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ABSTRACT

EVALUATION OF SALES FORECASTING METHODS: A CASE STUDY

by
Susan J. Canavan

This study investigated forecasting accuracy for sales. Three quantitative and one qualitative forecasting techniques were tested and two combinational models were generated and evaluated.

Three data sets, obtained from a market leader were used to forecast sales. The series represented monthly sales for three years. Three accuracy levels were employed in this study. these are: Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), and Root Mean Square Error (RMSE). Results indicated that the quantitative method outperformed the qualitative method; that combining two or more quantitative methods provide better forecasts than the individual methods; and that combining quantitative and qualitative methods provide more accurate forecasts than the individual qualitative method.

Future studies should focus on the reasons for the differences in accuracy achieved by the different forecasting models. In addition, more quantitative and qualitative methods should be investigated using several companies from different industries.

EVALUATION OF SALES FORECASTING METHODS:
A CASE STUDY

By
Susan J. Canavan

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APPROVAL PAGE

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This thesis is dedicated to my wonderful parents for their continuous encouragement and support.

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TABLE OF CONTENTS

Chapter	Page
1 INTRODUCTION.....	1
2 LITERATURE REVIEW.....	4
2.1 Quantitative Methods.....	7
2.2 Qualitative Methods.....	12
2.3 Combining Forecasts.....	16
2.4 Combining Qualitative Methods.....	18
2.5 Combining Quantitative Methods.....	18
2.6 Combining Qualitative and Quantitative Methods.....	19
2.7 Combining Techniques.....	20
2.8 Accuracy Measures.....	22
2.9 Summary and Conclusions.....	24
3 OBJECTIVE.....	26
4 RESEARCH METHODOLOGY.....	28
4.1 Statistical Hypotheses.....	28
4.2 The Company.....	29
4.3 The Data.....	29
4.4 Forecasting Methods.....	30
4.5 Measuring Forecast Accuracy.....	31
4.6 Research Design.....	31
5 ANALYSIS AND RESULTS.....	33
5.1 Combination of Quantitative Forecasts: (H01).....	33

TABLE OF CONTENTS
(Continued)

Chapter	Page
5.2 Subjective vs. Quantitative Methods: (H02).....	38
5.3 Combination of Forecasts from Quantitative and Subjective Methods: (H03).....	39
5.4 Summary.....	41
6 CONCLUSIONS AND DISCUSSION.....	42
7 SUMMARY AND RECOMMENDATIONS.....	45
8 REFERENCES.....	48

LIST OF TABLES

Table	Page
1 Summary of Forecasting Techniques.....	5
2 Ranking of Forecasting Techniques BY MAE, MAPE, and RMSE, According To the Performance of Each.....	34
3 Ranking of Forecasting Techniques and Their Combination BY MAE, MAPE, and RMSE, According To The Performance of Each Method.....	36
4 Ranking of Forecasting Techniques and Their Combination BY MAE, MAPE, and RMSE, According To The Performance of Each Method.....	38
5 Ranking of Quantitative and Subjective Forecasting Techniques and Their Combination BY MAE, MAPE, and RMSE, According To the Performance of Each Method.....	39

CHAPTER 1

INTRODUCTION

In businesses strategic planning has been growing as a tool to assist in building more profitable portfolios. Planning is a means for managers to define in the present what their organizations can achieve in the future. Therefore, the first step in the planning process should be to anticipate the future demand for products and services and the resources that are required to produce these outputs. In order for an organization to survive and achieve their goals an adequate sales volume must be obtained. Reliable sales forecasting has become a necessity for organizations to be successful, increasing in the need for accurate projections of both unit and dollar values (Mahmoud 1987, Mahmoud and Pregels 1990).

The importance of forecasting to organizations has been discussed by many authors and experts in the field. For example, Makridakis and Wheelright (1987) stated, "...in the turbulent environment of the 1970's and early 1980's, the need for forecasting became widely recognized." Events within all aspects of the firm and virtually all departments have some need for annual sales forecasts. Production, finance, human resources, accounting and the marketing functions implement the use of sales forecasting in their planning activities (Hughes 1987). Makridakis et al. (1993) supported this

position, noting that forecasting is an integral part of the in their decision making process. Armstrong (1978) believes that it is not only a part of the process but is necessary every time a decision is made.

Production planners require forecasts to schedule production, determine their human resources requirements, and purchase raw materials (Coccari 1989). Purchasing managers attempt to secure the necessary raw materials weeks prior to the actual need for the product. They also are concerned with maintaining proper stock positions. In this process, forecasting becomes an essential element of any inventory control system (Abott 1979).

In addition, financial planners employ forecasts to plan their cash and borrowing positions in advance. Forecasts are also used to assist in determining both work force availability and composition (Eby and O'Neil 1977). It is essential that accountants have accurate forecasts of revenues and expenses when they prepare their budgets (Donnelly et al.). Finally, marketing relies on sales forecasts to determine the size of the sales staff and the appropriate funds that will be needed for advertising expenditures that will likely be needed during the forecast period (Eby and O'Neil). Wright et al. (1986) agree that sales forecasting is an integral part of the marketing decision support system.

The importance of being able to make accurate predictions about future advents is not limited to the business sector. According to Bretschneider and Corr (1979), politicians have recognized the value of forecasting in state and local governments due to elevating financial constraints. Gambill (1978) found that 45 percent of the states responding to his survey used econometrics methods to forecast their revenues.

CHAPTER 2

LITERATURE REVIEW

When selecting the most appropriate forecasting method, decision makers must consider several factors such as, the objective of the forecast, the nature of the data, ease-of-use, the time horizon to be covered, the costs involved, the accuracy level that is desired, and the accuracy of the method that is chosen (Mahmoud 1982, Makradakis and Wheelright 1979).

It is important that the accuracy level of the forecasting model is considered once the purpose of the study has been defined. Several experts in the field view accuracy as the most important factor in producing accurate forecasts. This opinion is also supported by Makradakis et al.(1982). The financial implications are also an important issue. They stated that "in many situations even small improvements in forecasting accuracy can provide considerable savings" (Makridakis et. al. 1982). Taking into consideration the current economy and the competitive environments that businesses compete in this can be an important factor to the success or failure of an organization.

In his research Makradakis has provided an assessment of the current information available concerning the different forecasting methods. He states that no study has been done

that proves one method to be superior over another and the research has come up with contradictory results (Makradakis 1986). Several other studies have been conducted by Moriarty (1985), Miller (1985), Wright et al. (1986), Dalrymple (1987), and Tyebjee (1987) that have produced the same conclusion. They agree that there is no one best method that can predict most efficiently in all situations.

Table number one provides a brief description of some of the most common forecasting techniques.

Table 1.--Summary of Forecasting Techniques *

Technique	Description
Qualitative Methods	
Delphi Method	Question a panel of experts for their opinions.
Panel Consensus (Jury of Executive Opinion)	A panel of experts in a field meet to formally develop a consensus on a particular forecast.
Sales-force Composite	Questions salespeople for estimates of expected sales in their territories.
Market Research	Systematic, formal procedure that attempts to measure customer intentions by collecting a sample of opinions.
Visionary Forecast	Known as the "Scenario Development Methods." Individuals believed to be visionary, prepare several scenarios and to predict future events.

"Table 1.0 (Continued)"

Historical Analogy	Given information about similar events, forecasters attempt to predict future events in the life cycle of an organization.
Times Series Analysis and Projection	
Moving Average	Uses historical data to calculate an average of historical demand. The average is then considered to be the forecast.
Exponential Smoothing	Similar to the moving average, but more weight is given to the most recent periods. The pattern of weights is in exponential form.
Adaptive Filtering	A weighted combination of actual and expected outcomes are used to indicate any changes systemically adjust in the pattern of the data.
Time Series Extrapolation	A prediction of outcomes is obtained from the future extension of a least squares function fitted to a data series.
Box-Jenkins	A computer based program that produces an auto regressive, integrated moving average model. Using computer simulation forecasters propose and analyze models. The data is then tested and the models revised until the results are close to the actual historical data.
X-11 (Time Series Decomposition)	This technique decomposes time series into seasonal, trend cycles and irregular elements.
Trend Projection	Depending on the nature of the data, a linear or nonlinear function is developed and used to predict into the future.
Regression Model	A functional relationship is established between a set of independent variables X_1, X_2, \dots, X_n and an independent variable Y . This relationship is then used to predict future events.

"Table 1.0 (Continued)"

Econometrics Models	These models generally are a series of linear equations involving several independent variables.
Correlation Methods	Forecasts are generated from one or more preceding variables that are related to the variable that is to be predicted.
Input-Output Models	These models are used to determine long-term trends for the econometrics model. They also attempt to explain how a change in one industry will impact other industries.

* Generated from Georgoff and Merdick (1986)

2.1 Quantitative Methods

There has been extensive investigation conducted on the accuracy of quantitative techniques provided in forecasting literature (Armstrong and Groham 1972, Adam and Ebert 1976, Makradakis and Wheelright 1979, Moriarty and Adams 1979, Makradakis et al. 1982, Mahmoud 1982, 1984, Moriarty 1985, Carbone and Gorr 1985, Dalrymple 1987). Several of their studies have concluded that quantitative methods can be more accurate than qualitative techniques. For example, Adam and Elbert (1976) reported that using human forecasts proved to be less accurate than Winter's method. Mabert (1975) also concluded that forecasts based on corporate executives and the sales representatives were not only less accurate but they

were also more expensive than quantitative methods. A decade later a study conducted by Carbone and Gorr (1985) also supported Mabert's findings. They found that objective methods provided more accurate results than subjective techniques.

Those who support the use of quantitative methods believe that there are several inherent difficulties that arise when conducting research using qualitative data that limits its effectiveness. Accordingly, those researchers who employ qualitative methodologies have been particularly concerned with the level of accuracy they can achieve and the validity of the conclusions drawn from this form of data analysis. Kirk and Miller (1987) reported that the reliability of qualitative studies often can be questionable for several reasons. They feel the most critical reason can usually be attributed to the individual researchers incompetence, bias, or dishonesty in gathering or analyzing the data. Although McDonald (1985) does agree that there is a threat to the validity in qualitative analysis he also believes that the researcher disregards personal beliefs and perspectives when engaged in this form of research. Miles (1979) agrees that qualitative research does have several weaknesses. The most significant of these weaknesses can be attributed to the fact that there is no standardized method for analyzing this category of data.

He points out that the researcher is confronted with a vast amount of qualitative data and only a limited number of guidelines to which he can follow.

In other studies the comparison of different qualitative methods have been investigated. This area of research has produced conflicting findings and serious questions have arise about which method is superior. Qualitative models have typically categorized into to specific types, time series and causal.

Time series models are based on the assumption that past data can be indicative of the future. According to this technique, forecasts are based on past values, past errors or equally. These models are also known as extrapolative models. Causal models, on the other hand, assumes that the variable being forecasted is related to or dependent upon some other variable or variables. The classical models of this category are regression and econometrics models. The objective of these models are examine the relationship between the variables of interest and utilize this correlation to forecast future values of the independent variables based on he values of the independent variables (Gaither 1990).

According to Makradakis et al. (1993), time series models are less complicated to use than causal models. He also concluded that causal models require several independent

variables whose dimensions must be evaluated before any forecast can be generated. A study conducted by Newbold and Granger (1974) offers support for this view. They also noted that "relevant extraneous information may be unavailable or only obtainable at a prohibitively high cost". Goff (1973), Makradakis and Hibon (1979), and Makradakis et al. (1982) explored the performance of both the sophisticated and time series techniques. Their conclusions supported other research that had concluded that sophisticated methods are not superior to simple approaches. Many factors play a role in determining which approach is better in a given situation. Carbone et al. (1983) added "simpler methods were found to provide significantly more accurate forecasts than the Box-Jenkins method when applied by persons with limited training".

Gross and Ray (1965) conducted a comparison of the performance of smoothing models. In their conclusions they reported that exponential smoothing produced superior results for short-term forecasting. A subsequent study by Kirby (1966) concluded that Gross and Ray's results were only valid when executing a very short term forecast (month-to-month). In a time horizon of one to six months regression analysis was less accurate than both the moving average and exponential smoothing techniques. Research conducted by Enns et al. found that several structural and performance advantages were

prevalent when using a multiple exponential smoothing method as opposed to a simple exponential smoothing technique. He found that using a multiple exponential can reduce the forecast error.

A study executed by Dalrymple (1987) was designed to investigate how companies prepare their forecast, what methods they employ, and how well their methodology performs. The following is a brief summary of the methods they chose. He found that the naive approach was most popular with 30.6 percent of respondents using this method. Second in popularity was the moving average with 20.9 percent describing this as their preferred method. Finally, only 11.22 percent reported the use of an exponential smoothing technique.

