SPARE PARTS FORECAST IMPROVEMENT: A CASE STUDY OF A FORKLIFT COMPANY

By

WANRAWEE KAEWNGARM

A Final Report of the Six-Credit Course
SCM 2202 Graduate Project

Submitted in Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE IN SUPPLY CHAIN MANAGEMENT

Martin de Tours School of Management
Assumption University
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November 2010

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Master of Science in Supply Chain Management

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ABSTRACT

In today's highly competitive business situation, the ability to precisely forecast customer request is an important procedure to mange a product or service for desired growth. Forecasting is one of the vital steps of the planning process to discover the optimal stock for customer requests in order to decrease excess, take care of shortage of inventories and minimize the investment costs. The major purpose of this project is to propose the most suitable forecasting method that provides the least forecast errors and improves the forecast accuracy in order to plan the optimal stock management to satisfy customer requirements and also increase profitability for the firm. A forklift company is chosen to be a case study of this project.

Firstly, the analysis of company sales was used to identify which items should be focused. Top 3 items that generated one-third of total company sales, gear kit, torque kit and cylinder kit, were the main focus in this project. Then, the autocorrelation technique was utilized to examine the patterns of customer request data. The results of data pattern examination indicated that all customer request data were considered to have a stationary pattern. The forecasting techniques of moving average, simple exponential smoothing and multiple linear regression analysis were applied to investigate and predict the customer request. After that, the forecast error measurement methods, MAPE and tracking signal, were calculated to choose the most suitable forecasting method that provides the least forecast error for each item. The results presented that moving average and simple exponential smoothing were the most suitable forecasting methods as the highest percentage of forecast accuracy was demonstrated when compared to the current forecasting method. Finally, after applying these proposed forecasting methods, the total inventory cost and opportunity loss during 2008 and 2009 could save around 61 percent of costs compared to the current forecasting method.

ACKNOWLEDGEMENTS

I would like to take this opportunity to express my deepest appreciation to my advisor, Asst. Prof Dr. Nucharee Supatn, who offered valuable assistance and guidance while conducing of this project. Without her support and guidance, this project would have not be completed or written.

I would like to offer my sincere gratitude to members of the examination committee, Dr. Ismail Ali Siad, Asst. Prof. Brian Lawrence and A. Piyawan Puttibarncharoensri, who provided valuable comments and recommendations for completion of this project.

Besides, I would like to thank all of the lecturers in the Master of Science in Supply Chain who broadened my ideas in the supply chain field.

Lastly, I would like to thank my family who supported and provided me with all required information in order to complete this project. I owe them for all my achievements in my life.

Wanrawee Kaewngarm
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November, 2010

TABLE OF CONTENTS

Page

Committee's Approval Sheet ....

ABSTRACT ii

ACKNOWLEDGEMENTS iii

TABLE OF CONTENTS iv

LIST OF TABLES vi

LIST OF FIGURES viii

CHAPTER I: GENERALITIES OF THE STUDY

1.1 Background of the Study 1

1.2 Statement of the Problem 2

1.3 Research Objectives 4

1.4 Scope of the Research 4

1.5 Limitations of the Research 5

1.6 Significance of the Study 5

1.7 Definitions of Terms 5

CHAPTER II: REVIEW OF RELATED LITERATURE AND RESEARCH FRAMEWORKS

2.1 Importance and Role of Forecasting 7

2.2 Common Features of Forecasting 8

2.3 Types of Data Patterns 9

2.4 Exploring Data Patterns with Autocorrelation 11

2.5 Forecasting Techniques 14

2.5.1 Qualitative Methods 14

2.5.2 Quantitative Methods 15

2.5.2.1 Time Series Methods 16

2.5.2.2 Causal Methods 21

2.6 Measure of Forecast Error 22

2.7 Summary 24

CHAPTER III: RESEARCH METHODOLOGY

3.1 Item Identification 26

3.2 Data Collection 27

3.3 Examining Data Patterns with Autocorrelation 31

3.4 Formulation of Forecasting Technique and Error Measurement 37

3.5 Summary 39

CHAPTER IV: PRESENTATION AND CRITICAL DISCUSSION OF RESULTS

4.1 Forecasting Technique Results 40

4.1.1 Moving Average Model 40

4.1.2 Simple Exponential Smoothing Model 45

4.1.3 Multiple Linear Regression Model 49

4.2 Forecast Error Measurement Results 53

4.3 Forecast Evaluation Analysis 55

4.4 Performance Measurement Analysis 57

4.5 Summary 62

CHAPTER V: SUMMARY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions 63

5.2 Managerial Implication 64

5.3 Recommendations and Further Study 65

BIBLIOGRAPHY 66

LIST OF TABLES

TABLE **Page**

3.1 Calculation of Company Sales 26
3.2 Inventory and Customer Request of Gear Kit in 2007-2009 28
3.3 Inventory and Customer Request of Torque Kit in 2007-2009 29
3.4 Inventory and Customer Request of Cylinder Kit in 2007-2009 30
3.5 Calculation of Lag 1 Autocorrelation for Customer Request of Gear Kit 32
3.6 Autocorrelation for Customer Request of Gear Kit at 36 Periods 33
3.7 Autocorrelation for Customer Request of Torque Kit at 36 Periods. 35
3.8 Autocorrelation for Customer Request of Cylinder Kit at 36 Periods 36
3.9 A Guide for Selection of Forecasting Method 38
4.1 Forecast Value of Moving Average Model for Gear Kit 42
4.2 Forecast Value of Moving Average Model for Torque Kit 43
4.3 Forecast Value of Moving Average Model for Cylinder Kit 44
4.4 Forecast Value of Simple Exponential Smoothing Model for Gear Kit 46
4.5 Forecast Value of Simple Exponential Smoothing Model for Torque Kit 47
4.6 Forecast Value of Simple Exponential Smoothing Model for Cylinder Kit 48
4.7 General Factors Affecting Customer Request in 2007-2009 50
4.8 Analysis Results of Multiple Linear Regression for Gear Kit 51
4.9 Analysis Results of Multiple Linear Regression for Torque Kit 52
4.10 Analysis Results of Multiple Linear Regression for Cylinder Kit 52
4.11 Forecast Error Measurement of Moving Average Model 54
4.12 Forecast Error Measurement of Simple Exponential Smoothing Model 55
4.13 Comparison of Forecast Error among Proposed Forecasting Methods 56
4.14 Comparison of Forecast Accuracy Improvement between Current and Proposed Forecasting Methods 56
4.15 Opportunity Loss and Inventory Cost of Current and Proposed Forecasting Methods for Gear Kit 58
4.16 Opportunity Loss and Inventory Cost of Current and Proposed Forecasting Methods for Torque Kit 59

4.17 Opportunity Loss and Inventory Cost of Current and Proposed Forecasting Methods for Cylinder Kit 60
4.18 Comparison of Performance Measurement between Current and Proposed Forecasting Methods in 2008-2009 61

LIST OF FIGURES

FIGURES **Page**

1.1 Portfolio of Product Categories by Revenue 2
1.2 Inventory and Customer Request of Top 3 Items in Revenue 3
2.1 Stationary Data Pattern 9
2.2 Trend Data Pattern 10
2.3 Seasonal Data Pattern 10
2.4 Cyclical Data Pattern 11
2.5 Autocorrelation Function for Stationary Pattern.............................. 12
2.6 Autocorrelation Function for Trend Pattern 13
2.7 Autocorrelation Function for Seasonal Pattern 13
3.1 Forecasting Methodology of this Project 25
3.2 Autocorrelation Function for Customer Request of Gear Kit in 2007-2009 34
3.3 Autocorrelation Function for Customer Request of Torque Kit in 2007-2009 35
3.4 Autocorrelation Function for Customer Request of Cylinder Kit in 2007-2009 37

CHAPTER I

GENERALITIES OF THE STUDY

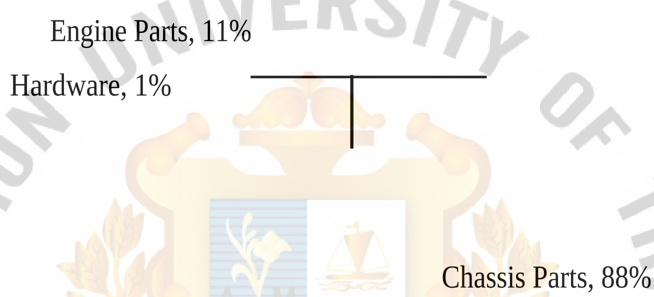
Forecasting is the estimate of the number of units that will be produced, stocked, or sold for the future demand. As all organizations are faced with future uncertainty, some errors between the forecast and actual demand can always happen (Hanke, Reitsch, & Wichern, 2001). Most of business owners would like to know about the future situations concerning their business operations so that the correct decision of forecasting must be made in order to minimize the deviation of those errors and smooth the supply chain process (Helms, Ettkin, & Chapman, 2000). Jain and Aggarwal (2009) stated that forecasting in the past relies on common sense or personal opinion rather than comprehensive information. Most companies predict the future situation with the systematic forecasting approaches.

