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Introduction

Jersey Central Power & Light Company procures, stocks and distributes over 3000 items for transmission and distribution work in a 3256 square mile area providing service for 787,000 customers. Material is procured from a central location, delivered by suppliers to two service area warehouses, and ultimately distributed to several outlying locations. This effort requires extensive planning and logistical support to ensure that adequate inventory levels are maintained to satisfy demand at the least possible cost. In order to aid in achieving these desired objectives, a detailed forecasting and inventory planning system was developed using SAS/ETS and base SAS® software.

This paper presents the development and methodology applied in designing the forecasting and inventory planning systems. The planning logic, including the selection of various forecasting models, and the dynamics of the system with respect to inventory position and reordering are the main topics for discussion. An example of the output document for material planning is also shown in detail. Other control and performance parameters that were built into the system are also reviewed.

Background

The purpose of the materials forecasting and inventory planning system is to provide Materials Management planners with a mechanism to improve the responsiveness, control and overall management of transmission and distribution material. This system will serve to draw on existing in place data bases and consolidate the various sources of information onto one "Planning Sheet" for each item.

The system is composed of two basic parts; a forecasting segment and an inventory control section. The forecasting segment is based on the assumption that demand can be accurately predicted using time series analysis based on 36 months of historical data. The inventory control section integrates various quantitative techniques with a practical planning approach into a complete material requirements planning tool. Since demand is not primarily determined from bills of material, i.e., no product structures exist, all items are assumed to be independent and forecast individually. The inventory system is based on reorder point logic consisting of average demand over item lead time and safety stock dynamically determined through forecast error. Because Jersey Central's service territory is divided into two distinct geographical regions with each region containing separate warehousing and distribution operations, material forecasting and planning is performed relative to each area. This requires individual planning for each item in both area.

Forecasting Segment

Exhibit I is a sample of the System's planning sheet. The forecasting segment detail on the planning sheet consists of four lines; two lines (FORECAST and PLANNED) for the previous 12 months of history and two lines for 12 months ahead. FORECAST represents the results of time series models, while PLANNED is input as a discrete known quantity. The aggregate FORECAST and PLANNED quantities determine gross item requirements. Each item is assumed to be independent, henceforth, forecasting models for every item must be selected.

In order to evaluate and select models with acceptable performance, test items representative of a common group were chosen for model testing and evaluation. The test group included a cross section of transmission and distribution materials chosen on the basis of dollar value, usage, and volume. The test group contained 30 items consisting of material such as cable, transformers, connectors and miscellaneous hardware.

Time series modeling was chosen to forecast item demand for the system. This is a logical approach when dealing with many items to eliminate rigorous and time consuming model selections and evaluation. The characteristics of time series is that observations occur in equal time intervals and that inherent patterns recur over time. Such models are identified solely on the basis of historical data.

Nine time series models were selected for evaluation using the group of test items. Since Jersey Central is in the Northeast, subject to seasonal construction patterns, three models with seasonal parameters were included in the group of nine. One of the initial objectives in the model selection process was to choose relatively simple models that could be used for a wide range of stock numbers. Timeliness and fast processing over a large number of items was essential. SAS/ETS (Econometrics and Time Series) procedures were used to model the behavior of univariate time series composed of 36 months of historical data for each stock item in the test group [5]. The periodic length for item forecasting was months, identical to inventory planning periods.

The nine models selected for testing and evaluation are shown below with a brief description of characteristics.

Model	SAS/PROC	Model Description	Trend
1	Forecast	Stepwise Autoregressive	Constant
1	Forecast	Stepwise Autoregressive	Linear
3	Forecast	Stepwise Autoregressive	Quadratic
4	Forecast	Exponential Smoothing	Constant
5	Forecast	Exponential Smoothing	Linear
6	Forecast	Exponential Smoothing	Quadratic
7	X11 &	Seasonally Adjusted	
	Forecast	Exponential Smoothing	Constant

Model	SAS/PROC	Model Description	Trend
8	X11 & Forecast	Seasonally Adjusted Exponential Smoothing	Linear
9	X11 & Forecast	Seasonally Adjusted Exponential Smoothing	Quadratic