Carbone and Makridakis (1986) reported that deseasonalized single exponential smoothing performed fairly well when a change in the pattern was evident in the more recent data. They attributed this to the fact that exponential smoothing tracked the changing mean of the product. McLeavy et al. (1981) stated that exponential double smoothing produced the most reliable results for analysis of data with low noise levels. In opposition to many other researchers Wright (1974) expressed his view that exponential double smoothing was difficult to understand.

Adam et al. conducted a study comparing seven individual item forecasting models. They found that simple methods were superior to other models. These conclusions are supported in a study conducted by Koehler (1986). The results of this research has also reinforced the conclusions of previous studies that show that simple times series models are preferable to the use of Box-Jenkins. Makridakis et al. conducted a study of several extrapolative methods in an attempt to gain more insight into the performance of exponential smoothing models. They used numerous exponential smoothing models and 1001 products. Their study concluded that single exponential smoothing techniques are extremely accurate for analyzing monthly data, however, there was no variation between the performance of Holt's and Holt-Winters' methods. Lewandowski's method did prove to be superior. In the same study, simple methods performed better than sophisticated methods when using micro data. Although the opposite was found to perform more accurately when macro data was being tested.

2.2 Qualitative Methods

Quantitative methods have historically been the most popular form of forecasting used in business. It has long been the belief of many managers that there is a need to incorporate their judgement to produce a more accurate forecast. Winkler

(1987) suggested that the judgement of experts is necessary to evaluate relevant data indirectly and to obtain the results needed in setting a standard. He also noted that "judgmental forecasts are useful in many public policy decisions". In a study conducted by Basu and Schroeser (1977) forecasting errors were reduced from 20% to 4% when the Delphi technique was used. Dalrymple (1987) reported that the use of the sales force composite and the executive opinion, both subjective models, were used by many American firms. He also concluded that by making seasonal adjustments, forecasting errors can be significantly reduced. These findings can be supported by a study conducted by Dalrymple in 1975.

The advantages of using qualitative models has been supported by many researchers. For example a study done by Wallace (1984) emphasized that qualitative research provides more flexibility. As described by Miles (1979), qualitative data are "rich, full, earthy, real, and holistic". Several other advantages have been identified by Wells (1986). He reported that qualitative data is more likely to be readily available when needed and is less costly to obtain.

The acceptance of subjective forecasting has also been supported by studies conducted by Mentzer and Cox (1984) and Lawrence, Edmundson and O'Connor (1995). In a study done by Lawrence et al. (1985), he found that judgmental forecasts were

as reliable as quantitative techniques. When conducting a study using MBA students and a sample of 10 time series models Carbone and Gorr (1985) found that judgmental modifications improved the accuracy of the objective forecasts.

Mahmoud et al. (1988) noted that in certain types of sales forecasting quantitative methods are not commonly used. For example, in industrial marketing. Furthermore, Powell (1979) emphasized that until more dependable quantitative methods have been determined, decision makers should continue to rely on their judgement.

Lewandowski (1987) proposed three reasons why forecasters should convert from quantitative to qualitative methods. First, he stated that quantitative methods can be difficult for the average person to understand. Second, that they consist of a number of unrealistic assumptions and finally, they do not integrate extrapolative and explicative variables into one model. To resolve these obstacles, Lewandowski developed a system that enables the user to incorporate explanatory variables which may improve the accuracy of the forecast. Jenks (1983) concurs, stating, "Quantitative advanced techniques such as regression modeling, Box-Jenkins, exponential smoothing and many more typically require staff specialists to develop them, they require time, research and experimentation to find satisfactory relationships." In

addition he found that quantitative methods are not efficient at anticipating one-time events such as unforeseen changes by competitors, nor are they accurate for long-term planning without adjustments by management.

In comparing different judgmental forecasting techniques, Armstrong (1975) conducted an extensive review for the social sciences. His findings concluded that causal judgmental methods were more accurate than naive judgmental techniques. He also found that subjective methods were not as accurate as objective methods.

In analyzing the performance of experts in the field of forecasting, Jonston and Schmitt (1974), Critchfield et al. (1978), Brandon and Jarrett (1979) noted that, when more accurate information is available, analysts can produce better forecasts than objective judgmental methods. However, Armstrong (1984) reported that management judgmental forecasting is more accurate than analysts' judgmental forecasts. Schnaars and Topol (1987) investigated whether multiple scenarios would improve the accuracy of judgmental sales forecasts, their findings showed no indication of this occurring.

2.3 Combining Forecasts

Due to the above mentioned inconsistencies, and the difficulties associated with choosing the best technique for a given situation, attention has been directed to the benefits of combining forecasts. According to Pokemper and Bailey (1970), it has become a common practice to use combinational techniques. Employing the use of these models has helped decision makers improve the accuracy of their forecasts (Georgoff and Murdick 1986).

The concept of using combinational models has been investigated in many contexts during the past few years. It was stated by Bunn (1989), that the idea of combining forecasts can be traced back to the early 1960's. It was at this time that, Bernard, according to Bunn, "took the first initiative to focus upon the forecasting context, and took as a motivating premise the apparently sensible desire to use all available evidence in making forecasts."

In studies conducted by Makradakis et al.(1982) and Makradakis (1983) empirical investigations to test the performance of several forecasting methods based on numerous accuracy measures, they concluded that a simple average and a weighted average of six forecasting methods were more accurate than any of the individual methods included in the study. In another study by Makradakis and Winkler in 1983 the authors

concluded that combining forecasts from two or more methods to obtain a single forecast can yield fewer forecasting errors. More specifically, the error reduction when combining as few as two models was 7.2 percent. When five models were used the error reduction increased by 16.3 percent. In a subsequent study, Armstrong (1986) investigated the literature of combining forecasts. He found that the increase in forecast accuracy varied from zero to 23 percent.

In a study conducted by Mahmoud (1984) he stated that by combining methods we can obtain more accurate forecasts because more information is captured regarding the potential market. He also reported that "In today's increasingly volatile markets, the combining of forecasting methods is particularly important." In a subsequent survey, Mahmoud and Makridakis (1989) stated that "theoretical work and empirical studies have demonstrated beyond reasonable doubt that there are considerable benefits to be gained from combining forecasts." They also added, "the effect of combining is that the forecasting errors of many models/methods and or people included are 'averaged out' making the composite error smaller on the average." This view is also supported by Flores and White (1989). They pointed out that any combination of forecasts provides a more accurate forecast regardless of the combining technique utilized.

2.4 Combining Qualitative Methods

In combining several different judgmental methods, Ashton and Ashton (1985) acquired superior accuracy when a number of subjective forecasts made by advertising sales executives were combined. Lawrence et al. (1986) also concluded that the accuracy level was always improved when a set of judgmental methods were aggregated. This was also supported by a study conducted by Flores and White (1989). The researchers compared the performance of subjective and objective combinations of several judgmental forecasts. They concluded that combining methods almost always produces a more accurate forecast than any individual method.

2.5 Combining Quantitative Methods

Several studies have been done to evaluate the performance of combining quantitative techniques exclusively (Bates and Granger 1969, Newbold and Granger 1974, Pindyck and Rubinfeld 1976, Falconer and Sivesind 1977, Dalrymple 1978, Adams 1978, Mabert 1978, Gregg 1980, Mahmoud 1982, Makridakis et al. 1982, 1984, Winkler and Makridakis 1983, Makridakis and Winkler 1983, Longbottom and Holly 1985, Bopp 1985, Mills and Stephenson 1985, Russell and Adam 1987). These studies found that a combined approach provided more accurate information.

For example, Makridakis and Winkler (1983) used 111 time series models to combine fourteen quantitative methods. Utilizing the simple average combination, the researchers concluded that the accuracy of combined forecasts was influenced by the quantity of methods used and the type of methods being averaged. Another study done by Winkler and Makridakis (1983) applied 10 forecasting techniques to the 1001 time series used in Makridakis et al. (1982). Again, the results demonstrated an improvement in the accuracy when the methods were combined.

2.6 Combining Qualitative and Quantitative Methods

Combining quantitative and qualitative methods has been extensively examined in forecasting literature (e.g., Gold 1979, Mahmoud 1982, Fildes and Fitzgerald 1983, Moriarty and Adams 1984, Zarnowitz 1984, Moriarty 1985, Lawrence et al. 1986, Newbold et al. 1987, Mahmoud and Makridakis 1987, Zbib and Savoie 1989, Pereira et al. 1989). For example, Lawrence et al. (1986) noted an improvement in the level of accuracy that can be obtained when a combination of statistical and judgmental methods are employed. Pereira et al. (1989) combined time series techniques with subjective predictions from open-market operators. Their conclusions showed that accuracy levels can be increased when these techniques are

combined. Brandt and Bressler (1983) combined several forecasting methods (quantitative and qualitative) to forecast livestock prices. They found that the combining method caused a reduction in large forecasting errors.

Moriarty and Adams (1984) proposed that a combinational model that includes both systematic and judgmental forecasts would be superior to either single method. However, in a subsequent study, Moriarty (1985) combined management judgement and time series models and found no significant improvement in the accuracy of the forecast. He, therefore, recommended that both methods should be retained. In addition, Mahmoud and Makridakis (1989) stated that "it is advisable that managers prepare a judgmental forecast separately and then formally combine it with a quantitative forecast."

2.7 Combining Techniques

Forecasting methods can be combined using several different techniques that range from simple averages to more complex weighted methods. Several combinational methods have been proposed, including unrestricted regressions (Granger and Ramanathan 1984), historical weighing (Doyle and Fenwick 1976), subjective weights (Doyle and Fenwick 1976), Odds-Matrix method (Gupta and Wilton 1987), weighted average based on the sample covariance matrix (Newblod and Granger 1974,

Makridakis and Winkler 1983), linear combination (Holden and Peel 1986), constrained versus unconstrained weights (Nelson 1972, Makridakis et al. 1982, Granger and Ramanathan 1984), focus forecasting (Smith and Wright 1987), composite predictors (Moriarty and Adams 1984, Phillips 1987), and multiple objective linear program model (Reeves and Lawrence 1982, Gullledge et al. 1986).

In their frequently cited study (known as the M competition), Makridakis et al. (1982) used both the simple and the weighted average, based on the covariance matrix of fitting errors. The results of the study were in support of the simple approach. Also endorsing the simple approach to combining are studies by Einhorn (1972), Gupta and Wilton (1978), Mahmoud (1982), Ashton (1982), Carbone et al. (1983), Winkler and Makridakis (1983), Figlewski and Urich (1984), Lawrence et al. (1986), Clemen and Winkler (1986), Kang (1986), and Holden and Peel (1986). For example, Lawrence et al. (1986) stated that the simple average was less time consuming and more accurate than judgmental combination. Kang (1986) agrees, noting that the simple average is superior to the weighted average because the weights in the later are unstable. While the simple average has gained the interest of many researchers and has proven accurate, its academic justification remains absent (Gupta and Wilson 1987). Studies

such as Bates and Granger (1969), Newbold and Granger (1974), Makridakis et al. (1982), Makridakis and Winkler (1983), Granger and Ramanathan (1984), Engle et al. (1985), and Dieblod and Pauly (1987) concluded that the weighted average techniques are superior to the simple average. Gupta and Wilton (1987) introduced a new weighted combining method, called the Odds-Matrix (OM) method. They claimed the OM method is highly superior to simple averaging, especially if the forecast errors are nonstationary. Others (Nelson 1972, and Holmen 1987) concluded that a linear combination provides more accuracy than other methods, especially the simple average.

Flores and White (1989) conducted an experiment to compare the accuracy of subjective and objective combining methods. Their results favored the subjective approach. Also, Sessions and Chatterjee (1989) investigated the performance of ten combinational methods and concluded that they allow local bias adjustments and are preferred to the simple average method.

2.8 Accuracy Measures

Since accuracy plays a vital role in assessing forecasting techniques, many studies have attempted to find the best way to measure how reliable a forecasting model is. Unfortunately, none of these has resulted in a single universally accepted

instrument (Makridakis et al 1983). A summary of accuracy measures, based on several sources, is provided by Makridakis and Wheelright (1978) and Mahmoud (1984, 1989).

In evaluating the results of any forecasting method, many comparative techniques are available. Some of these techniques are more popular than others. "Clearly the forecaster or the practitioner is faced with a trade-off between the cost of applying a forecasting technique or an opportunity loss from basing decisions upon an inaccurate forecast and the value of increased accuracy in the selection of a technique." (Mahmoud 1984).

The most widely used method is the mean squared error (MSE). However, this technique has two problems. According to Makridakis et al. (1983), an MSE that is developed during the fitted phase may give misleading information about the accuracy of the model at the forecasting phase. Another problem with this method, according to the authors, is that different forecasting techniques use various procedures in the fitting phase. Other studies also criticize the use of this measure for comparisons containing more than one data set (Wrinkler and Makridakis 1983, Gardner 1983, Guerts 1983). Their argument is that the criterion is highly influenced by the magnitude of the data.