Since decision-making and planning in today's highly competitive business situation are driven by the forecast results. The ability to accurately forecast customer demand is an important procedure to mange the product or service into the desired growth (Sanders, 1995). Additionally, the benefits of forecast accuracy are lower level of inventory, reduced stock-out, decreased inventory holding and investment costs, and improved customer satisfaction (Wisner, Tan, & Leong, 2008). Several current forecasting techniques both qualitative and quantitative methods have been developed in order to forecast in the different data patterns and forecast horizons. Hence, choosing a suitable forecasting method which provides the lowest forecast error is a very vital procedure for contributing to the firm's achievement.

1.1 Background of the Study

The studied firm in this project is named CY Company which is the pseudonym, located in Ramkamhaeng, Bangkok. This firm supplies mainly forklift spare parts and also provides repair services for clients. The company has operated and offered quality spare parts and services for more than 10 years. Nowadays, the company offers forklift spare parts of over 100 SKUs with high quality and reasonable prices to customers. Most of them are imported from Japan whereas the rest are imported from other countries including Thailand. For the service, the firm will send the professional mechanics to repair the forklifts at the customer's workplace. The mission of this firm is to provide the best quality with the purpose of becoming the most reliable choice for customers in forklift spare parts and repair services.

Figure **1.1:** Portfolio of Product Categories by Revenue



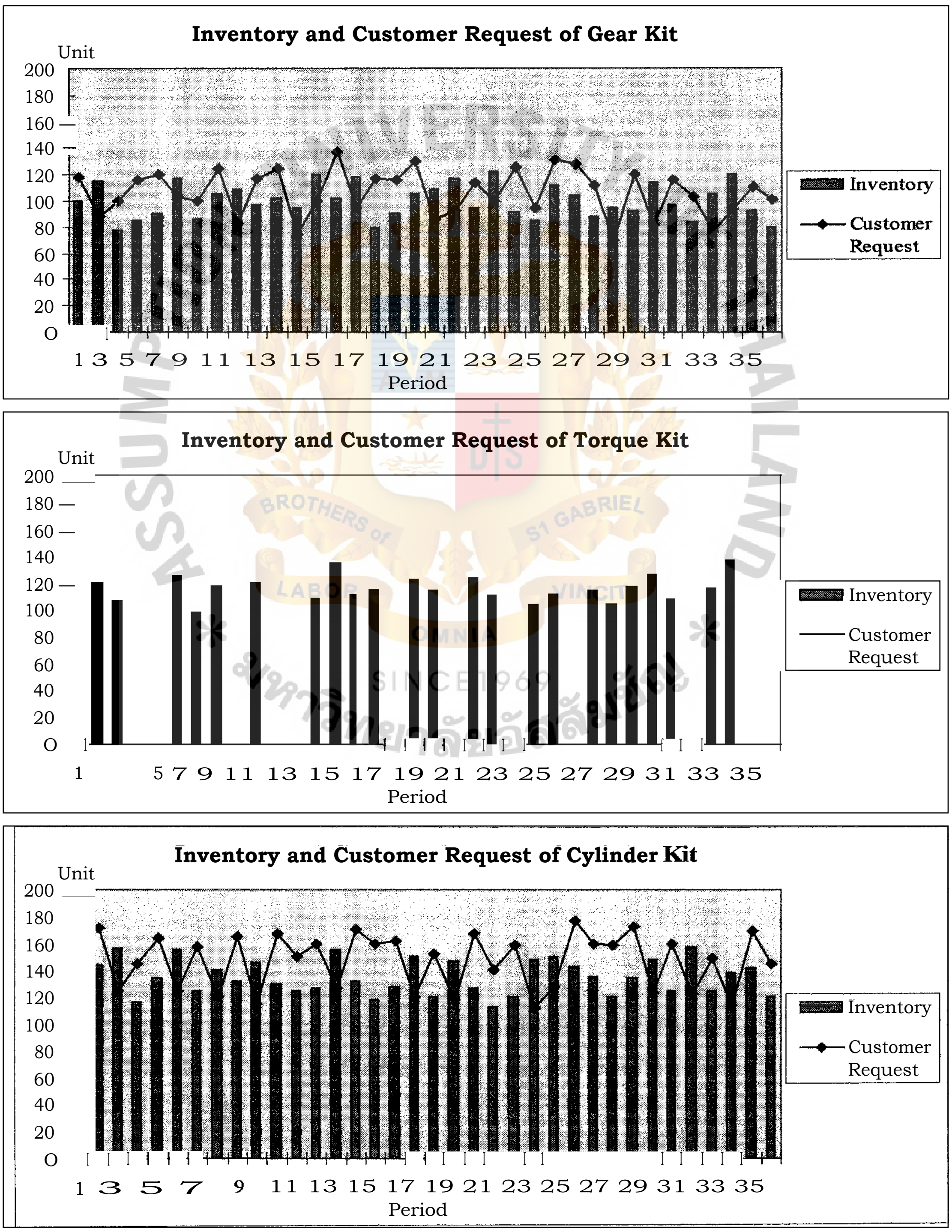
Source: Company Record

As demonstrated by portfolio of product categories in Figure 1.1, the firm divides forklift spare parts into three main categories. The majority of company revenue, 88 percent, comes from chassis parts such as gear kits, torque kits, cylinder kits and rollers. The other 11 percent is the category of engine parts such as pistons, rings and metal assys. The rest of the 1 percent provides the least company revenue and covers additional substances and devices such as lubrication, adhesives and sandpaper.

1.2 Statement of the Problem

The CY Company currently conducts forecast by using the expert judgment method. The experience of each sales manager is used for the prediction of future demand. Forecasting by this approach often causes an inaccurate estimate of mismatch between supply and demand. The forecast inaccuracy impacts either opportunity loss of sales owing to stock shortage or higher investment cost due to increased level of inventory. In case of service, the company cannot sometimes provide the repair service to the customer's forklifts as some forklift spare parts are stocked-out. The effects of inaccurate forecast not only lose revenue but also destroy the creditability of firm in the business. Thus, the competitors can take a chance to substitute for selling their similar products.

Figure 1.2: Inventory and Customer Request of Top 3 Items in Revenue



According to the inventory and customer request of top 3 items in Figure 1.2, it is noticeably seen that only during some periods, the inventory of top 3 items, gear kits, torque kits and cylinder kits, is higher than the customer request but the inventory is lower than the customer request most of the time. This causes the stock-out of the major spare parts over time which leads to customer dissatisfaction and loss of potential sales. Thus, the forecast accuracy should be focused. As a consequence, the question ***"What is the most suitable forecasting method which provides the lowest forecast error in order to plan the optimal stock management of the major forklift spare parts for the CY Company?"*** is raised.

1.3 Research Objectives

As this project aims to find the most appropriate forecasting technique that can predict less error-requests of the customers, the following are the objectives of this project.

1. To study the systematic forecasting techniques and the measures of forecast error.
2. To propose the most appropriate forecasting method for the firm that indicates the least forecast error in order to serve the customer request at the optimal stock.
3. To compare the current and proposed forecasting methods in order to explore the improvement of forecast accuracy.

1.4 Scope of the Research

This project focuses on the development of forecasting method for forklift spare parts in the short term horizon. The forecasting methods are examined and the forecast errors are detected by using Microsoft Excel and SPSS programs. The historical data on the inventory and customer request of top 3 items in revenue and general factors affecting customer request that are of the 36 months in 2007-2009 are used. The details of variation of inventory and customer request from promotion and new item introduction are not included in this project.

1.5 Limitations of the Research

Since the total data of inventory, customer request and general factors affecting customer request in 2010 are not available, the forecast results will be based on the 2007 to 2009 data only. Furthermore, the results of this project cannot be utilized with the similar demand patterns of other companies because of the different contexts across firms.

1.6 Significance of the Study

This project studies the forecast of forklift spare parts for the future request by exploring the data pattern based on historical data of the firm, and then examining the most appropriate forecasting method with the lowest forecast error. Forecasting is one of the vital steps of the planning process to discover the optimal stock for customer request in order to decrease excess, take care of shortage of inventories and minimize the investment cost. This project can be adapted to be a direction for forecasting the future demand in other companies.

1.7 Definitions of Terms

Autocorrelation is popular standard tool to explore data patterns before choosing forecasting techniques.

Customer request is the quantity of items requested by customers for the procurement.

Import value of forklift explains the expansion of forklift imports in Thailand.

Industrial confidence index is the economic indicator that shows the expansion of industrial investment and buying intention.

Industrial production index is the economic indicator that represents the expansion of real industrial production.

Inventory is the number of available forklift spare parts in the stock.

Mean absolute percentage error is the measure of forecast error calculated by averaging the sum of all absolute percentage errors.

Moving average is the forecasting method computed by averaging the specified set of the most recent observations to forecast the next period.

Multiple linear regression is the statistical procedure which estimates the relationship between the dependent variable and more than one independent variable.

Simple exponential smoothing is the forecasting method that uses the series of previous observations to forecast future observations of the same series

Stock Keeping Unit (SKU) is the numeric character that uniquely identifies each product.

Tracking signal monitors change by calculating the forecast errors and setting limits so that when the value of tracking signal goes outside these limits and the forecaster will be alerted.

CHAPTER H

REVIEW OF RELATED LITERATURE, AND RESEARCH FRAMWORK

This chapter begins with the literature review that discusses the importance and role of forecasting, followed by common features of forecasting. Then, types of data patterns and exploring data patterns with autocorrelation are discussed respectively. After that, two major forecasting techniques which consist of qualitative and quantitative methods are presented. Finally, the measure approaches of forecast error are described.