Item demand for the periods of January 1986 and May 1986 along with 35 months of preceding history were used to measure model performance. The criteria for model selection was minimum forecast error based on the standard deviation and standard error of the mean, which was used to rank each model by stock number. The two highest ranking models for each stock number were weighted 2 and 1, respectively, and aggregated to determine the best fitting model for each stock group. Stock groups are segmented by the first two digits of their stock number with ranges from 11 to 39. The following table displays those models that were determined to yield minimum error for each group of stock items:

Model Description

- MODEL 1 - Stepwise Auto Regressive with Constant Trend
- MODEL 2 - Stepwise Auto Regressive with Linear Trend
- MODEL 7 - Exponential Smoothing with Constant Trend adjusted for seasonality (X11)

The Forecast Procedure

The SAS/ETS FORECAST procedure fits univariate time series data automatically and produces forecasts. This PROC procedure is the basis for the three models identified as statistically favorable. The FORECAST procedure combines the time trend (long-term behavior) and the time series (short-term fluctuations) method to model the behavior of the series over time. Following are detailed descriptions of the three models identified for use with the Forecasting/Inventory Materials Planning system:

MODEL 1 - Stepwise Auto Regressive (Trend = Constant)

In the STEPAR method, PROC FORECAST first fits a time trend model to the series and takes the difference between each value and the estimated trend. (This process is called detrending). The data for MODEL 1 is fitted to a constant trend. In this case, the assumption is that the series is a constant plus random fluctuations from one time period to the next. The X_t or forecast values are generated according to the equation:

$$X_t = b_0 + e_t$$

b_0 = time series mean
 e_t = random error

The remaining variation (error) is fit using an autoregressive model. The STEPAR method fits the autoregressive process to the residuals of the trend model using a backwards-stepping method to select parameters. The trend and autoregressive parameters are retained. The autoregressive model to explain the residuals or error terms is:

$$e_t = a_0 + a_1 e_{t-1} + e_{t-2} + \dots + a_n e_{t-n}$$

MODEL 2 - Stepwise Auto Regressive (Trend = Linear)

MODEL 2 uses the same principles as MODEL 1 except that a linear trend is added. For the linear trend model, the estimates of X_t are generated according to the equation:

$$x_t = b_0 + b_1 t + e_t$$

The linear model has two parameters and is a first-degree polynomial in time. The error is sequentially fit like MODEL 1 using the autoregressive process. Forecasts are generated and output to a data file for use in the inventory section of the system.

MODEL 7 - Seasonal adjustment using X11 procedure and exponential smoothing with Constant Trend.

Seasonal adjustment of a time series is based on the assumption that seasonal fluctuations can be measured in the original series and separated from the trend and irregular fluctuations. The seasonal component of a time series is defined as intrayear variation that is repeated continuously. A multiplicative seasonal series using exponential smoothing was developed. The input data set must contain at least 3 years of history to satisfy conditions for X11. The X11 Procedure is the first step in estimating the parameters for Model 7. X11 reads and verifies the time series data. Missing values are assigned a value equal to the average monthly demand. The original time series data are deseasonalized according to monthly intervals. The X11 procedure is used again with the YRAHEADOUT option to produce final seasonal factors for the 12 month ahead planning horizon.

The seasonally adjusted series is used as the input for PROC FORECAST. METHOD = EXPO is specified to generate a forecast using exponential smoothing. Exponential smoothing is used to fit a trend model across time such that the most recent data are weighed more heavily than the data in the early part of the series. The weight of an observation extends into the past relative to the current period. The function is written as:

$$W_t = (1 - \alpha)^{T-t}$$

- T = OBSERVATION NUMBER of the past observation
- t = current observation
- α = weighting constant specified

The model is specified with the TREND = option: TREND = 1 for MODEL 7 specifies the constant model, and performs single exponential smoothing. The single exponential smoothing operation is expressed by the formula:

$$F_t = \alpha x_t + (1 - \alpha) F_{t-1}$$

F_t = smoothed value at current period t
 X_t = current actual value of the series

The smoothed value F_t is the forecast of X_{t+1}

and is calculated as the smoothing constant α times the value of the series, x_t , in the current period plus $(1 - \alpha)$ times the previous smoothed value, F_{t-1} (which is the forecast of X_t computed at time $t-1$). The resulting deseasonalized exponential smoothed forecast is multiplied by the seasonal factors for each month created with X11 to produce the item demand forecast. Weight = 0.2 is specified in MODEL 7 for α . The larger the value of α results in more weight or influence of the current observation into the forecast.