Because of the problems inherent in the MSE measure, some decision makers prefer to use the mean absolute percentage error (MAPE) and/or the median absolute percentage error (MAPE) (Gardner 1983). Other techniques are also used such as the mean percentage error (MPE), the mean error (ME), mean absolute deviation error (MAD), and R-squared (Bretschneider and Carbone 1979, Armstrong 1978, Makridakis and Hibon 1979).

2.9 Summary and Conclusions

Forecasting is a subject that has consistently been a concern to many scholars (e.g., Makridakis et al. 1982, 1986, Mahmoud 1982, 1984, Armstrong 1978, 1985,). The existence of several forecasting methods raise a controversial question. Managers are questioning the accuracy of these techniques and are inquiring which method provides the most accuracy.

A wide range of methods is available to asset decision makers in predicting the future. Various types of qualitative techniques are used (e.g. jury of executive opinion, sales force composite, management judgement, and the Delphi approach), as well as quantitative univariate and multivariate quantitative methods (time series and causal). Results have been mixed when these two methods are compared. For example, studies such as Makridakis and Hibon (1979) and Mahmoud (1984), found that quantitative methods were superior to management judgement. On the other hand, several studies (e.g. Mabert

1976, Staelin and Turner 1973, Dalrymple 1987) recognize the potential benefits of subjective forecasts. Others (Carbone and Gorr 1985) reported that revised judgement forecasts are more accurate than the initial judgement.

Combining quantitative and qualitative forecasting methods has been investigated extensively in the forecasting literature (e.g. Winkler and Makridakis 1983, Dalrymple and Parsons 1983, Moriarty and Adams 1984, Lawrence et al. 1986, Mahmoud and Makridakis 1989). Most of these studies exhibited that increased accuracy can be obtained when these techniques are combined. Moriarty (1985), however, combined time series and management judgement and discovered no significant improvement in accuracy. These inconsistencies suggest that additional research into the accuracy of combining forecasts is warranted (Mahmoud 1984, Mahmoud and Makridakis 1989).

Results have also been mixed when combining techniques are compared. Some studies found that the simple average method is superior to a weighted technique (e.g. Makridakis et al. 1982, Mahmoud 1982). Other studies such as Newbold and Granger (1969), and Granger and Ramanathan (1984) suggest that the weighted average method is more accurate.

The proposed research has evoked from the contradictory results shown in the reviewed literature. The main goal of this study is to investigate the accuracy of combining quantitative and management judgement forecasts.

CHAPTER 3

OBJECTIVE

Recent studies have not resolved the inconsistencies in the literature exploring which forecasting methodology is most accurate. In many cases, the investigators claimed that combining methods provides more accurate forecasts than using one approach alone. Nevertheless, few studies have empirically tested the effectiveness of combining quantitative methods with management judgment (e.g., Lawrence et al. 1986, Moriarty and Adams 1984, Moriarty 1985, Zbib and Savoie 1989). The inconsistencies noted above, along with the lack of convincing empirical research, specially on a micro level, suggest that further research into the accuracy of combining forecasts is warranted. In fact, Mahmoud (1984) suggested that more theoretical and empirical research is needed to determine whether combining is better, and which techniques should be combined. In another study, Mahmoud and Makridakis (1989) stated that "the field of forecasting needs further insights into combining." Lawrence et al. (1985) specifically suggested that a combination model incorporating judgmental forecasting models should be investigated. In still other studies, more empirical research dealing with micro time series were recommended (e.g. Sanders and Ritzman 1989).

These studies suggest that more comparisons of forecasting methods should be made using micro data, such as data on individual products.

This paper investigates whether the accuracy of forecasts can be improved by combining judgmental forecasts with forecasts from statistical models that are widely used in the forecasting literature. In addition, this study investigates the difference among selected combining methods.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 Statistical Hypotheses

The primary interest in the study is to investigate whether combination of forecasts produces a lower forecast error than the single best model. Based on this objective, the following statistical hypotheses are tested:

Hypotheses 1 (H01):

Combination of forecasts from several quantitative methods leads to more improvements in accuracy. Specifically, combining two or more time series methods produces lower forecast error than either (or any) of the separate methods.

Hypotheses 2 (H02):

In general, objective forecasting methods are superior to subjective methods. Specifically, management judgment forecasts are less accurate than forecasts produced using time series methods.

Hypotheses 3 (H03):

Combination of forecasts from quantitative and subjective methods leads to more improvements in accuracy. Specifically, combining time series methods and revised management judgment methods is superior to the individual forecasts.

4.2 The Company

The company under investigation is a market leader in the cosmetics industry. It produces a variety of products with a total product range comprising in excess of 200 individual items. Short-term forecasting for individual products within the company takes place on a monthly basis, using qualitative methods. A single econometric forecasting model is used to generate forecasts for all products.

4.3 The Data

The data used in the study consist of actual monthly sales for three products. For each product, thirty data sets were used to forecast sales. All series represent monthly sales from January 1988 to December 1989. In addition, monthly forecasts for the same three products generated by the management's judgmental method were obtained. This subjective method utilizes the expertise of managers from different units within the company who get together once a month to discuss sales. It is purely subjective, and depends on the managers' expectations. All three products exhibited seasonality and trend.

4.4 Forecasting Methods

Three time series methods and one qualitative method, and their combinations were investigated in this study. The three time series techniques tested here are: Pegels'(A-2)/Gardner's(4-3), Pegels'(A-3)/Gardner's(3-3) and Pegels'(B-2)/Gardner's(4-2).

Several factors were taken into consideration in the selection of these methods. First, they are commonly investigated in the literature. Second, the methods were proven to be accurate in a number of comparative studies. Third, they were selected based on both their simplicity. Finally, these selected methods provide forecasts quickly. This is considered important these days when forecasts may need to be generated daily.

Two combination forecasts were generated from these four techniques, resulting in one three-technique simple average combination and one two-technique simple average combination. Although more combinations could have been investigated, some studies state that accuracy is not significantly affected by the selection of techniques in the combination (e.g. Makridakis et al. 1982, Makridakis and Winkler 1983, Winkler and Makridakis 1983, Sanders and Ritzman 1989). All possible combinations were first investigated and the following two were selected for this study:

Simple Average:

1. COMB1s: Three Time Series Models
2. COMB2s: One Time Series and One Subjective Models

The forecasts for the combinations were obtained period by period by taking the simple average .

4.5 Measuring Forecast Accuracy

The accuracy measures used in this study are Mean Percentage Error (MPE), Mean Absolute Percentage Error (MAPE), Root Mean Squared Error (RMSE). Managers are advised to use more than one comparative measure because no one universally accepted measure exists (Gardner and Dannenbring 1980, Mahmoud 1984). Therefore, three accuracy measures are used in order to better evaluate the accuracy of the various forecasting methods in this study. These three measures were selected because of their common use.

4.6 Research Design

In this study, 24 data points were used to forecast twelve points ahead. The accuracy of the fitted phases were compared to the accuracy of the forecasted values provided by the three time series models used in this study. Then, the most accurate quantitative model was selected and used for comparison and combining with management judgment forecasts.

Second, two different combinations were developed and tested for accuracy using three accuracy measures (MPE, MAPE, and RMSE). The results of the combinational models are then compared with the individual methods. One combining technique was used for this purpose. It is the simple average.

Third, to test whether subjective methods are more accurate than quantitative methods, the management judgment forecasts were tested and compared with the corresponding forecasts generated by the three time series models.

The fourth step in the study was to combine the management judgment forecast with the quantitative methods selected in step one. A simple combining technique was used for this purpose. Then, the combining forecasts were tested and compared with the individual forecasts.

All three time series techniques were executed in an automatic mode using SMOOTH, an interactive program developed by Pegels' 1969.

CHAPTER 5

ANALYSIS AND RESULTS

This section begins with an examination of the accuracy of several quantitative methods. The results of the simple average combining of these techniques are presented next, followed by a discussion of the forecasts generated from the qualitative method. Then, forecasts generated from combining quantitative and subjective methods are analyzed and discussed. Finally, the paper concludes with a summary of the findings.

5.1 Combination of Quantitative Forecasts: (H01)

To test whether combining quantitative forecasts improves accuracy over the constituent forecasts, the accuracy of three time series models and one combination were tested and compared. The results are shown in Table 2.

Table 2 ranks the three individual forecasting models on their overall performance for the three time series using all three accuracy measures. Shown are the mean percentage error (MPE), mean absolute percentage error (MAPE), and root mean squared error (RMSE) scores for each technique in each of the forecasted phases individually, and in aggregate. The several similarities among the rankings of the three accuracy measures

are interesting. For example, the three are consistent in ranking Models 2 and 5 as the least accurate models. However, It is important to note that no one time series method is most accurate in all instances.

Table 2.-- Ranking of Forecasting Techniques BY MAE, MAPE, and RMSE, According To the Performance of Each

Method						
Acc. Measure	Model					
	M2	(R)	M3	(R)	M5	(R)
Data Set 1						
MAE	6833	2	6308	1	7015	3
MAPE	15.8	2	14.4	1	16.36	3
RMSE	9610	2	9295	1	9614	3
Data Set 2						
MAE	3841	2	3495	1	4121	3
MAPE	20.1	2	17.8	1	21.4	3
RMSE	5213	2	4921	1	5374	3
Data Set 3						
MAE	4912	2	4561	1	5924	3
MAPE	15.8	2	14.7	1	19.2	3
RMSE	6812	2	6530	1	8048	3

Mean Ranks		2		1		3
=====						

Note: R = Rank
MAE = Mean Absolute Error
MAPE = Mean Absolute Percentage Error
RMSE = Root Mean Squared Error

Also, the three measures show that the combining technique is more accurate than the individual techniques in the combination. Table 3 ranks the individual forecasting models and their simple average combination on their overall performance. Presented are the MPE, MAPE, and RMSE scores for each technique.

Table 3.-- Ranking of Forecasting Techniques and Their Combination BY MAE, MAPE, and RMSE, According To the Performance of Each Method

Acc. Measure	Model							
	M2	(R)	M3	(R)	M5	(R)	C1	(R)
Data Set 1								
MAE	6833	3	6308	2	7015	4	6095	1
MAPE	15.8	3	14.4	2	16.4	4	13.0	1
RMSE	9610	3	9295	2	9614	4	5592	1
Data Set 2								
MAE	1841	3	3495	2	4121	4	2975	1
MAPE	20.1	3	17.8	2	21.4	4	12.0	1
RMSE	5213	3	4921	2	5374	4	3864	1
Data Set 3								
MAE	4912	3	4561	2	5924	4	3134	1
MAPE	15.8	3	14.7	2	19.2	4	11.0	1
RMSE	6812	3	6530	2	8048	4	3589	1
Mean Ranks		3		2		4		1
Note:								
	R	= Rank						
	MAE	= Mean Absolute Error						
	MAPE	= Mean Absolute Percentage Error						
	RMSE	= Root Mean Squared Error						
	C1	= Combination 1 (combining all three models)						

Tables 2 and 3 shed considerable light on the issue of forecasting accuracy. The resulting forecasting errors show that the combination outperformed the individual models across all three accuracy measures. Important to note, however, is that the accuracy of various methods differs sometimes, depending upon the accuracy measure being used. Clearly, this supports other studies (e.g. Mahmoud et al. 1990, Winkler and

Makridakis 1983) which concluded that different forecasting procedures perform differently over various time periods.

5.2 Subjective vs. Quantitative Methods: (H02)

To test whether subjective methods provide more accurate forecasts than quantitative methods, the accuracy of management judgment (subjective) and three time series (quantitative) models were compared. To accomplish this comparison the management judgment forecasts for the three products were compared with the corresponding forecasts generated by time series models. The MPE, MAPE and RMSE from each of these models are presented in Table 4.

Table 4.-- Ranking of Forecasting Techniques and Their Combination BY MAE, MAPE, and RMSE, According To the Performance of Each Method

Acc. Measure	Model							
	M2	(R)	M3	(R)	M5	(R)	S	(R)
Data Set 1								
MAE	6833	2	6308	1	7015	3	13157	4
MAPE	15.8	2	14.4	1	16.4	3	28.4	4
RMSE	9610	2	9295	1	9614	3	45232	4
Data Set 2								
MAE	3841	2	3495	1	4121	3	6953	4
MAPE	20.1	2	17.8	1	21.4	3	32.2	4
RMSE	5213	2	4921	1	5374	3	76716	4
Data Set 3								
MAE	4912	2	4561	1	5924	3	17621	4
MAPE	15.8	2	14.7	1	19.2	3	51.4	4
RMSE	6812	2	6530	1	8048	3	45818	4

Mean Ranks		2		1		3		4
=====								

Note: R = Rank
 MAE = Mean Absolute Error
 MAPE = Mean Absolute Percentage Error
 RMSE = Root Mean Squared Error
 S = Subjective Forecasts

5.3 Combination of Forecasts from Quantitative and Subjective Methods: (H03)

To test whether combining quantitative and subjective methods leads to more accurate forecasts, an examination was made of combining one time series and one subjective (management judgment) methods. Table 5 shows all three series the MPEs, MAPEs, and RMSEs of the best quantitative (M3) the management judgment (S), and the combined forecasts (C2).