2.1 Importance and Role of Forecasting

Makridakis, Wheelwright, and Hyndman (1998) explained that forecasting is an essential constituent part of decision making procedure of business management. The organization can prepare its resources for events which will occur in the future because of the estimate by forecasting (Lines, 1996). The aim of business forecast is to decrease the uncertainty of the future based on the analysis of past and current circumstances. As each functional area is related to the entire organization, the decision of good or bad forecasting in each area can affect the future of an organization (Golden, Milewicz, & Herbig, 1994). Therefore, to run the business in a smooth manner, the forecasting of future situations with certain techniques is more valuable to the organization than uneducated guess. According to Montgomery, Johnson, and Gardiner (1990), business forecast is the significant aid in effective planning on the basis of inventory management, production, inventory, marketing and finance. The following are some examples of the decision by functional areas in which forecasting currently plays a vital role.

1. **Inventory management:** In controlling inventories, the forecast of the usage rate for each item has to be identified in terms of the quantity of the purchased items. Moreover, to set up the reordering points, the variability of forecast error should also be calculated (Montgomery et al., 1990).
2. **Production planning:** The forecast of demand for each item by delivery period for the number of months in the future is required to plan the production line. This forecast is then translated into the forecast of requirement for resources and raw materials so that the entire production system can be scheduled (Heizer & Render, 1991).
3. **Marketing planning:** Marketing strategies can be planned owing to the availability of reliable demand by forecasting (Bowerman, O'Connell, & Koehler, 2005). Moreover, the forecast of sales volume should be made for the tactical price-setting (Shearer, 1994).
4. **Financial planning:** New capital acquisitions can be planned and financed if the interest rates are forecasted. Furthermore, the forecast of receipts and expenditures is also required to predict cash flows and maintain the liquidity of firm (Montgomery et al., 1990).

2.2 Common Features of Forecasting

Chopra and Meindl (2001) discovered that even though each forecasting technique is obviously quite different, there are the common features of forecasting that underlie them all.

1. Forecasting is very rarely perfect and should include both the expected observation and the measure of forecast error. The analysis of the forecast error should be one of the major components for supply chain decision making.
2. Long-term forecasting is frequently less correct than short-term forecasting. This is because long-term forecasting tends to have the greater standard deviation of error than short-term forecasting.

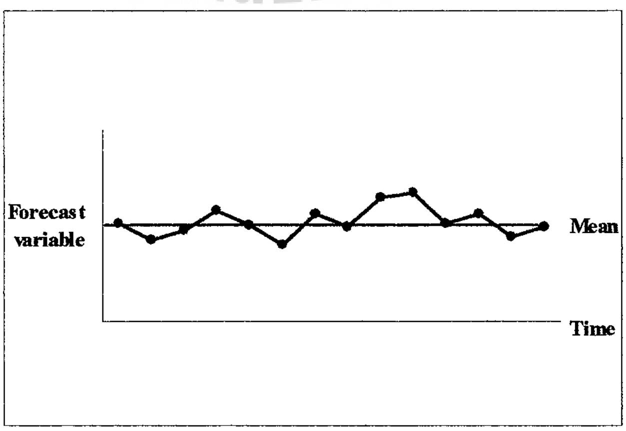
3. Aggregate forecasting of total demand is generally more accurate than disaggregate forecasting of specific product demand for specific customers since the standard deviation of error of aggregate forecasting tends to be smaller than that of disaggregate forecasting (Smith, Herbig, Milewicz, & Golden, 1996). Furthermore, the reason of greater error on the disaggregate forecasting is that the optimism or pessimism of the forecaster is easily built into each product forecast for specific customers (Holmstrom, 1998).

2.3 Types of Data Patterns

One of the significant steps in choosing the suitable forecasting method is to consider the types of data patterns. Therefore, the most appropriate approach to these patterns can be used in forecasting. According to Makridakis and Wheelwright' findings (1989), common types of time series data pattern are stationary, trend, seasonal and cyclical.

1. **Stationary:** The stationary data pattern in the time series is the data values that fluctuate around a consistent mean as illustrated in Figure 2.1. The data is also considered to have the stationary pattern when there is neither a positive nor a negative trend (Wilson & Keating, 2002).

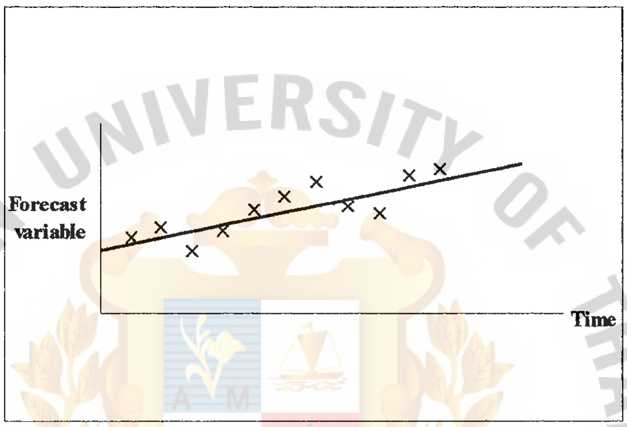
Figure 2.1: Stationary Data Pattern



Source: Makridakis & Wheelwright (1989)

2. **Trend:** The trend data pattern in the time series is the long-term change that indicates the increase or decrease in the data as represented in Figure 2.2. If the data moves upward over an extended time period, there is the positive trend in the data. In the contrast, if the level of data moves downward over time, the data will represent the negative trend (Wilson & Keating, 2002).

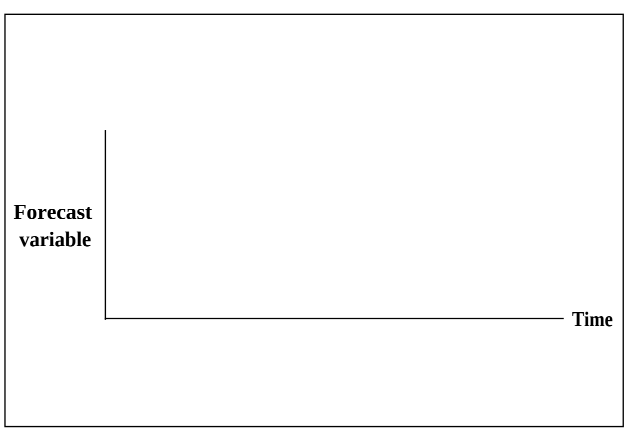
Figure 2.2: Trend Data Pattern



Source: Makridakis & Wheelwright (1989)

3. **Seasonal:** The seasonal data pattern in the time series is the pattern of change that completes itself within a calendar year and is then repeated on a yearly basis as shown in Figure 2.3. Thus, the seasonal data pattern may be the months or the four quarters of the year (Hanke et al., 2001).

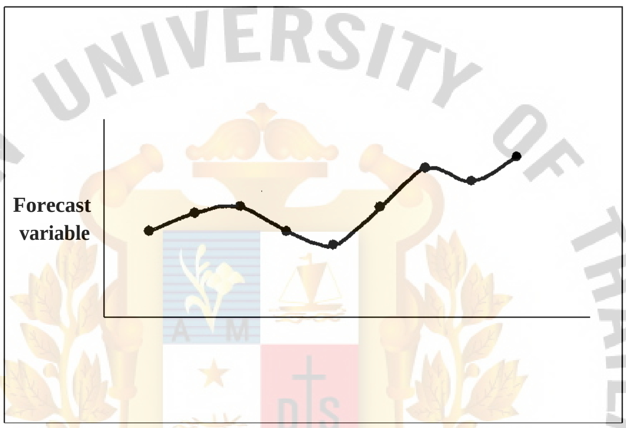
Figure 2.3: Seasonal Data Pattern



Source: Makridakis & Wheelwright (1989)

4. Cyclical: The cyclical data pattern in the time series is exhibited by upward and downward movements of the long-term trend data that are not of a fixed period as illustrated in Figure 2.4. The cyclical data pattern is similar to the seasonal pattern, but the key distinctions between these two patterns are that the average length of a single cycle is generally longer than one year and less regular than seasonal patterns (Makridakis & Wheelwright, 1989).