Forecasting - Materials Planning Sheet

The headings on the planning sheet shown in Exhibit I as FORECAST and PLANNED for the previous year of history and FORECAST, PLANNED and TOTAL for the current month and year ahead are produced from a forecast model and known demands. PLANNED refers to committed work for specified periods based on outstanding work orders and future requirements. The PLANNED section will be updated on a continuous basis through separate data input. The planning horizon is twelve months for PLANNED WORK.

A forecast tracking signal has been included to monitor the performance of the various forecasting models. The forecast tracking signal is calculated by summing the residuals (actual-forecast) and dividing by the Mean Absolute Deviation (MAD). MAD is defined as the mean of sum of the absolute value of the residuals. The MAD expression is written as follows:

$$e_i = X_i - F_i$$

where, X_i = actual value

F_i = forecast value

Sum of residuals = $e_1 + e_2 + \dots + e_n$

$$MAD = \frac{\sum_{i=1}^n |e_i|}{n}$$

$$FORECAST TRACKING = \frac{\sum_{i=1}^n e_i}{MAD}$$

Based on normal variations, the forecast tracking signal threshold has been set at 5. Anything greater than 5 will produce an exception message for the specific item. A forecast tracking value greater than five indicates that the forecasting model needs to be reconsidered and perhaps replaced with an improved model. Since forecast error is used to determine safety stock level, improved forecasting models will tend to decrease safety stock and thus inventory investment.

Inventory Control Section

The following are definitions of the items contained on the Material Planning sheet shown in Exhibit I:

CURRENT MONTH - This is the reporting month. The material control system is updated based on accounting cutoff dates and the quantities reflected are all based on these dates for each month. The current month is one month after the account-

ing date.

LOCATION - The location is either the Northern Area or the Southern Area warehouse.

PLANNER CODE - This code relates directly to the planner person responsible for a particular item.

MODEL CODE - Refers to the Model used to generate the forecast.

STOCK NUMBER - A six digit code consisting of the group number (first two digits) and 4 others given to each stock number.

ITEM NAME/DESCRIPTION - Short description of item.

UI - Unit of issue.

UNIT COST - Cost of 1 unit in dollars.

SPT - Standard package type.

SPQ - Standard package quantity.

LEADTIME:

INT. - This is the internal leadtime required for processing a purchase order intracompany. For blanket items it has been set for 7 days and 45 days for requisitioned items.

EXT. - This is the leadtime or time from when the order is placed to its actual delivery date.

BLANKET - This is a purchasing order for items in continuous demand. A price for the items may be negotiated annually with deliveries made on request during the year.

BLANKET VENDOR NAME - Suppliers name.

REORDER POINT - The reorder point determines at what point replenishment should take place. Whenever the inventory on hand is equal or below the reorder point item requirements need to be reviewed. This is another exception message. The logic for calculating this quantity is:

$$\text{Reorder Point} = \text{Forecast of Demand over the Lead Time} + \text{Safety Stock}$$

SAFETY STOCK - A set amount of inventory to ensure against stock outs due to inconsistent demand over the lead time. Safety stock requirements are calculated as follows:

$$\text{Safety Stock} = Z\sigma$$

Where Z = safety factor (number of standard deviations from mean)

σ , = standard deviation of demand over the leadtime.

Z	Service Level
0.84	80%
1.04	85%

Z	Service Level
1.28	90%
1.65	95%
2.33	99%

A 95% service level is used for all items. The exact expression for calculating safety stock is as follows: [1]

$$1.65 \sqrt{\frac{(\text{FST DMND} + \text{RTRNS} - \text{ISSUES})^2 * (\text{TO LD TIME})}{(12 - 1) (\text{MO} = 30 \text{ DAYS})}}$$

CURRENT MO. ON HAND - Amount of stock on hand as of report date of current month.

S/IC = Set up cost / (Inventory carrying cost x Unit cost).

This is the control factor in the LTC EOQ calculation. This represents the number of items which if carried in inventory for one period would result in an inventory charge equal to the set up cost.

6 MO. ISSUES TO DATE - Cumulative total of the last six months of issues.

EOQ = Standard Economic Order Quantity expression given by,

$$Q = \sqrt{20D/H}$$

Where Q = Number of item ordered each replenishment period.