Table 5.-- Ranking of Quantitative and Subjective Forecasting Techniques and Their Combination BY MAE, MAPE, and RMSE, According To the Performance of Each Method

Acc. Measure	Model					
	(R)	M3	(R)	S	(R)	C2
Data Set 1						
MAE	6308	1	13157	3	8619	2
MAPE	14.4	1	28.4	3	18.0	2
RMSE	9295	1	45232	3	31809	2
Data Set 2						
MAE	3495	1	6953	3	4770	2
MAPE	17.8	1	32.2	3	20.6	2
RMSE	4921	1	76716	3	5329	2
Data Set 3						
MAE	4561	1	17621	3	8363	2
MAPE	14.7	1	51.4	3	31.0	2
RMSE	6530	1	45818	3	42982	2

Mean Ranks		1		3		2
=====						
Note:	R	=	Rank			
	MAE	=	Mean Absolute Error			
	MAPE	=	Mean Absolute Percentage Error			
	RMSE	=	Root Mean Squared Error			
	M3	=	Model 3 (Quantitative)			
	S	=	Subjective Forecasts			
	C2	=	Combining 2 (M3 and S)			

Importantly, some instances of some accuracy measures of the combined forecast being worse than those of quantitative method (M3) were noted. This result is expected due to the nature of the simple average combining technique. The fact that the subjective method was much less accurate than Model 3, when the simple average was used to combine, the combinational forecasts generated were more accurate than the

subjective model but still less accurate than the quantitative model (M3). Therefore, a weighted combining technique is recommended in this case. Examining the individual values of the accuracy measures for each series is also recommended.

5.4 Summary

Three hypotheses were proposed about forecasting accuracy. These suggested that combining several quantitative methods is more accurate than individual methods; that time series methods are more accurate than management judgment; and that combining quantitative and qualitative methods provide more improvement in accuracy when a weighted average is utilized. Prior evidence on these hypotheses was mixed. However, they did receive strong support in this study.

CHAPTER 6

CONCLUSIONS AND DISCUSSION

Though micro time series is commonly found in business, the forecasting literature has not given this type of data the attention it deserves (Sanders and Ritzman 1989). A few investigations are made at a micro level, such as dealing with data on individual products. Most empirical studies have investigated macro time series such as gross sales data on a firm or industry.

This study focused on forecasting accuracy of several individual and combinational models using three different products. Contradictory results have been found regarding which forecasting method is more accurate.

This study has evolved from the mixed results shown in the reviewed literature and from the lack of sufficient forecasting research dealing with micro data. The major purpose of this study has been to investigate and identify the accuracy of both quantitative and qualitative techniques implemented by the company under study, and to test the accuracy of different time series models for microeconomic data. Focus has been placed on testing the combining as a tool to improve forecasting accuracy. Of particular interest is whether combining time series and judgmental forecasts provide more accurate results than individual methods.

Three data sets were used in this study to forecast sales. All series represented monthly sales for individual products.

The findings made by this study has implications for both theoretical and practical contexts. The finding's theoretical importance is in expanding understanding of the complex process of forecasting accuracy by supporting the combinational models of forecasting. The practical significance is the potential for substantially improving forecasting accuracy of the company under study in particular and organizations in general. The intent of this study was to explore the inconsistencies in the forecasting literature and to provide information of practical interest to forecasters, managers, and scholars.

From all analysis of 3 series, conclusions can be drawn that the performance of various time series methods differs sometimes, depending upon the series tested and the accuracy measure being used. The results show that no single method can be used for all products. This is especially true when products change due to characteristics. This supports and extends the conclusions suggested by Makridakis et al. (1982) and Schnaars (1984). Therefore, for a particular product, one needs to follow closely the change in data and suggest different models at different time intervals.

Given the subjective nature of the management judgment technique, perhaps not surprisingly, this qualitative method has been shown to be less accurate than quantitative methods. Previous studies (e.g. Makridakis and Wheelwright 1977) showed that management judgment forecasts provide better forecasts for longer time horizons. The forecasters in the company under investigation may be applying this method to inappropriate time horizons. Other studies (e.g. Hogarth and Makridakis 1981) state that judgmental forecasts in general are less accurate than quantitative methods because of the biases inherent in information-processing.

The conclusion is that any time series method would seem to offer more accurate forecasts than may be obtained from the judgmental method currently employed by the firm to predict micro sales data. In short, the firm is suggested to either use time series models or a combination of judgmental and one or more time series methods.

The results of this study also show the benefits that can be gained from combining judgmental and time series forecasts. A combinational model that integrate management judgment with a time series model has been tested and evaluated.

CHAPTER 7

SUMMARY AND RECOMMENDATIONS

Several important findings emerge from this study. First, objective methods are more accurate than subjective methods. In fact, a highly significant difference was found between time series and management judgment methods. Second, combinations of quantitative and subjective methods improve forecasting accuracy. This study has shown the benefits that can be gained from combining time series and judgmental forecasts.

Assuredly, the results of the study were constrained by the data series employed and by the limited number of methods compared. This limitation is especially true for hypothesis three.

The proposed combinational model can be used to improve forecasting accuracy in comparison to individual models. However, additional research regarding the application of this model is suggested. Specifically, this model should be tested over a wider range of time series than those used in this study to determine its reaction to trend and seasonality. Also, more theoretical and empirical research is required to define the best technique for combining forecasting methods, and which techniques should be included in the combination

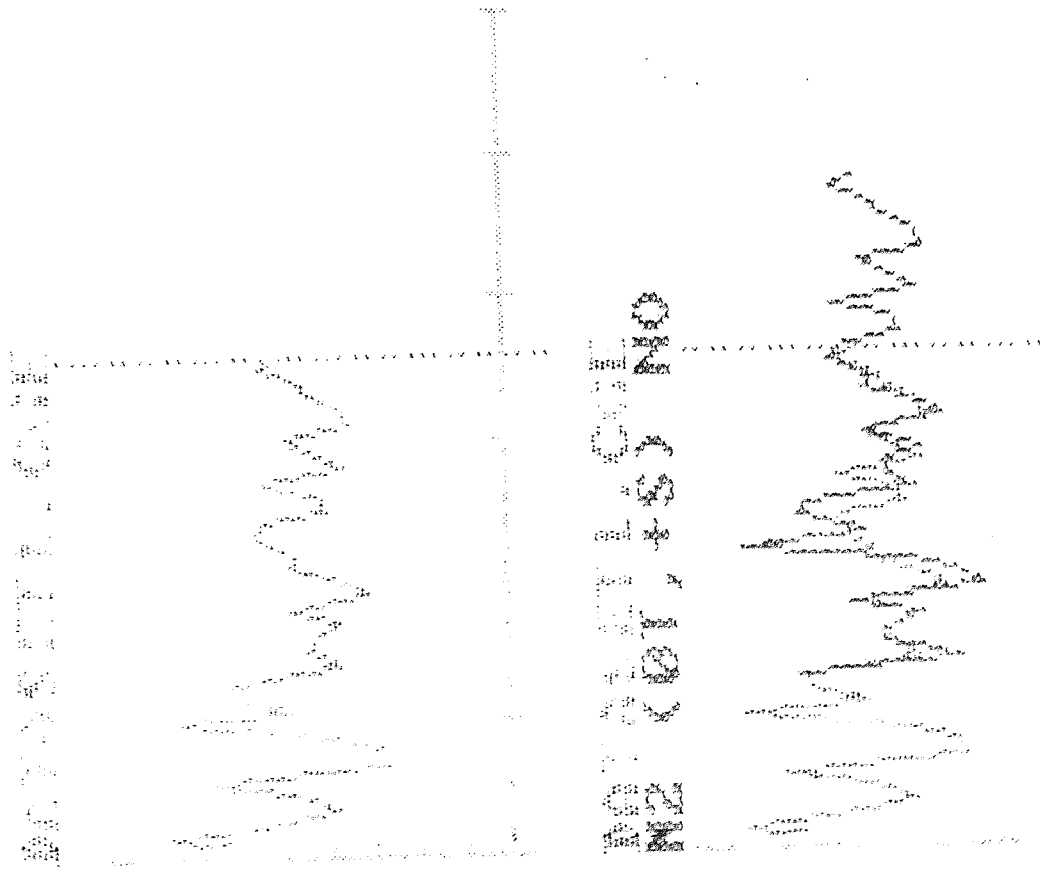
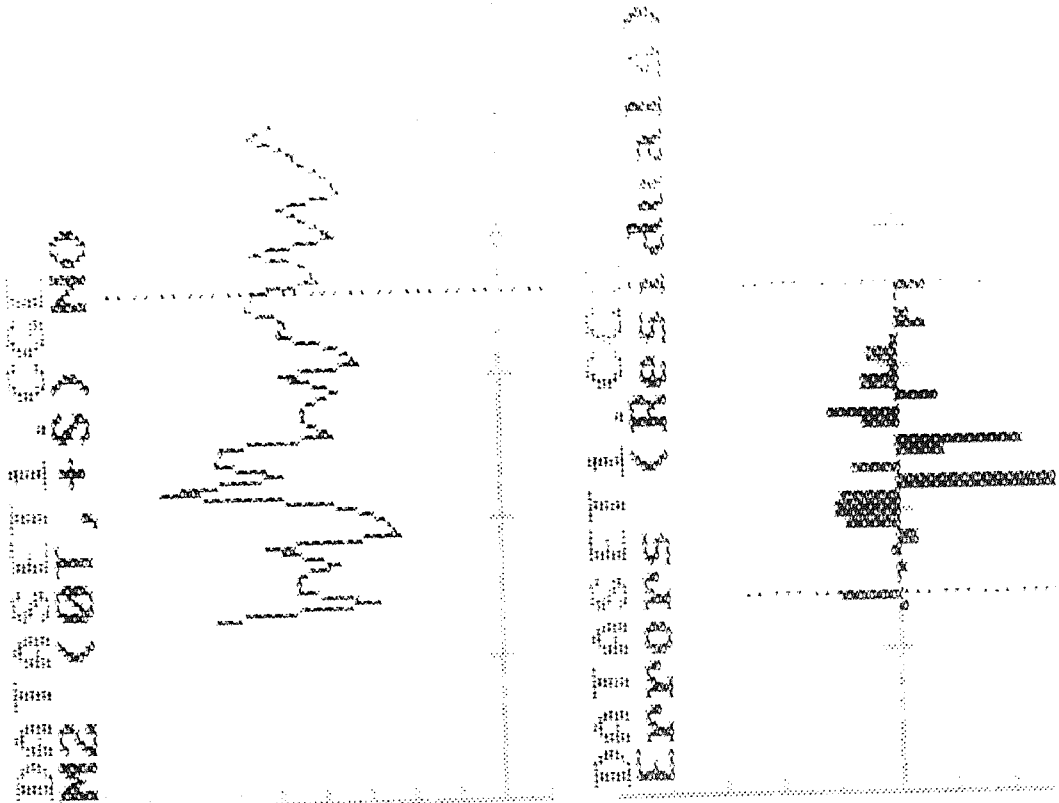
(Mahmoud 1984). In a recent study, Mahmoud and Makridakis (1989) suggested that future studies should investigate how combining could help managers learn and improve individual forecasting.

In addition, other combining basis should be tested and compared to the one used in this study. A combinational weighing technique which incorporates an adjustment for bias could also be developed and tested for accuracy, as could a combinational model that includes other subjective techniques. Finally, the set of individual models included in the combination in this study could be extended to include other time series methods.