Figure 2.4: Cyclical Data Pattern



Source: Makridakis & Wheelwright (1989)

2.4 Exploring Data Patterns with Autocorrelation

Makridakis et al. (1998) stated that the autocorrelation is the popular standard tool in the measure of correlation between successive observations over time in order to explore the data patterns. The component of autocorrelation at various lags is called the autocorrelation function or ACF. The ACF graph is helpful for checking the time series data patterns before forecasting. This tool will consider whether the autocorrelation is significantly large by calculating the critical values of 2 where n is the amount of periods, and then representing in the upper and lower limits. The autocorrelation technique can be computed by Equation 2.1 (Hanke et al., 2001).

$$\overset{..}{}_{k} \qquad \frac{\sum_{t=k+1} \; _t - \quad - \;)}{ - \bar{Y})^2 \quad \sum_{t=1}} \qquad \text{Equation 2.1}$$

where

r_k - Autocorrelation value for a lag of k periods

Y Mean value of the series

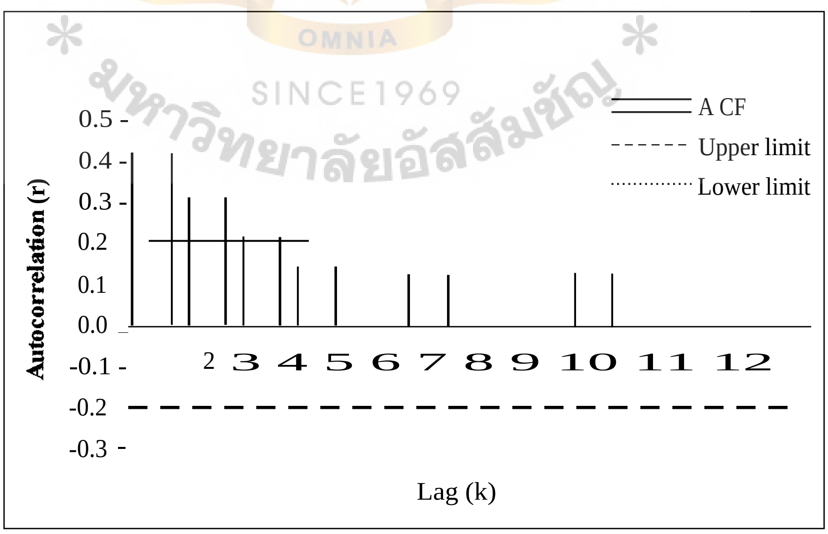
\- Value of the series at period t

\- Value of the series at period t-k

As discovered by Wilson and Keating (2002), the following are some examples of data patterns examined by autocorrelation function.

1. **Stationary pattern:** The value of r_k will lessen quickly toward zero when the amount of periods increases as shown in Figure 2.5 (Yaffee & McGee, 2000).

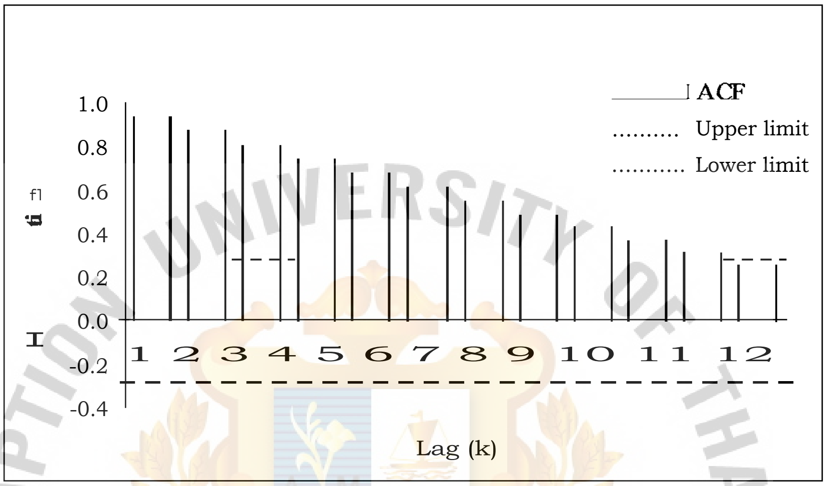
Figure 2.5: Autocorrelation Function for Stationary Pattern



Source: Wilson & Keating (2002)

2. **Trend pattern:** The value of r_k will differ from zero for the first several lags and then slowly decline toward zero when the amount of periods increases as represented in Figure 2.6.

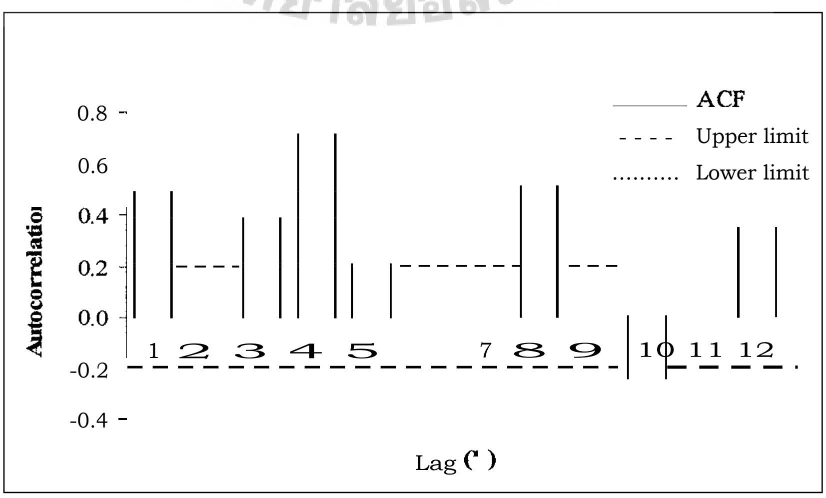
Figure 2.6: Autocorrelation Function for Trend Pattern



Source: Wilson & Keating (2002)

3. **Seasonal pattern:** The value of r_k will differ from zero at which the seasonal time lag is 4 for quarterly data and 12 for monthly data as illustrated in Figure 2.7.

Figure 2.7: Autocorrelation Function for Seasonal Pattern



Source: Wilson & Keating (2002)

2.5 Forecasting Techniques

Forecasting techniques can be categorized into two major groups which consist of qualitative and quantitative methods (Wisner et al., 2008). Each group is obviously different in the terms of the amount of observations, the required data patterns, the forecast horizon and the logic basis of forecasting.

2.5.1 Qualitative Methods

Shim (2000) stated that the qualitative or judgmental forecasting methods involve subjective estimation via the opinions of experts. Qualitative methods are often required when historical data are not available at all. Hence, the required data is primarily accumulated knowledge and judgment from specially trained people. There are four better known methods of qualitative forecasting which are sales force composites, customer surveys, jury of executive opinion, and Delphi method.

1. **Sales Force Composites**

   The sales force can be a better source of data for forecasting future trends due to the closeness of the salespeople to the customers. Salespeople have continual contact with customers and are the closest contact that most companies have with their customers. Generally, salespeople who contact the limited amount of prospects are better sources of forecasting than those who contact an extensive number because salespeople of the fist group spend more time with each prospect than that of the second group (Gross & Peterson, 1983). Consequently, the required information is the estimates of salespeople regarding the current and expected future sales. If the available data from the sales force are gathered in an objective procedure, significant insight into the future sales volumes can be attained.

2. **Customer Surveys**

   Forecasting based on surveys of buying intentions requires no historical data. Therefore, the companies can conduct customer surveys through several ways such as telephone contact, personal interviews or even questionnaires. Survey data is concerned with how buyers plan their purchases and follow their plans. Survey results are frequently applied by statistical analysis in order to help predict certain consumer behaviors. This customer survey method should not be considered if there is a sense of urgency in getting the forecast because this method is appropriate for medium- to long-term forecasting (Wilson & Keating, 2002).

3. **Jury of Executive Opinion**

   Jury of executive opinion is the combination of the opinions of executives and managers who are most likely to have the best insights about the firm's business in order to predict the future sales. Based on years of experience within the industry or within one that is similar, the judgments of experts can provide useful forecasting data. The forecast data do not require a formal set, but they require only the experiences that have developed to make judgments of the forecast variable during the interesting period (Wilson & Keating, 2002).

4. **Delphi Method**

   The Delphi method is the approach that experts participate into produce predictions concerning specific questions. Each participant is individually asked to provide a sequence of forecast through the response to questionnaires, and then return the completed questionnaires to a panel coordinator. After the first questionnaire has been completed and sent, the second questionnaire is filled out concerning the opinions of the group as a whole. Therefore, the Delphi method requires no historical data and, sometimes, this method is helpful for the sales forecast of new products (Bowerman et al., 2005).

2.5.2 Quantitative Methods

As found by Waddell and Sohal (1994), quantitative methods are the examination of historical data based on statistical analysis in order to forecast the future events. Each method is stated by different logic and also requires the different historical data patterns. Quantitative methods are divided into two main groups, time series methods and causal methods (Aiken & West, 1991). The difference between the time series and causal methods is given below.

2.5.2.1 Time Series Methods

According to Chatfield's findings (2003), the analysis of time series methods requires the historical values of the variable being forecasted to predict the future values. The assumption of these methods is what occurs in the future is the function of what has occurred in the past (Render, Stair, & Hanna, 2006). Thus, time series methods are helpful in forecasting when conditions of management are expected to remain the same. There are the common methods of time series forecasting as follow.

