16.7 | 18.4 | 19.2 | 18.3 | 19.3 | 20.5 |
| HOLT EXP | 15.7 | 18.5 | 21.1 | 21.3 | 23.4 | 25.1 |
| BROWN EXP | 16.5 | 19.7 | 22.8 | 23.6 | 26.8 | 30.3 |
| QUAD. EXP | 18.6 | 23.1 | 28.4 | 31.7 | 40.4 | 47.7 |
| REGRESSION | 20.0 | 21.4 | 22.5 | 22.9 | 25.4 | 29.5 |
| NAIVE 2 | 12.3 | 13.8 | 14.9 | 14.9 | 16.4 | 17.8 |
| D MOV. AVRG. | 15.4 | 17.8 | 19.0 | 18.4 | 19.1 | 20.6 |
| D SING EXP | 11.6 | 13.2 | 14.1 | 14.0 | 15.3 | 16.8 |
| D ARR EXP | 12.9 | 14.4 | 15.1 | 14.7 | 15.8 | 17.1 |
| D HOLT EXP | 11.7 | 13.8 | 16.1 | 16.4 | 18.0 | 19.7 |
| D BROWN EXP | 11.7 | 13.9 | 16.2 | 17.0 | 19.5 | 22.3 |
| D QUAD EXP | 13.1 | 16.4 | 20.3 | 22.2 | 25.9 | 30.2 |
| D REGRESS | 15.7 | 17.3 | 18.2 | 18.8 | 21.3 | 25.6 |
| WINTERS | 12.1 | 14.1 | 16.3 | 16.4 | 17.8 | 19.5 |
| AUTOM. AEP | 12.5 | 14.3 | 16.3 | 16.2 | 17.4 | 19.0 |
| BAYESIAN F | 12.8 | 14.1 | 15.2 | 15.0 | 16.1 | 17.6 |
| COMBINING A | 12.8 | 12.6 | 14.3 | 14.4 | 15.9 | 17.7 |
| COMBINING B | 10.8 | 12.8 | 14.4 | 14.7 | 16.2 | 17.7 |
| BOX-JENKINS | 11.2 | 13.4 | 14.8 | 15.1 | 16.3 | 18.0 |
| LEWANDOWSKI | 11.7 | 14.7 | 15.5 | 15.6 | 17.2 | 18.6 |
| PARZEN | 13.5 | 12.4 | 13.3 | 13.4 | 14.3 | 15.4 |
| MFS | 10.4 | 11.5 | 12.1 | 12.8 | 13.7 | 14.3 |
| MFS RANK | 1 | 1 | 1 | 1 | 1 | 1 |

ARR = Adaptive Response Rate
QUAD = Quadratic
SING. = Single
D = Deseasonalized

MOV. = Moving
EXP. = Exponential Smoothing
WINTERS = Holt-Winters Exponential Smoothing

Notes: 1. For a more detailed description of competition techniques, see Appendix 2 of Makridakis, et al. (1982).
2. First 24 rows of table adopted from Makridakis, et al. (1982).

the impact of improved forecasting processes on logistics operations costs such as inventory levels, customer service, and the incident of trans-shipping inventory.

From a research perspective, the development of new time series forecasting techniques and their incorporation into such an environment as MFS allows for measurement of the impact of new technique development upon overall accuracy. A concluding hypothesis which the authors will leave to future researchers is the question of whether forecasting techniques, improved systems, or coordinated forecasting administration contributes more to overall forecasting accuracy. The answer to this question may change with various types of organizations and, if so, another challenge to future research is to delineate those factors that determine which aspect of the forecasting process should receive the most attention from management.

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## NOTES

[1]David J. Closs, Susan L. Oaks, and Joseph P. Wisdo, "Design Requirement to Develop Integrated Inventory Management and Forecasting Systems," *Annual Conference Proceedings* (Oak Brook, Ill.: Council of Logistics Management, 1989), pp. 233-260.

[2]For reviews of this literature, see D. M. Georgoff and R. G. Murdick, "Manager's Guide to Forecasting," *Harvard Business Review* 64, no. 1 (Jan.-Feb. 1986): 110-120; or J. Scott Armstrong, "Forecasting by Extrapolation: Conclusions from 25 Years of Research," *Interfaces* 14, no. 6 (Nov.-Dec. 1984): 52-66.

[3]Same reference as Note 1.

[4]Same reference as Note 1.

[5]John T. Mentzer and James E. Cox, Jr., "Familiarity, Application, and Performance of Sales Forecasting Techniques," *Journal of Forecasting* 3 (Jan.-March 1984): 27-36.

[6]Spyros Makridakis, et al., "The Accuracy of Extrapolation (Time Series) Methods: Results of a Forecasting Competition," *Journal of Forecasting* 1 (1982): 111-153.

## ABOUT THE AUTHORS

**John T. Mentzer** is the Harry J. and Vivienne R. Bruce Excellence Chair of Business Policy in the Department of Marketing, Logistics and Transportation at the University of Tennessee. He has published widely in academic journals.

**Jon Schroeter** is inventory control manager at Brake Parts, Inc. He has fifteen years of practical experience in logistics management, encompassing physical distribution, finished goods planning, purchasing, customer service, and transportation in the electrical and automative aftermarkets. A graduate of Illinois Wesleyan Unviersity, he is a MBA candidate at Cardinal Strich College, Milwaukee, Wisconsin.