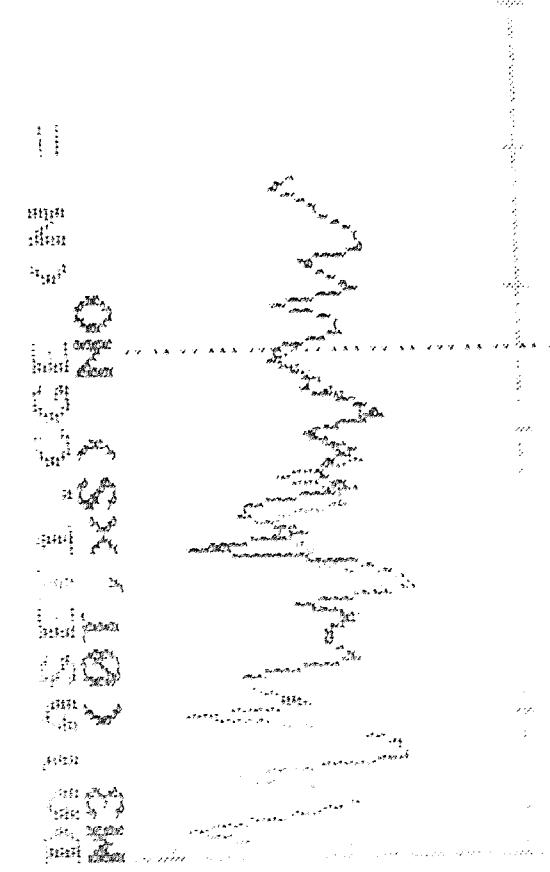
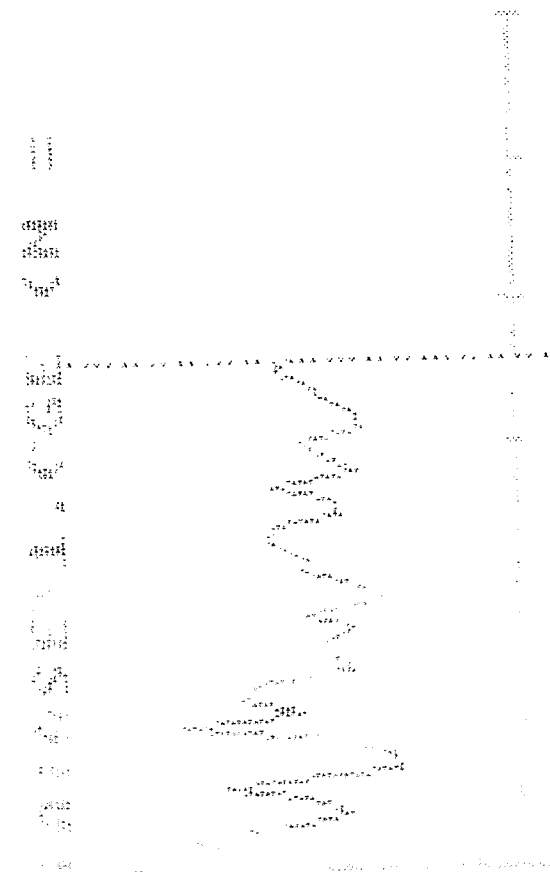
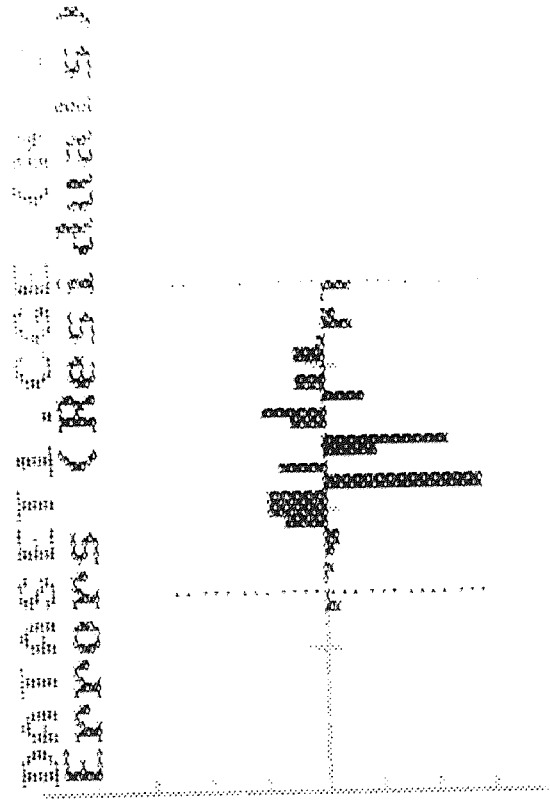
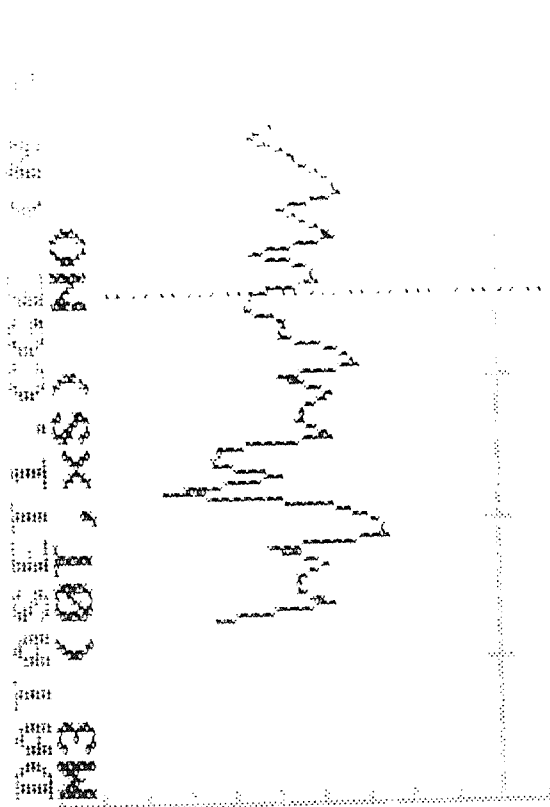
Without doubt, this study needs to be repeated using a variety of companies in order to test the generalizability of the results. The fact that the findings of this study are company-specific should not negate the importance of the results. Indeed, the objective of this study is to test forecasting accuracy for micro variables. This raises the question of whether some of the findings suggested by previous cross-industry/cross-company studies can also be applied when micro sales are being forecast. Another question raised by this study is whether a company possesses a unique set of forecasting characteristics and, if so, what these characteristics are.

Future research should focus on the reasons for the differences in accuracy achieved by the different forecasting techniques (Makridakis et al. 1982, Mahmoud et al. 1990). In order to do this, more quantitative and qualitative techniques should be tested at both macro and micro levels. Further research in this direction may set the stage for providing consistent results which are lacking in the forecasting literature.

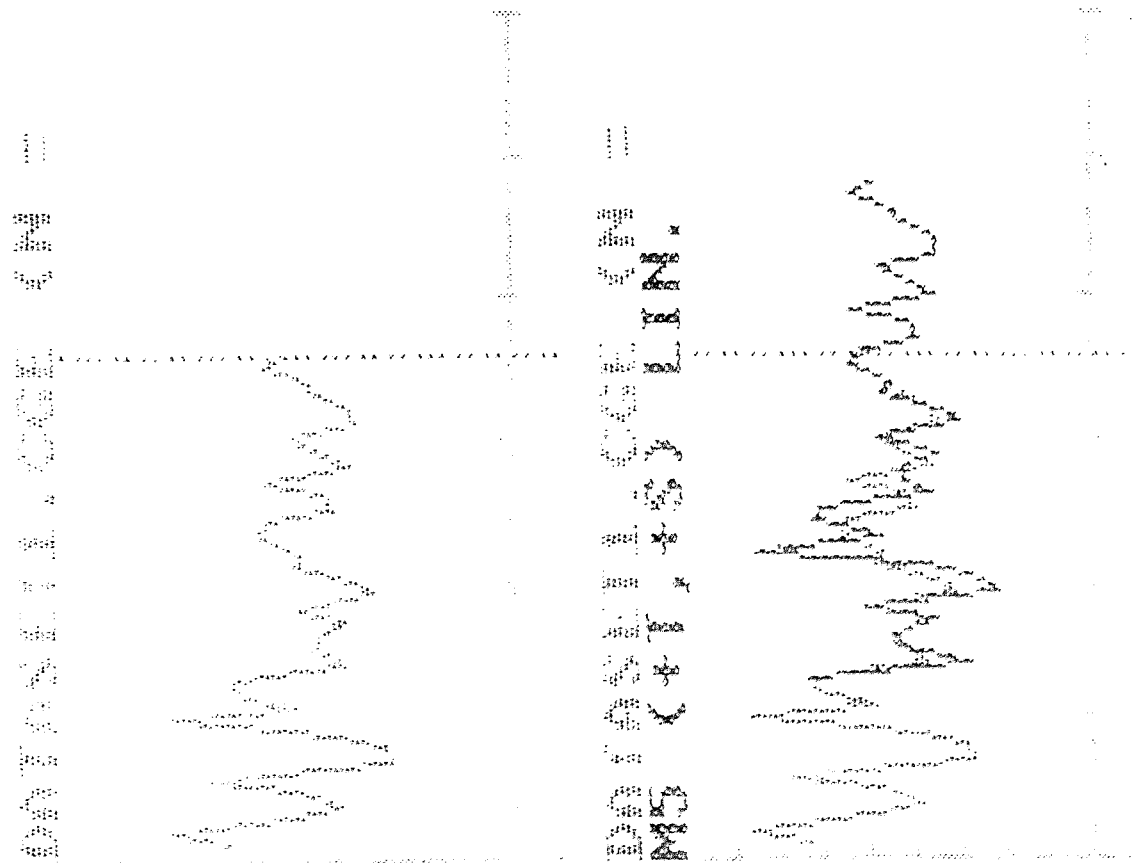
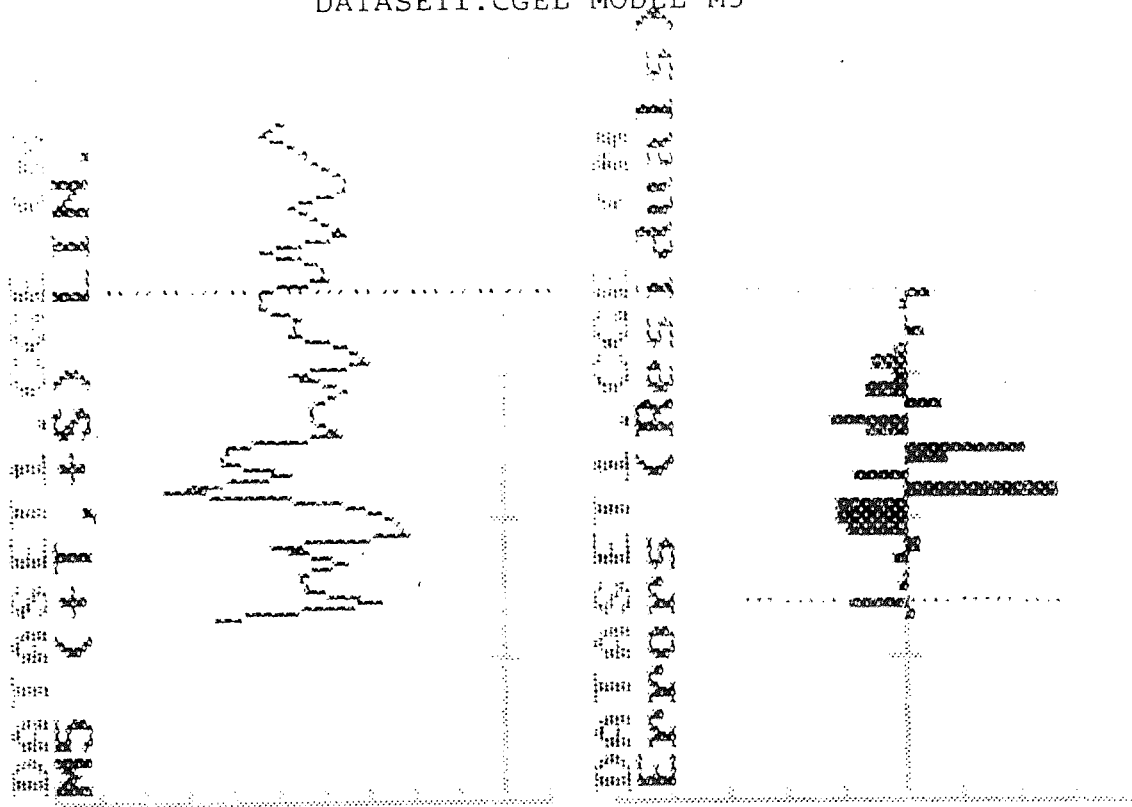
APPENDIX B
DATASET1.CGEL MODEL M2