1. Moving Average

Moving average is obtained by calculating the mean for a specified set of observations in order to forecast the next period. The amount of past observations must equal to the amount of terms in the moving average. The amount of data points in each average does not change as time continues and includes the most recent observation. The moving average forecasting is appropriate when the data is stationary and does not handle trends or seasonality. The moving average model can be computed by Equation 2.2 (Hanke et al., 2001).

$$\frac{(Y_t + Y_{t-1} + Y_{t-2} + \ldots + Y_{t-k+1})}{k} \qquad \text{Equation 2.2}$$

where

$\hat{Y}_{t+1}$	Forecast value of the series for next period
Y_t	Actual value of the series at period *t*
k	Number of terms used in the moving average

2. **Simple Exponential Smoothing**

Simple exponential smoothing requires the series of historical observations to predict the future observations of the same series, and is appropriate when there is no predictable upward or downward trend or seasonality in the information. The smoothing constant or a is assigned as the weighting factor that is the key component in the analysis. As the value of a in exponential smoothing form is between zero and one, when a is a small value, the new forecast will be similar to previous forecast. On the other hand, when a is a large value, the new forecast will adjust some error that occurred in the previous forecast. The simple exponential smoothing model can be computed by Equation 2.3 (Hanke et al., 2001).

$$\hat{Y}_{t+1} = \alpha Y_t + (1 - \alpha)\hat{Y}_t \qquad \text{Equation 2.3}$$

where

		Forecast value of the series for next period
a	=	Smoothing parameter of the data ($0 < a < 1$)
Y_t	=	Actual value of the series at period t
		Forecast value of the series for period t

3. **Exponential Smoothing Adjusted for Trend: Holt's Method**

Holt's method can be utilized efficiently when the data represents positive or negative trends. Consequently, when upward or downward movements in the time series data exist, the estimates of the current slope and level are required by using different smoothing constants for each. Holt's method of forecasting discovers using two smoothing constants, a and β, with the values between 0 and 1, and extends single exponential smoothing to linear exponential smoothing in order to allow trend data forecasting. Two additional extensions of the smoothing model are used in order to bring the forecast values closer to the observed values. This method is suitable for short-and medium-term forecasting. The three equations used in Holt's model can be computed by Equation 2.4 (Hanke et al., 2001).

The exponentially smoothed series:

$$- \qquad \alpha Y_t + (1 - \alpha)(L_{t-1} +$$

The trend estimate:

$$\beta(L_t - L_{t-1}) \qquad \beta)T_{t-1}$$

Holt's forecast value for *p* periods into the future:

$$\hat{Y}_{t+p} \qquad L, + pT, \qquad \text{Equation 2.4}$$

where

L_t - Smoothed value of the series at period *t*

α - Smoothing parameter of the data (0 < a < 1)

Y_t - Actual value of the series at period *t*

β - Smoothing parameter of trend estimate ($0 < \beta < 1$)

T_t - Smoothed value of trend estimate at period *t*

p - Number of time periods used in the future forecast

$\hat{Y}_{t+p}$ - Holt's forecast value of the series for *p* periods

4. Exponential Smoothing Adjusted for Trends and Seasonality: Winter's Method

Winter's method can use when the data represents the trend and seasonality. Winter's model extends Holt's model by including the seasonality in the data. Therefore, this method includes three linear exponential smoothing models as similar as Holt's model and one further equation of a seasonal component. Winter's method is suitable for short-to medium-term forecasting and requires the minimum of 4 or 5 observations per season or 16 or 20 observations for quarterly data in forecasting. The four equations used in Winter's model can be computed by Equation 2.5 (Hanke et al., 2001).

The exponentially smoothed series:

$$L_t = a \quad {}^{t}_{t} + (1-\alpha)(L_{t-1} +$$

The trend estimate:

$$T_t = fig\ t \quad Lt\text{-}i) + \quad f^{6})Tt\text{--}1$$

The seasonality estimate:

$$S_t \quad \frac{}{L_t} + (1-\gamma)S_{t-s}$$

Winter's forecast value for p periods into the future:

$$\hat{Y}_{t+p} = (L1 + pT_t)S_{t-s+p} \qquad \text{Equation 2.5}$$

where

L_t	=	Smoothed value of the series at period t
α	=	Smoothing parameter of the level ($0 < \alpha \leq 1$)
Y_t	=	Actual value of the series at period t
β	=	Smoothing parameter of trend estimate (0 <fl < 1)
T_t	=	Smoothed value of trend estimate at period t
	-	Smoothing parameter of seasonality estimate (0 <y < 1)
S_t	=	Smoothed value of seasonality estimate at period t
	•	Number of time periods used in the future forecast
	-	Length of seasonal cycle
		Winter's forecast value of the series for p periods

5. Time Series Decomposition

Hanke et al. (2001) explained that time series decomposition involves the identification of component factors separately, and each component is then combined to forecast the future values. There are two simplest models relating the observed time series value *(Y_e)* to the trend (T_1), cyclical (C_r), seasonal *(S_1)*, and irregular (I_t) components, the multiplicative component model and the additive component model. The multiplicative component model is appropriate when the level of time series increases or decreases because of the fluctuation of seasonal component. Conversely, the additive component model is appropriate when the time series being analyzed do not vary throughout the length of the series. Both multiplicative and additive component models used in time series decomposition can be computed by Equation 2.6 (Cranage, 2003).

Multiplicative Component Model

$$= T_t \times C_t \times S_t \times I_t \qquad \text{Equation 2.6}$$

Additive Component Model

$$Y_t = T_t + C_t + S_t + I_t$$

where

		Forecast value of the series for period *t*
T_1	=	Value of long-term trend component at period *t*
C_t	=	Value of cyclical component at period *t*
S_t	=	Value of seasonal component at period *t*
		Value of irregular component at period *t*

2.5.2.2 Causal Methods

Causal methods are statistical tools that describe the relationship between the time series of variable to be forecasted and one or more other time series of independent variables. The objective of these methods is to discover the form of the relationship and use the values of independent variables to forecast the future values of dependent variable (Makridakis et al., 1998). If other variables are correlated with the variable of interest to be predicted, causal forecasting methods are appropriate to exhibit this relationship. There are two normal methods of causal forecasting, simple linear regression and multiple linear regression as follow (Bowerman et al., 2005).

1. **Simple Linear Regression**

   Simple linear regression is the method that estimates the statistical relationship between the dependent variable and the single independent variable. The dependent variable is the variable that is required to forecast the future. Forecasting by using simple linear regression is appropriate when there is one predictor variable involved. The simple linear regression model can be computed by Equation 2.7 (Bowerman et al., 2005).

$$Y = \beta_0 + \beta_1 X \qquad \text{Equation 2.7}$$

where

	Value of dependent variable
X	Value of single independent variable
β_0	Intercept of the regression line (value of Y when $X = 0$)
	Slope of the regression line associated with the single independent variable

2. **Multiple Linear Regression**

   Frank, Garg, Raheja, and Sztandera (2003) indicated that multiple linear regression is the statistical procedure which reflects the relationship between the dependent variable and more than one independent variable. Forecasting by multiple linear regression is appropriate when there are several predictor variables involved. Hence, the statistical analysis of this method is complicated. The multiple linear regression model can be computed by Equation 2.8 (Bowerman et al., 2005).

$$= \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_k X_k \qquad \text{Equation 2.8}$$

where

		Value of dependent variable
X_i	=	Value of respective independent variables
β_0	=	Intercept of the regression line (value of Y when $X = 0$)
		Slope terms of the regression line associated with the respective independent variables

2.6 Measure of Forecast Error

The measure of errors between forecast and observed values is used to assess the efficiency of forecast. The forecast error may occur from the external or internal sources or choosing the inappropriate forecasting method (Wacker & Lummus, 2002). Therefore, the decision to choose the proper forecasting technique involves whether that method will produce a relatively small forecast error. There are general measures for forecasting errors like mean absolute deviation, mean squared error, mean absolute percentage error and tracking signal (Hanke et al., 2001). Those are given below:

1. Mean Absolute Deviation

The mean absolute deviation (MAD) is the technique that evaluates the forecast error by averaging the summation of each absolute error. This approach is helpful when the firm requires the measure of forecast accuracy in the same units. The measurement model of MAD can be computed by Equation 2.9 (Hanke et al., 2001).

$$MAD = \quad n \;\; {}_{t=1} \left| Y_t \qquad \right| \qquad \text{Equation 2.9}$$

where

Actual value of the series at period *t*

Forecast value of the series for period *t*

n Number of time periods used in the computation

2. Mean Squared Error

The mean squared error (MSE) is the approach that measures the forecast error by computing the summation of each squared error and then dividing it by the amount of periods. This technique provides large forecast errors as the errors are squared before being summed. The measurement model of MSE can be computed by Equation 2.10 (Hanke et al., 2001).

$$MSE = \frac{1}{n}\sum^{n} (Y_t \qquad {}^{2} \qquad \text{Equation 2.10}$$

3. Mean Absolute Percentage Error

The mean absolute percentage error (MAPE) is the technique that computes the forecast error in terms of percentage. This method is measured by averaging the summation of each absolute error that is divided by the actual observed value for that period, and then converting those error values into the percentage form. MAPE represents the size of forecast error in comparison to the actual values. The measurement model of MAPE can be computed by Equation 2.11 (Hanke et al., 2001).

$$MAPE = \frac{1}{n} \;{}^{n}_{t=1} \left| Y_t \qquad \right| \qquad \text{Equation 2.11}$$

4. Tracking Signal

The tracking signal (TS) is the approach to monitor change by computing the summation of the error and then dividing it by mean absolute deviation. This technique checks whether the cumulative error exceeds the acceptable control limits. Generally, the analysts recommend using the tracking signal of ± 6. If tracking signal exceeds this range, the forecaster will be alerted and the forecast is biased (Chopra & Meindl, 2001). Consequently, the company may consider choosing the new forecasting technique as the biased forecast may lead to the excess or shortage of inventories. The measurement model of TS can be computed by Equation 2.12 (Wisner et al., 2008).

$$TS = \frac{\sum_{t=1}^{n}\left(Y_t - \hat{Y}_t\right)}{MAD} \qquad \text{Equation 2.12}$$