O = Ordering cost.

D = Annual demand (forecasted).

H = Inventory carrying cost rate (expressed as of a % of unit cost).

LTC EOQ - This is an inventory method based on the same theory as the classic EOQ formula, i.e., that the least total cost is at a point where the inventory cost and the set up cost are equal. Least Total Cost is expressed as follows:

S = Set up cost

C = Unit cost of item

I = Inventory carrying charge per period

R_n = Requirement quantity in period n

n = Number of periods ordered or period number

Therefore, LTC EOQ:

$$OR_1 + 1R_2 + 2R_3 + \dots + (n-2) R_{n-1} + (n-1) R_n = S/IC$$

Order at the point where the expression on the left is most nearly equal to S/IC. The calculation for LTC EOQ for the planning sheet is rounded to the first period (month) where the LTC quantity is greater than the S/IC quantity. [2]

MIN. - This is the minimum quantity on-hand level for the stock item. This number is controlled by Materials Management and will be used to review "C" items.

TURNOVER RATE - Rate at which inventory is replenished. The turnover rate = Annual Issues/

Average Amount on Hand. For the Material Planning Sheet this is equal to:

$$2 * [6 \text{ mo. issues to date}] / 6 \text{ mo. avg. amt. on hand}$$

AVG. RETIRES/MON. - This is an updated moving average number of retirements from inventory per month computed using the historical data. Only the retirements at the area storerooms are included.

RETURNS - This includes returns to the area storerooms only. Returns are distributed to the year ahead planning horizon as a moving average updated monthly.

PO/PR - Purchase Order/Purchase Requisition Quantity which is allocated to the planning sheet according need date.

PLAN REL - This is the PLANNED RELEASE line for Material Planners to compute the amounts required. The month where an item is expected to reach its reorder point is noted with an "**".

In determining the amount to order, a planner may perform the following analysis:

Amount to Order = Optimum Order Quantity (EOQ)
 + Safety Stock
 - On Hand
 - On Order
 + Demand Over Leadtime

AVAILABLE - This line represents the cumulation of items that make up the forecast. The items are summed follows:

TOTAL = FORECAST + PLANNED

AVAILABLE = TOTAL + ON HAND + RETURNS - PO/PR

The remaining part of the planning sheet displays all of the current purchase order information for the stock item.

RQN NO. - the requisition number. Information is tracked from the requisition level for purposes of updating the monthly available quantity.

RQN. ITEM is the line item number

P.O. NO. is the Purchase Order number followed by

PO ITEM which is the line number.

OPEN QUANTITY - is the outstanding quantity to be delivered.

DATE ORDERED, DELIVERY DATE (expected) and NEED DATE are all related to the Purchase Requisition or the Purchase Order. The remaining items in the Purchase Information System are the VENDOR and the VENDOR NO.

The final selection of the planning sheet is reserved for system messages. The system messages will flag certain criteria for the planner, highlighting the need to review the stock item. Following is a listing of the current system messages:

Forecast Tracking Signal Exceeds 5.
Current Month on Hand is Below Safety Stock.
Reorder Point Reached in This Month.
Reorder Point Reached in Next Month.
Reorder Point Reached in 2 Months.
Reorder Point Reached in 3 Months.
The Forecast has a Negative Trend.
Open Order #(XXXX) is Due in 2 Weeks.
Open Order #(XXXX) is Past Due Period.
Open Requisition #(XXXX) is Past Due Period.
Blanket Order #(XXXX) will expire in 60 days.
Blanket Order #(XXXX) has expired.

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** RAMIS 11 is a proprietary product of Mathematica Products Group, Inc., Princeton, NJ, USA.

Test Plan Implementation

In order to assess the Material Planning Forecasting/Inventory System and to prepare for total stock item implementation, a three month system test period was established. Real data was generated for 25 different stock items for the Northern and Southern Area warehouses. A beginning of the month and middle of the month planning sheet will be created for each stock item in the test group. It is important that the test plan be implemented as documented and all comments noted to facilitate optimal system implementation. A four page "Test Plan Documentation Summary Sheet" has been developed for use during the testing period. This will enable the results to be monitored and assessed, thereby facilitating the implementation process.