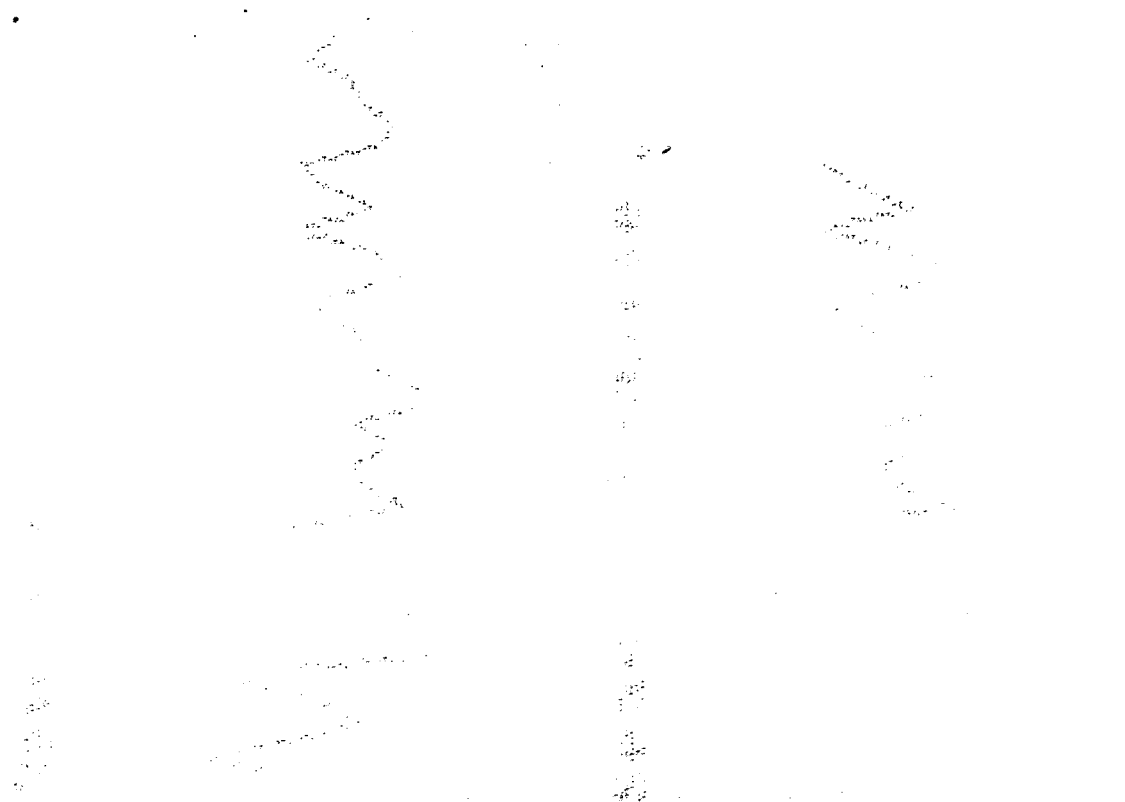
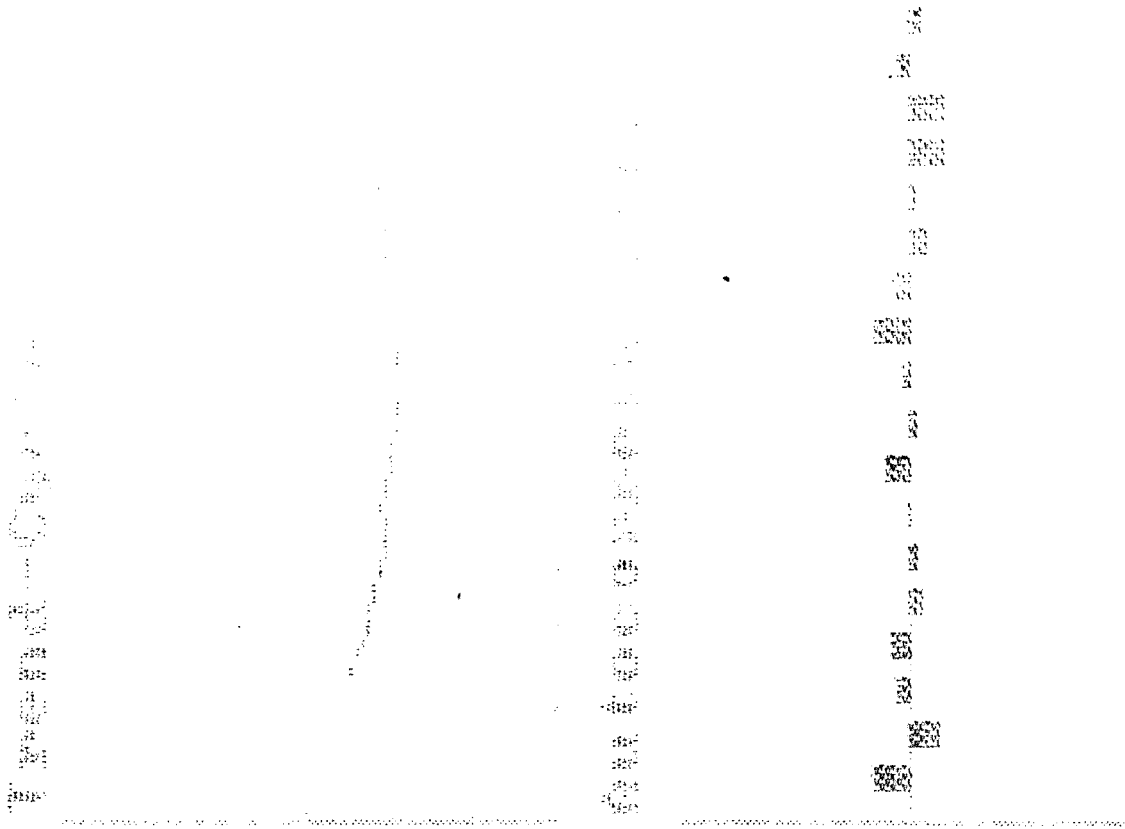
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DATASET1.CGEL MODEL M3



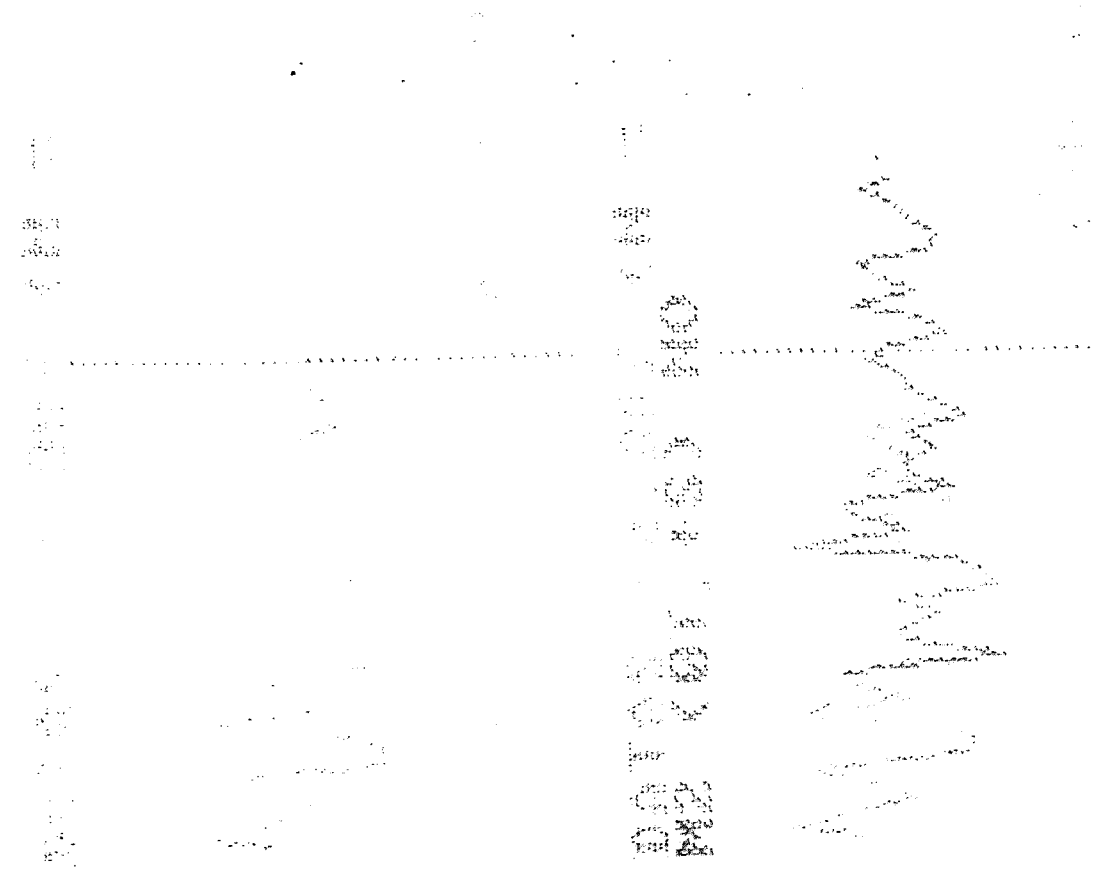
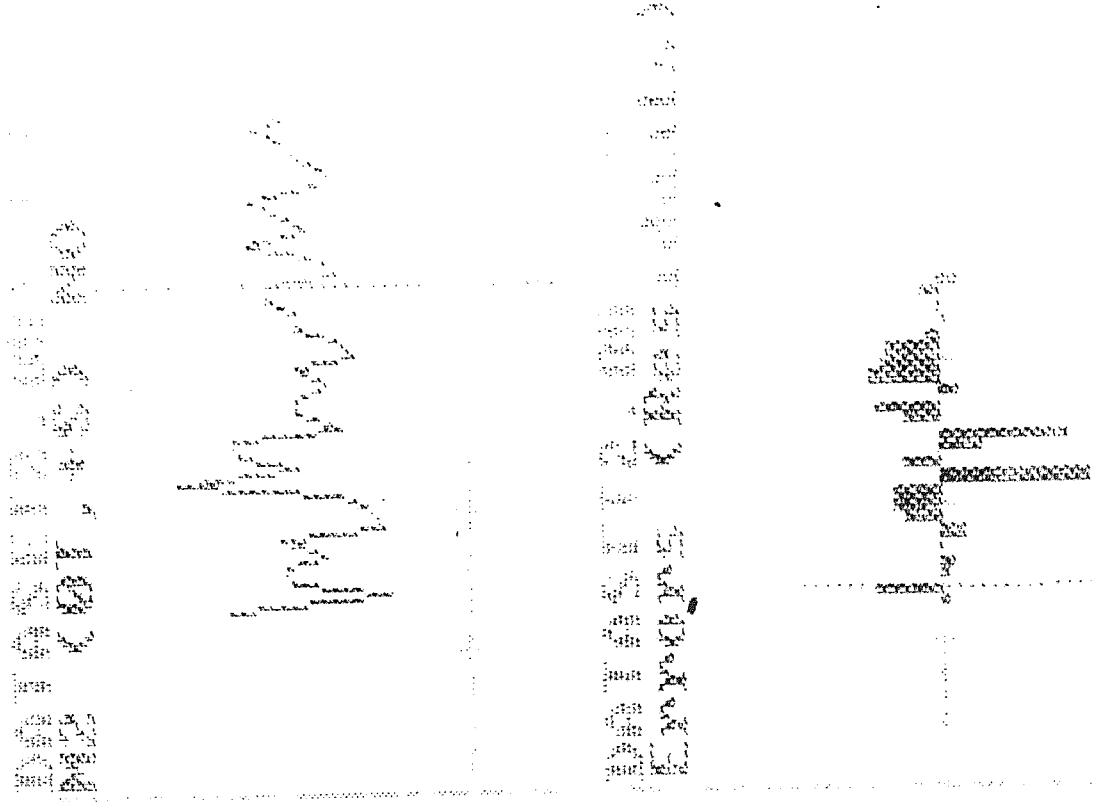
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DATASET1.CGEL MODEL M5