2.7 Summary

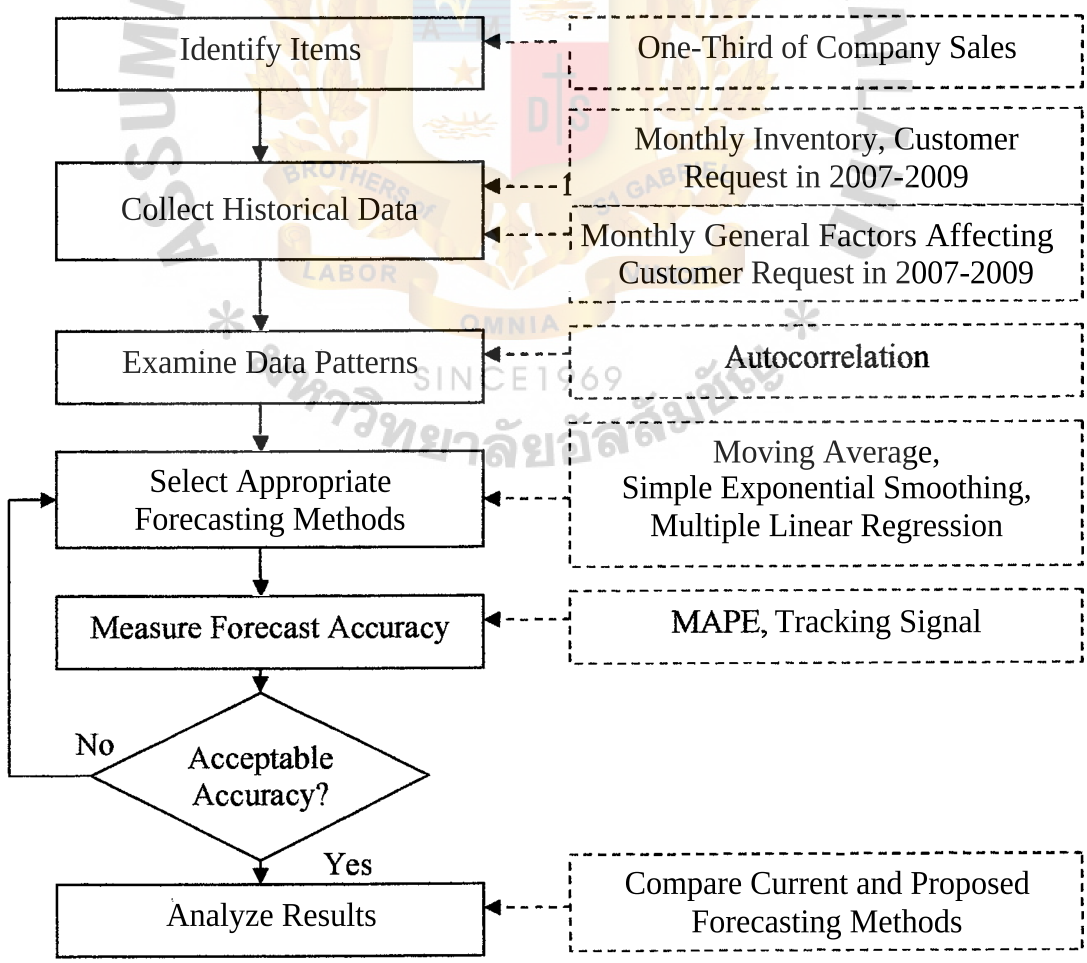
The literature that relates to forecasting is reviewed in this chapter. Forecasting is the crucial constituent part of the decision-making processes in order to decline the uncertainty of future demand and plan the optimal stock management. The importance role and common features of forecasting are firstly reviewed. After that the suitable forecasting techniques, types of data patterns which include stationary, trends, seasonal and cyclical patterns, and exploration of these patterns with autocorrelation technique are discussed. Furthermore, the mentioned literature in this chapter categorize the forecasting techniques into two major groups which consist of qualitative and quantitative methods since each forecasting technique is obviously quite different in the terms of the required data pattern, the forecast horizon, and the logical basis of forecasting. In addition, the measures of forecast errors between forecast and observed values are finally described to assess the efficiency of the forecasting technique.

CHAPTER III

RESEARCH METHODOLOGY

This chapter focuses on forecasting methodology in order to find the most appropriate forecasting techniques that can predict less error-request of customers for the major items of the CY Company. Forecasting methodology in this chapter is illustrated in Figure 3.1. Initially, the item identification is demonstrated. After that, the historical data of monthly inventory and customer request of the top 3 items in company revenue like gear kits, torque kits and cylinder kits, during January 2007 and December 2009 are represented. Lastly, the analysis of data patterns and choice of suitable forecasting methods are discussed respectively.

Figure 3.1: Forecasting Methodology of this Project



3.1 Item Identification

As the CY Company offers a variety of forklift spare parts, the analysis of company sales is used to identify which items should be focused upon since they have a high effect on the value of annual sales of the firm. According to company sales' analysis, this project only concentrates on top 3 items of company sales like gear kits, torque kits and cylinder kits since these 3 selected items are the major forklift spare parts of the firm that generate one-third of total company sales. The calculation of company sales is demonstrated in Table 3.1.

Table 3.1: Calculation of Company Sales

Item	Description	Total Annual Sales (Baht)	Percentage of Sales	Cumulative Percentage of Sales
1	Gear Kit	6,796,800	13.31%	13.31%
2	Torque Kit	5,698,500	11.16%	24.47%
3	Cylinder Kit	4,915,560	9.63%	34.10%
4	Roller 1321	2,910,960	5.70%	39.80%
5	Master Cylinder	2,593,340	5.08%	44.87%
6	Roller 2121	2,134,440	4.18%	49.05%
7	Steering Kit	2,010,600	3.94%	52.99%
8	Pin	1,989,000	3.90%	56.89%
9	Lift Kit	1,967,680	3.85%	60.74%
10	Bushing	1,741,500	3.41%	64.15%
11	Seal 32180	1,696,500	3.32%	67.47%
12	Disc	1,290,600	2.53%	70.00%
13	Plate	1,202,400	2.35%	72.36%
14	Wheel Bolt	1,014,540	1.99%	74.34%
15	Seal 15130	842,520	1.65%	75.99%
16	Hub Bolt	633,600	1.24%	77.23%
17	Seal 15140	596,160	1.17%	78.40%
18	Bearing	432,960	0.85%	79.25%
19	Wheel Nut	383,880	0.75%	80.00%

Source: Company Record

3.2 Data Collection

The historical data of inventory and customer request of the 3 selected items were gathered from the company on a monthly basis from January 2007 to December 2009, which is a total of 36 months. The inventory data elucidates the number of available forklift spare parts in the stock since the Company normally checks the stock during every last week of the month. Moreover, the data of customer request clarifies the quantity of items requested by customers for procurement. Currently, the Company collected these data via the request of customers both by calling and directly contacting salespeople at the CY Company. Consequently, to predict less error-request of customers for the 3 selected items in the future, the monthly inventory and customer request data of gear kits, torque kits and cylinder kits are shown in Table 3.2, 3.3 and 3.4 respectively.

Table 3.2: Inventory and Customer Request of Gear Kit in 2007-2009

Year	Period	Inventory (Unit)	Customer Request (Unit)	Error (Unit)	Cost / Unit (Baht)	Opportunity Loss of Sales (Baht)
2007	Jan	100	118	-18	4,420	93,492
2007	Feb	115	88	27	4,420	-
2007	Mar	78	95	-17	4,420	88,298
2007	Apr	85	106	-21	4,420	109,074
2007	May	90	115	-25	4,420	132,125
2007	Jun	117	104	13	4,420	-
2007	Jul	86	97	-11	4,420	58,135
2007	Aug	105	120	-15	4,420	79,275
2007	Sep	108	83	25	4,420	-
2007	Oct	97	117	-20	4,420	107,460
2007	Nov	102	125	-23	4,420	123,579
2007	Dec	95	77	18	4,420	-
2008	Jan	120	107	13	4,650	-
2008	Feb	102	137	-35	4,650	191,380
2008	Mar	118	102	16	4,650	-
2008	Apr	80	107	-27	4,650	150,012
2008	May	90	106	-16	4,650	88,896
2008	Jun	105	124	-19	4,650	105,564
2008	Jul	108	86	22	4,650	-
2008	Aug	117	93	24	4,650	-
2008	Sep	95	114	-19	4,650	107,008
2008	Oct	122	108	14	4,650	-
2008	Nov	92	126	-34	4,650	191,488
2008	Dec	85	95	-10	4,650	56,320
2009	Jan	112	131	-19	4,900	108,832
2009	Feb	104	128	-24	4,900	137,472
2009	Mar	88	112	-24	4,900	137,472
2009	Apr	95	74	21	4,900	-
2009	May	93	118	-25	4,900	145,175
2009	Jun	114	93	21	4,900	-
2009	Jul	97	109	-12	4,900	69,684
2009	Aug	84	103	-19	4,900	110,333
2009	Sep	105	83	22	4,900	-
2009	Oct	120	94	26	4,900	-
2009	Nov	93	111	-18	4,900	106,452
2009	Dec	80	101	-21	4,900	124,194