Program and Processing Structure

The series of programs were designed to generate a Material Requirements Plan for Jersey Central planners by combining demand summary data, materials management planned requirements and purchase information into one integrated Planning Sheet per area for all stock items in Groups 11 thru 39. Forecasting is performed monthly and held in suspension until the next period. The forecasting segment is generated using SAS/ETS software. Inventory and procurement status can be applied against the frozen forecast at any time, usually weekly or bi-monthly. All of the data extract files have been developed using RAMIS II. The program which generates the Planning sheets is written using base SAS software.

References

- [1] Brauer, D. C., "Effect of Lead Time and Service Level on Safety Stock for a Continuous Review Inventory System with Independent Demand," *Production and Inventory Management*, Vol. 26, No. 2, 1985.
- [2] Montgomery, Douglas C. and Johnson, Lynwood, A., Forecasting and Time Series Analysis, 1st Edition, McGraw-Hill, 1976.
- [3] Naddor, Eliezer, Inventory Systems, John Wiley & Sons, 1966.
- [4] Plossol, George W. and Wight, Oliver W., "Material Requirements Planning by Computer," *American Production and Inventory Control Society*, 1971.
- [5] SAS Institute Inc., SAS/ETS User's Guide, Version 5 Edition, 1984.

EXHIBIT I

SAS

11:43 MONDAY, NOVEMBER 10, 1986 86

JCP&L MATERIAL REQUIREMENTS PLAN CURRENT MONTH: NOV LOCATION: SOUTHERN PLANNER CODE(J5924) MODEL CODE(A)

STOCK NUMBER 121083 ITEM NAME / DESCRIPTION CABLE 3/C 600V TX 2C 4/0&1C 2/OAA XLP OB UI FT 0.715 UNIT COST 215160 003 SPT REEL SPQ 1000 LEAOTIME INT. 7 EXT. 14

BLANKET 215166 001 REYNOLDS METALS CO
BLANKET VENDOR NAME SOUTHWIRE COMPANY

REORDER POINT 108416 SAFETY STOCK 44921 CURRENT MO. ON HAND 297721 FORECAST TRACKING 5.980901 S/IC 5245 6 MO ISSUES TO DATE 637106 EQ 30846 LTC EQ 191383 MIN. 0 TURNOVER RATE 4 AVG. RETIRES/MON. 0

12 MONTH HISTORY													
	NOV85	DEC85	JAN86	FEB86	MAR86	APR86	MAY86	JUN86	JUL86	AUG86	SEP86	OCT86	AVG./MO.
FORECAST PLANNED	87925	99979	76326	63809	87866	74480	88936	98587	81225	97508	98463	85859	86747
ISSUES	146608	82169	113036	61810	49809	101993	105955	117090	93990	79478	98093	142500	99378
RETURNS	350	1100	0	0	0	0	0	0	0	1000	0	204	204
ONHAND	0	0	0	0	0	0	0	0	0	297719	297720	297721	74430

MATERIAL PLAN													
	NOV86	DEC86	JAN87	FEB87	MAR87	APR87	MAY87	JUN87	JUL87	AUG87	SEP87	OCT87	AVG./MO.
FORECAST PLANNED	106390	84993	95242	78232	74247	91575	92891	96588	88918	84099	90280	105026	90707
TOTAL ON HAND	106390	84993	95242	78232	74247	91575	92891	96588	88918	84099	90280	105026	90707
RETURNS	204	204	204	204	204	204	204	204	204	204	204	204	204
PO/PR	0	132000	0	0	0	0	0	0	0	0	0	0	0
AVAILABLE PLAN REL	191535	238746	143708	65680	-8363	-99734	-192421	-288805	-377519	-461414	-551490	-656312	

RQN NO	RQN. ITEM	P.O. NO	PO	OPEN QUANTITY	DATE ORD.	DELIVERY DATE	NEED DATE	VENDOR	VENDOR NO.
1.	8350861958	4	223212	004	123000	861003	861202	SOUTHWIRE COMPANY	14014002
2.	8350861957	3	223210	003	9000	861003	861205	REYNOLDS METALS CO	13850001

SYSTEM GENERATED MESSAGES:

*** FORECAST ERROR EXCEEDS 5
*** REORDER POINT REACHED IN 3 MONTHS , FEB87