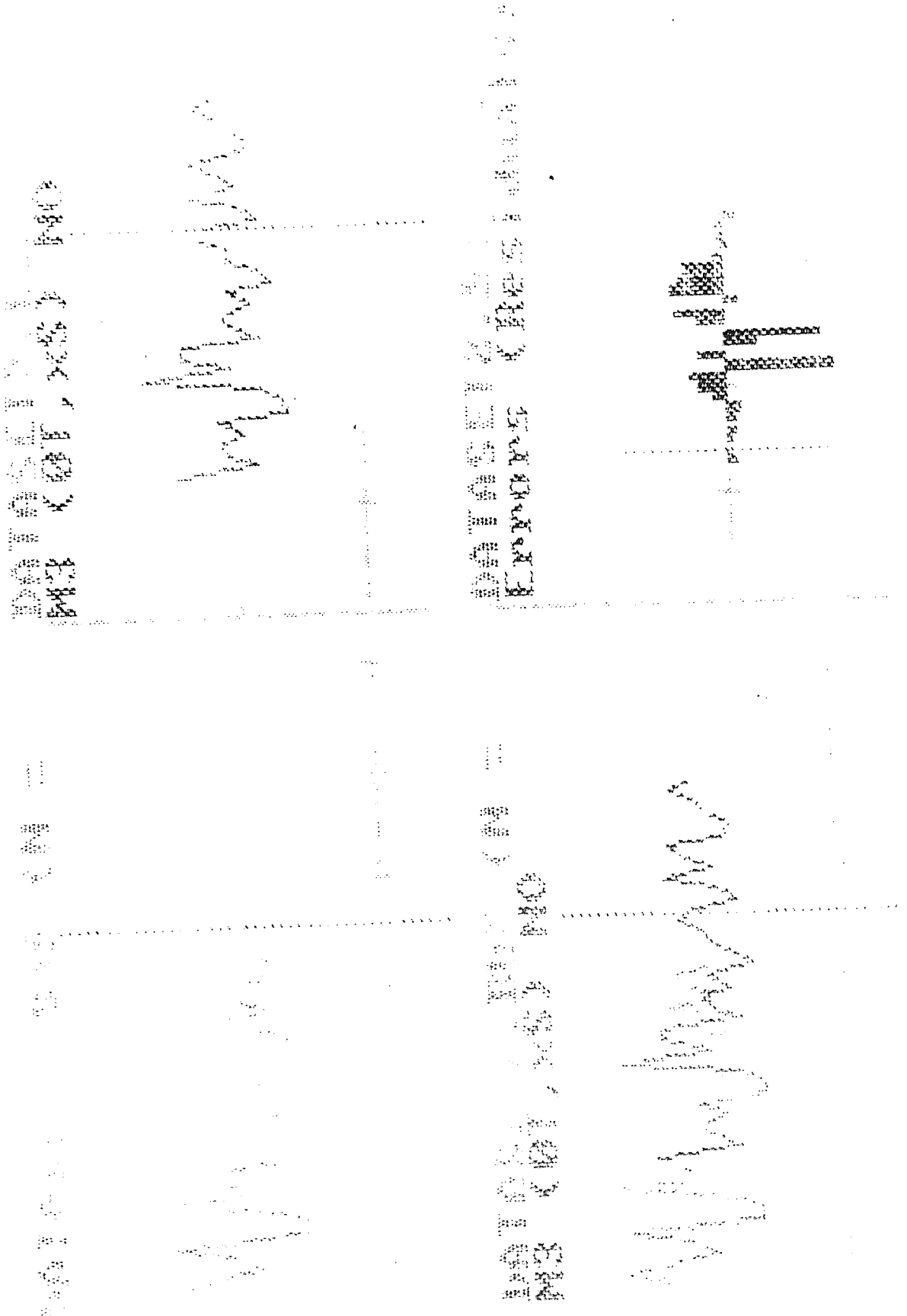
APPENDIX E
DATASET2.BUFF RAW DATA



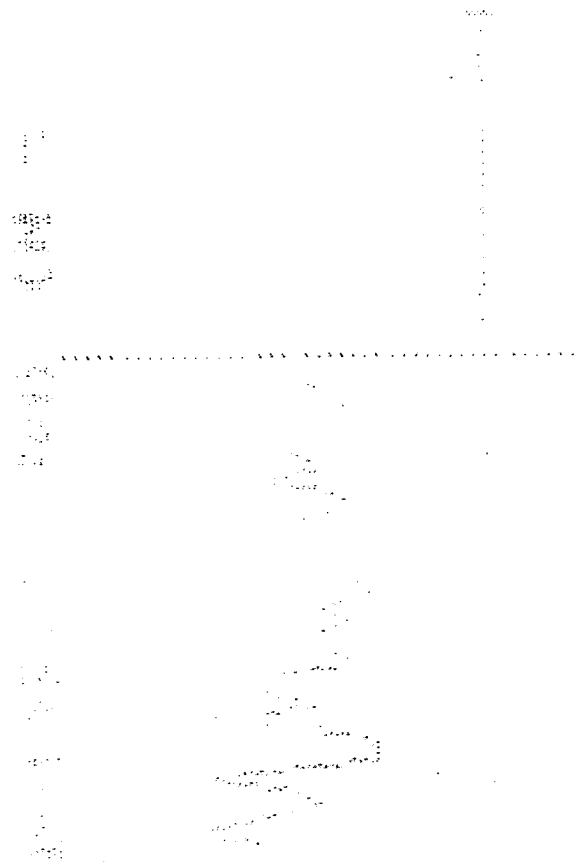
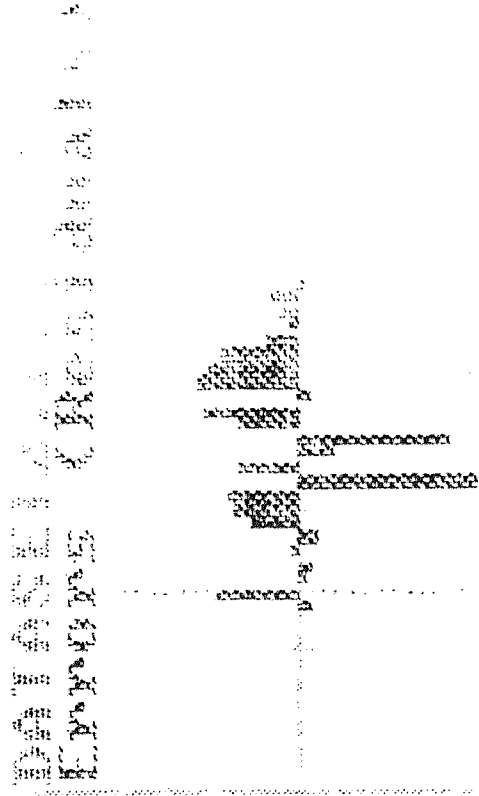
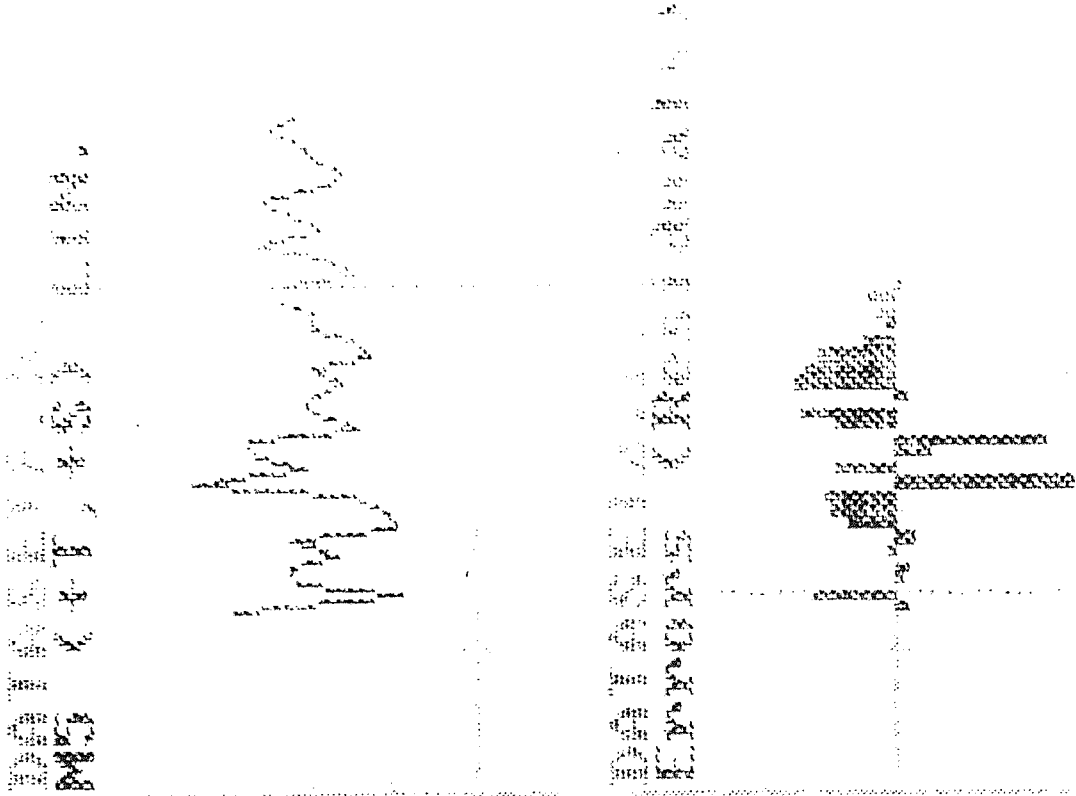
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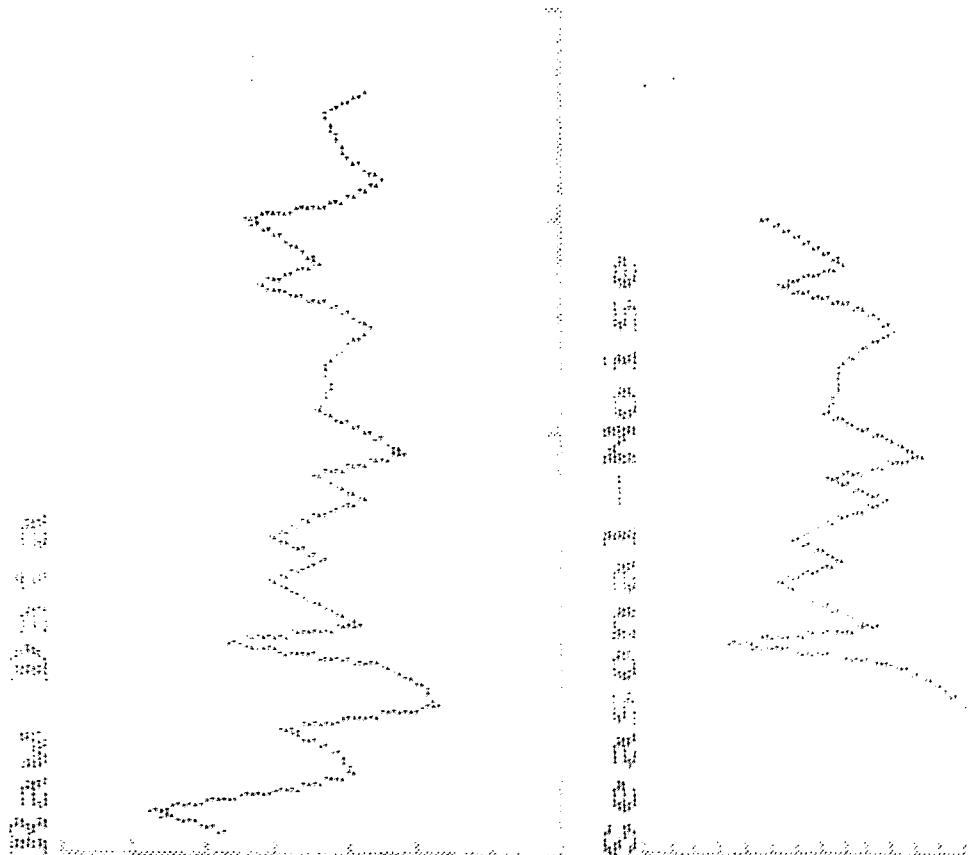
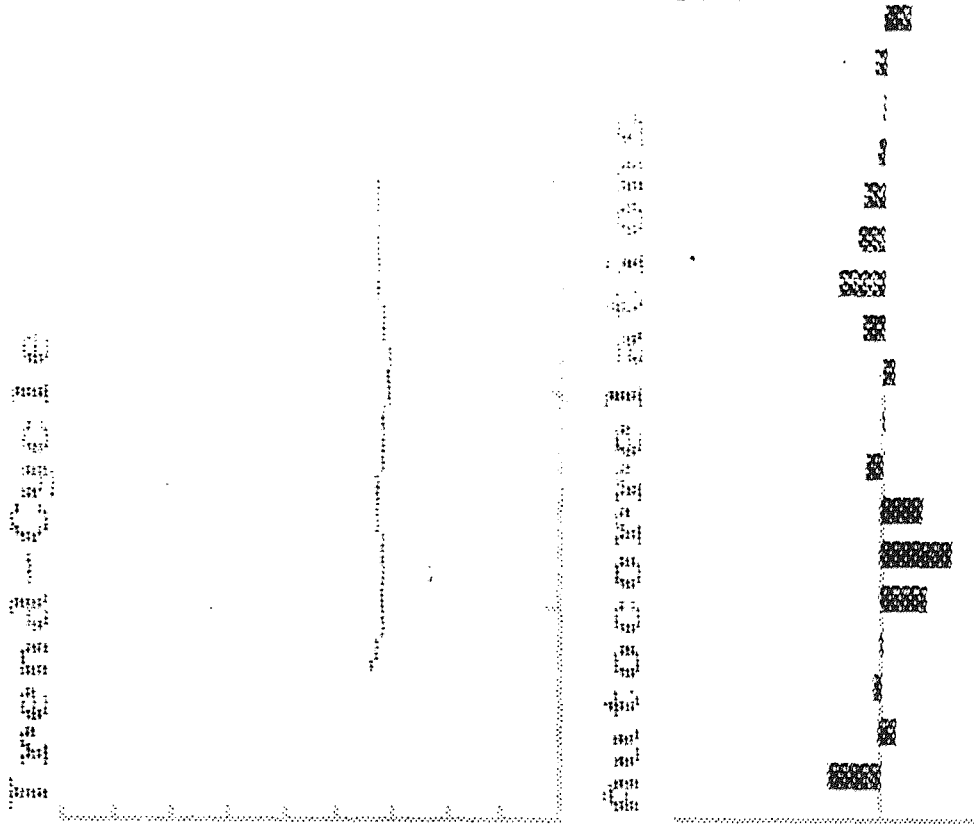
APPENDIX G
DATASET2.BUFF MODEL M3