Source: Company Record

Table 3.3: Inventory and Customer Request of Torque Kit in 2007-2009

Year	Period	Inventory (Unit)	Customer Request (Unit)	Error (Unit)	Cost / Unit (Baht)	Opportunity Loss of Sales (Baht)
2007	Jan	113	128	-15	3,340	58,875
2007	Feb	120	149	-29	3,340	113,825
2007	Mar	107	131	-24	3,340	94,200
2007	Apr	93	107	-14	3,340	54,950
2007	May	117	97	20	3,340	-
2007	Jun	126	101	25	3,340	-
2007	Jul	98	121	-23	3,340	91,701
2007	Aug	118	144	-26	3,340	103,662
2007	Sep	105	117	-12	3,340	47,844
2007	Oct	120	92	28	3,340	-
2007	Nov	100	126	-26	3,340	105,768
2007	Dec	104	132	-28	3,340	113,904
2008	Jan	109	137	-28	3,515	116,004
2008	Feb	135	110	25	3,515	-
2008	Mar	110	135	-25	3,515	105,350
2008	Apr	115	94	21	3,515	-
2008	May	112	129	-17	3,515	71,638
2008	Jun	123	99	24	3,515	-
2008	Jul	115	148	-33	3,515	139,062
2008	Aug	98	127	-29	3,515	122,206
2008	Sep	124	97	27	3,515	-
2008	Oct	113	141	-28	3,515	119,728
2008	Nov	127	101	26	3,515	-
2008	Dec	104	126	-22	3,515	94,072
2009	Jan	112	83	29	3,700	-
2009	Feb	98	125	-27	3,700	117,504
2009	Mar	115	144	-29	3,700	126,208
2009	Apr	104	121	-17	3,700	73,984
2009	May	118	142	-24	3,700	106,440
2009	Jun	127	90	37	3,700	-
2009	Jul	108	133	-25	3,700	110,875
2009	Aug	123	98	25	3,700	-
2009	Sep	97	115	-18	3,700	79,830
2009	Oct	117	138	-21	3,700	93,135
2009	Nov	106	93	13	3,700	-
2009	Dec	95	117	-22	3,700	99,616

Source: Company Record

Table 3.4: Inventory and Customer Request of Cylinder Kit in 2007-2009

Year	Period	Inventory (Unit)	Customer Request (Unit)	Error (Unit)	Cost / Unit (Baht)	Opportunity Loss of Sales (Baht)
2007	Jan	145	173	-28	2,290	75,376
2007	Feb	144	171	-27	2,290	72,684
2007	Mar	156	129	27	2,290	-
2007	Apr	116	136	-20	2,290	53,840
2007	May	134	164	-30	2,290	82,710
2007	Jun	155	128	27	2,290	-
2007	Jul	125	153	-28	2,290	77,196
2007	Aug	140	126	14	2,290	-
2007	Sep	132	165	-33	2,290	90,981
2007	Oct	146	120	26	2,290	-
2007	Nov	130	162	-32	2,290	90,816
2007	Dec	124	150	-26	2,290	73,788
2008	Jan	127	158	-31	2,420	90,303
2008	Feb	155	137	18	2,420	-
2008	Mar	130	160	-30	2,420	89,550
2008	Apr	118	152	-34	2,420	101,490
2008	May	128	154	-26	2,420	77,610
2008	Jun	150	130	20	2,420	-
2008	Jul	120	144	-24	2,420	71,640
2008	Aug	147	124	23	2,420	-
2008	Sep	127	163	-36	2,420	110,952
2008	Oct	113	135	-22	2,420	67,804
2008	Nov	120	151	-31	2,420	95,542
2008	Dec	148	117	31	2,420	-
2009	Jan	150	128	22	2,550	-
2009	Feb	143	174	-31	2,550	98,456
2009	Mar	135	158	-25	2,550	79,400
2009	Apr	120	156	-39	2,550	123,864
2009	May	134	170	-36	2,550	117,504
2009	Jun	148	133	15	2,550	-
2009	Jul	125	157	-32	2,550	104,448
2009	Aug	157	122	35	2,550	-
2009	Sep	124	140	-16	2,550	52,224
2009	Oct	138	114	24	2,550	-
2009	Nov	142	169	-27	2,550	90,126
2009	Dec	120	145	-25	2,550	83,450

Source: Company Record

3.3 Examining Data Patterns with Autocorrelation

Since the customer request data of forklift spare parts have a correlation between successive observations over time, the autocorrelation technique is used to examine whether the pattern of these data is stationary, trend, seasonal, or cyclical in this step. Hence, the customer request data from 2007 to 2009 which is totally 36 periods in Table 3.2, 3.3 and 3.4 are utilized to calculate the autocorrelation based on Equation 2.1. The example of computation of lag 1 autocorrelation or r1 for gear kits is represented in Table 3.5. After that, details of the examination of data patterns with the autocorrelation technique for all customer request data are elaborated.

1 2 3 4 5 6

Table 3.5: Calculation of Lag 1 Autocorrelation for Customer Request of Gear Kit

Period	Y_t	**	$-\bar{Y}$	$Y_{t-1}-\bar{Y}$	$(Y_t \ \bar{Y})^2$	$(Y_t \ \bar{Y})(Y_{t-1}-\bar{Y})$
1	118	-	12.25	-	150.06	-
2	88	118	-17.75	12.25	315.06	-217.44
3	95	88	-10.75	-17.75	115.56	190.81
4	106	95	0.25	-10.75	0.06	-2.69
5	115	106	9.25	0.25	85.56	2.31
6	104	115	-1.75	9.25	3.06	-16.19
7	97	104	-8.75	-1.75	76.56	15.31
8	120	97	14.25	-8.75	203.06	-124.69
9	83	120	-22.75	14.25	517.56	-324.19
10	117	83	11.25	-22.75	126.56	-255.94
11	125	117	19.25	11.25	370.56	216.56
12	77	125	-28.75	19.25	826.56	-553.44
13	107	77	1.25	-28.75	1.56	-35.94
14	137	107	31.25	1.25	976.56	39.06
15	102	137	-3.75	31.25	14.06	-117.19
16	107	102	1.25	-3.75	1.56	-4.69
17	106	107	0.25	1.25	0.06	0.31
18	124	106	18.25	0.25	333.06	4.56
19	86	124	-19.75	18.25	390.06	-360.44
20	93	86	-12.75	-19.75	162.56	251.81
21	114	93	8.25	-12.75	68.06	-105.19
22	108	114	2.25	8.25	5.06	18.56
23	126	108	20.25	2.25	410.06	45.56
24	95	126	-10.75	20.25	115.56	-217.69
25	131	95	25.25	-10.75	637.56	-271.44
26	128	131	22.25	25.25	495.06	561.81
27	112	128	6.25	22.25	39.06	139.06
28	74	112	-31.75	6.25	1,008.06	-198.44
29	118	74	12.25	-31.75	150.06	-388.94
30	93	118	-12.75	12.25	162.56	-156.19
31	109	93	3.25	-12.75	10.56	-41.44
32	103	109	-2.75	3.25	7.56	-8.94
33	83	103	-22.75	-2.75	517.56	62.56
34	94	83	-11.75	-22.75	138.06	267.31
35	111	94	5.25	-11.75	27.56	-61.69
36	101	111	-4.75	5.25	22.56	-24.94
Y***	105.75			Total	8,484.75	-1,672.06

Remarks: is the customer request data of gear kit at period *t*.

Y_{t-1} is the customer request data of gear kit at period *t-1*.

*** Y is the average of customer request data of gear kit at 36 periods.

$$r1 = \frac{-1,672.06}{8,484.75} = -0.1971$$

The autocorrelation of lag 2 until lag 36 is also calculated by using the same method in Table 3.5 but the 1 column will be shifted down, based on the number of lag periods. The result of the autocorrelation for customer request of gear kit at 36 periods is shown in Table 3.6.

Table 3.6: Autocorrelation for Customer Request of Gear Kit at 36 Periods

k x	**r** *	**k**	**r**	**k**	**r**
1	-0.1971	13	0.0812	25	0.0374
2	-0.1973	14	-0.1728	26	0.0470
3	0.1524	15	0.0977	27	-0.0199
4	0.0965	16	-0.0380	28	0.0044
5	-0.1232	17	0.0009	29	-0.0314
6	-0.0652	18	0.0241	30	0.0456
7	-0.0522	19	-0.0842	31	0.0535
8	-0.0352	20	-0.1383	32	-0.0151
9	0.0534	21	0.1806	33	-0.0219
10	0.0047	22	-0.0412	34	0.0175
11	-0.0777	23	-0.1828	35	-0.0069
12	0.0410	24	0.0625	36	0.0000

Remarks: * k is a lag of k periods.
r is the autocorrelation value.