APPENDIX H
DATASET2.BUFF MODEL M5



APPENDIX I
DATASET4.CBRM RAW DATA

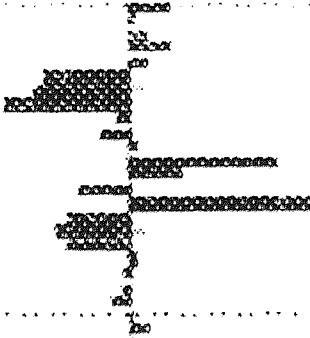


APPENDIX J
DATASET4.CBRM MODEL M2

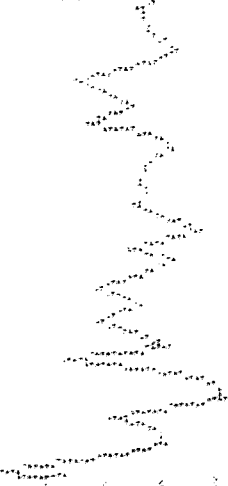
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COT, +\$3 NO



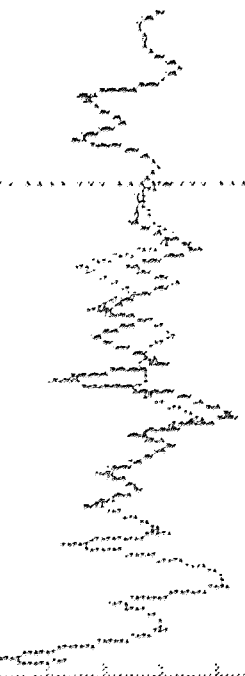
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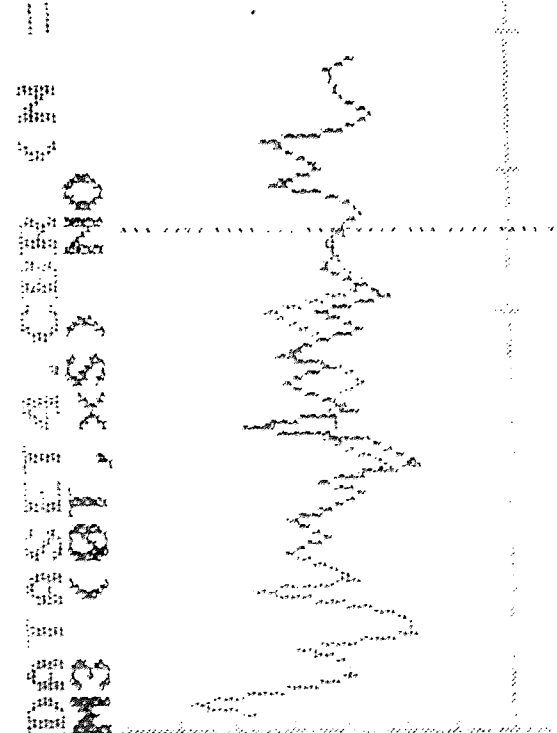
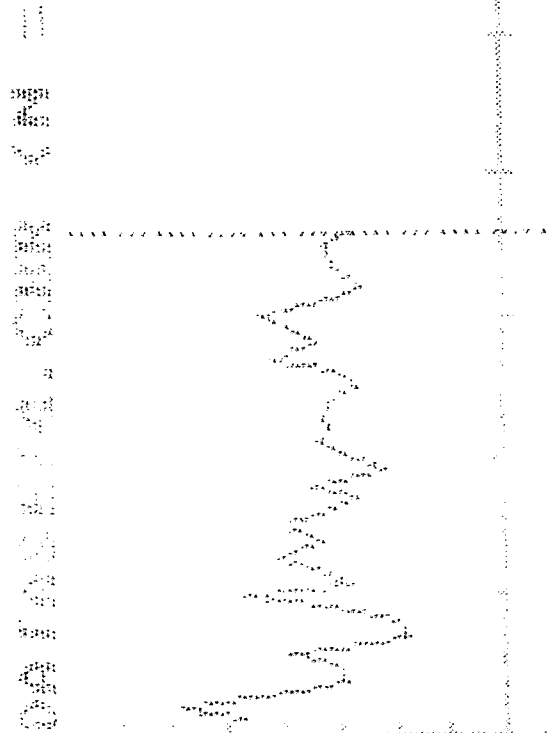
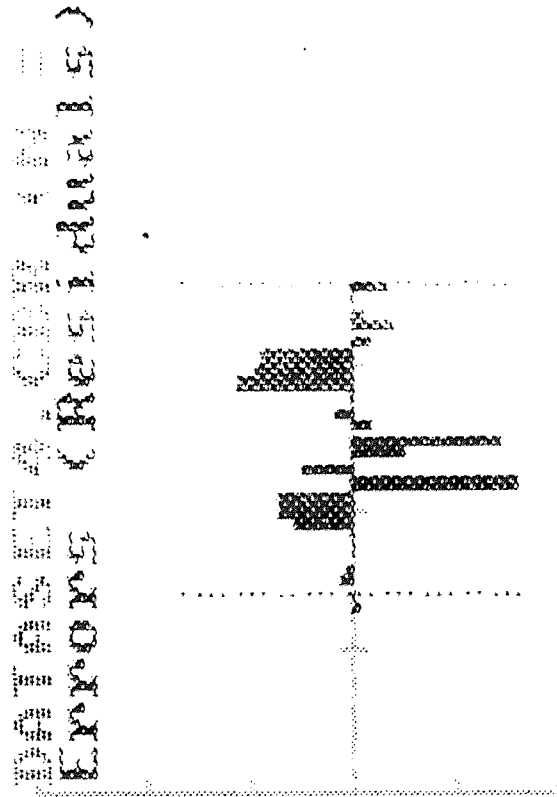
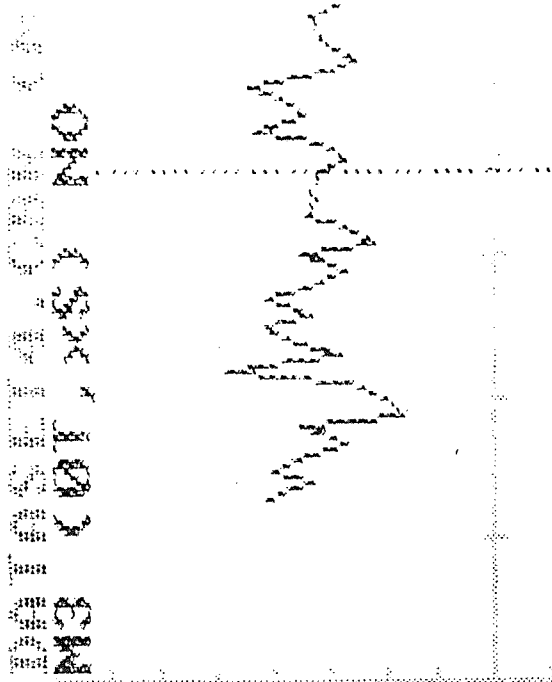
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COT, +\$3 NO



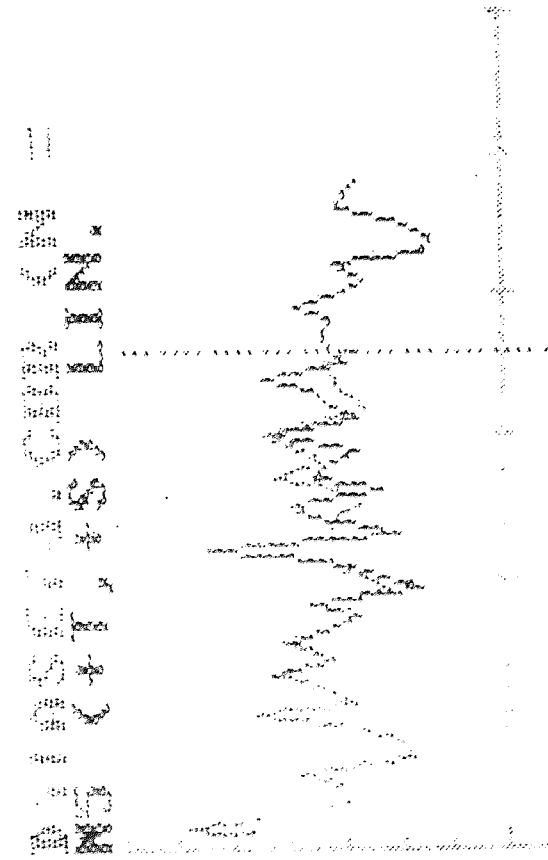
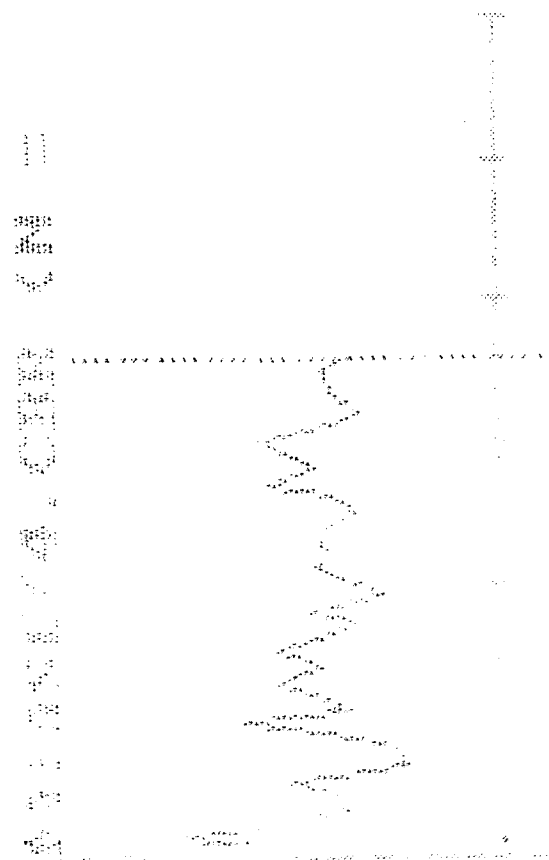
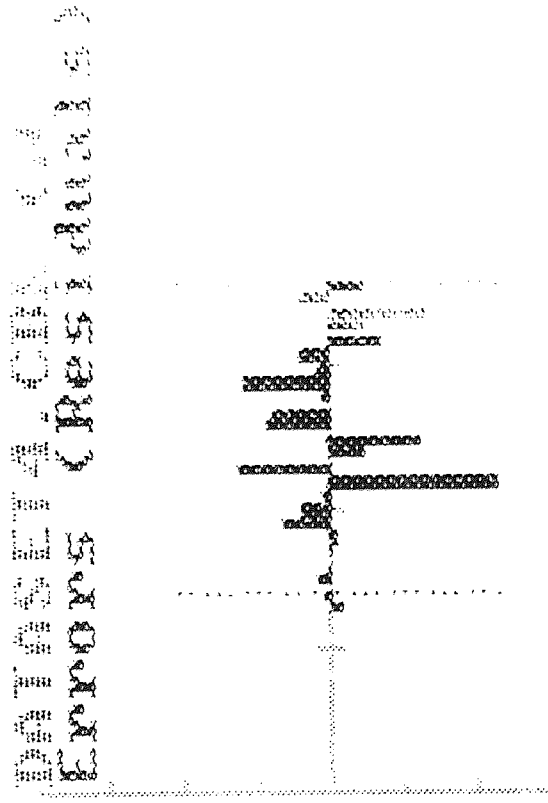
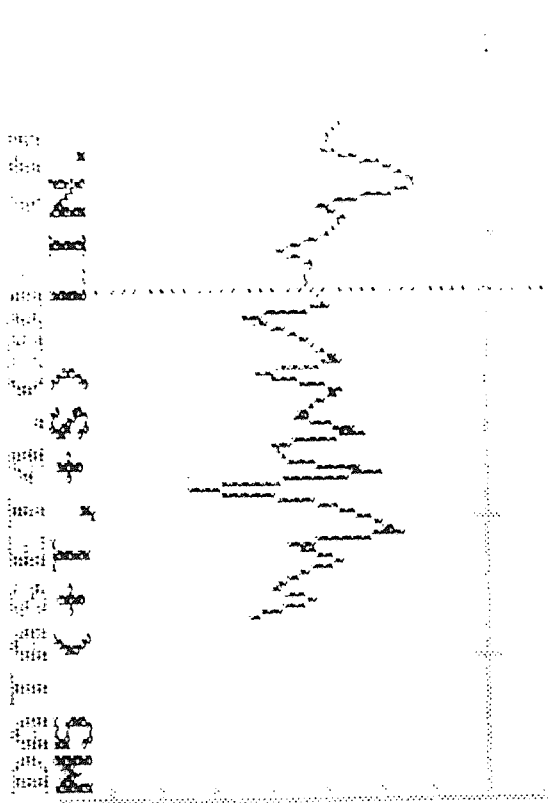
MEAN
COT, +\$3 NO



APPENDIX K
DATASET4.CBRM MODEL M3



APPENDIX L
DATASET4.CBRM MODEL M5



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