After the autocorrelation at various lags is computed, these autocorrelation values are plotted into the autocorrelation function graph in order to explore the data patterns. Furthermore, to consider whether the autocorrelation is significantly large, the data is calculated the critical values of $2 I\sqrt{n}$, where n is the amount of periods, and then represents the upper and lower limits. The calculation of upper and lower limits is given as follows;

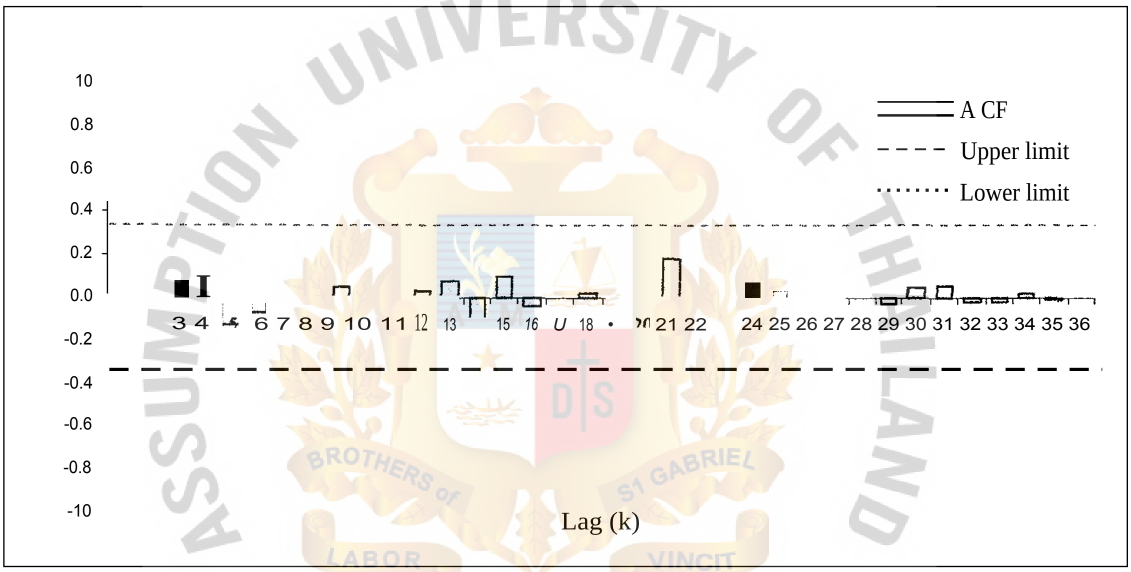
$2/\sqrt{n} = 2/\sqrt{36} = 0.3333$

The upper limit = 0.3333

The lower limit = -0.3333

The autocorrelation function and the upper and lower limits for customer request of gear kits are plotted in Figure 3.2.

Figure 3.2: Autocorrelation Function for Customer Request of Gear Kit in 2007-2009



According to Figure **3.2,** all of autocorrelations in year 2007 to 2009 are within the range of upper and lower limits. The autocorrelations also lessen rapidly toward zero when the amount of periods rise. Thus, the customer request data series of gear kits are considered to have the stationary pattern.

The result of the autocorrelation for customer request of torque kits at 36 periods is demonstrated in Table 3.7.

Table 3.7: Autocorrelation for Customer Request of Torque Kit at 36 Periods

k*	**r****	**k**	**r**	**k**	**r**
1	-0.2681	13	-0.2704	25	0.1137
2	0.0333	14	0.1414	26	0.1221
3	-0.2668	15	-0.0079	27	0.0093
4	-0.1433	16	0.0244	28	-0.0471
5	0.2798	17	-0.0474	29	0.0005
6	-0.2503	18	-0.0250	30	-0.0133
7	0.3177	19	0.0763	31	0.0218
8	-0.2860	20	0.0709	32	0.0191
9	0.0646	21	0.0152	33	-0.0502
10	0.0113	22	-0.1110	34	-0.0232
11	0.0460	23	-0.1182	35	-0.0015
12	0.1456	24	-0.0834	36	0.0000

Remarks: * k is a lag of k periods.

** r is the **autocorrelation** value.

The **autocorrelation** function and the upper and lower limits for customer request of torque kits are plotted in Figure 3.3.

Figure 3.3: Autocorrelation Function for Customer Request of Torque Kit in 2007-2009

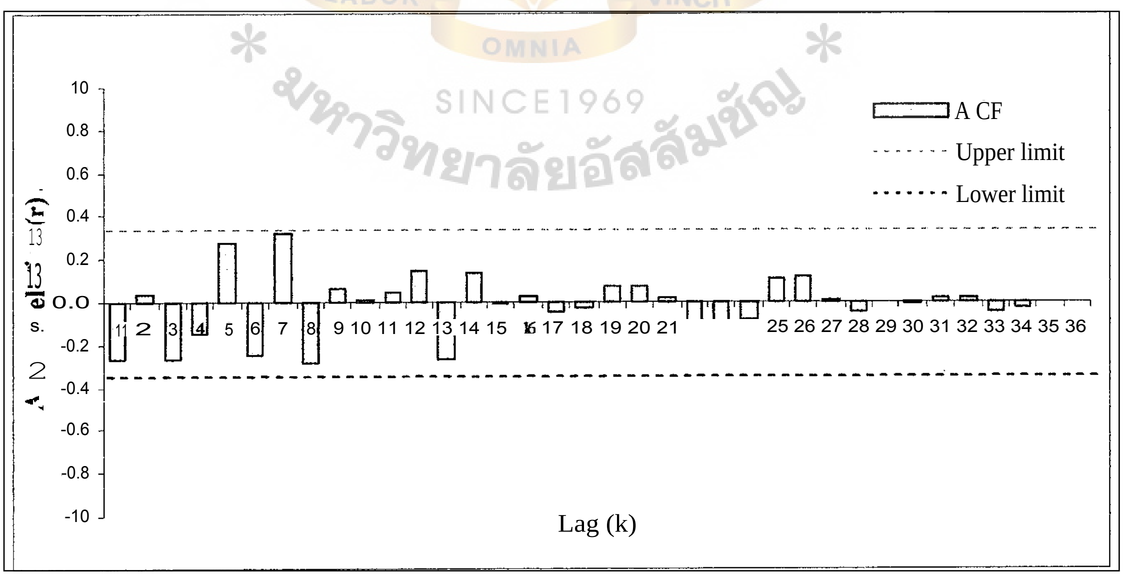


Figure 3.3, it obviously indicates that when the time period increases, the autocorrelation of torque kits drops rapidly toward zero, and all of the autocorrelations are also within the boundary of upper and lower limits. Therefore, the customer request data series of torque kits are considered to have the stationary pattern.

The result of the autocorrelation for customer request of cylinder kit at 36 periods is represented in Table 3.8.

Table 3.8: Autocorrelation for Customer Request of Cylinder Kit at 36 Periods

k	**r** **	**k**	**r**	**k**	**r**
1	-0.2589	13	-0.1883	25	-0.0969
2	0.2033	14	0.3457	26	0.1793
3	-0.3011	15	-0.0522	27	-0.0048
4	0.1345	16	0.1097	28	0.0929
5	-0.2547	17	-0.1064	29	-0.0543
6	0.0396	18	-0.0259	30	0.0500
7	-0.1656	19	-0.1294	31	-0.0454
8	0.0444	20	0.0757	32	-0.1215
9	-0.1664	21	-0.1059	33	-0.0253
10	0.2724	22	0.0713	34	0.0516
11	-0.1882	23	-0.2827	35	-0.0032
12	0.2077	24	0.1990	36	0.0000

Remarks: * k is a lag of k periods.
** r is the autocorrelation value.

The autocorrelation function and the upper and lower limits for customer request of cylinder kits are plotted in Figure 3.4.

Figure 3.4: Autocorrelation Function for Customer Request of Cylinder Kit in 2007-2009

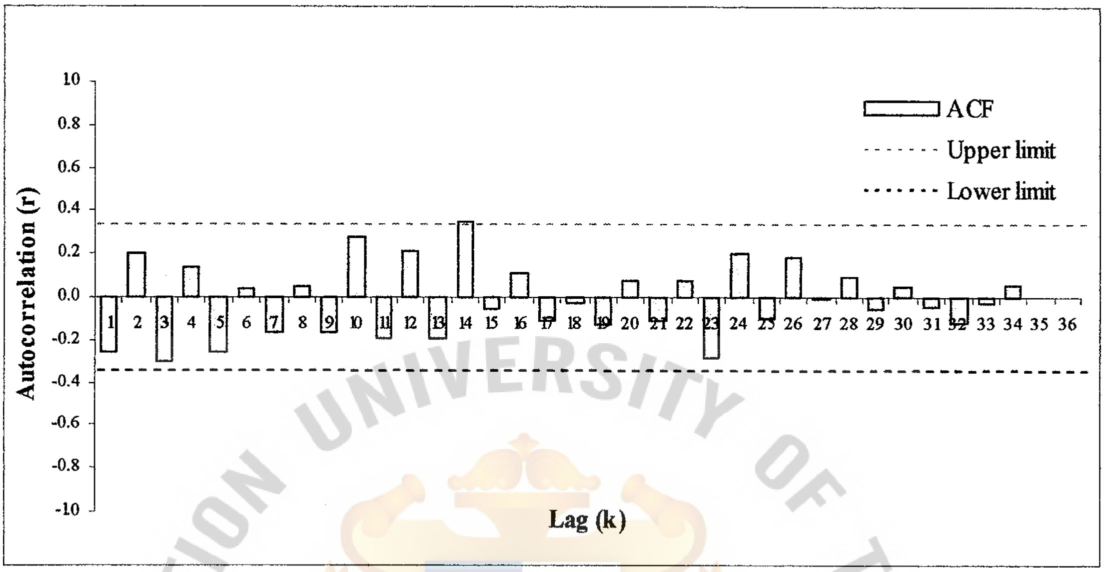


Figure 3.4 indicates that the autocorrelation of cylinder kits exceeds the upper limit at lag 14 only whereas others are within the boundary of upper and lower limits, and also decline swiftly toward zero when the amount of periods rise. Consequently, the customer request data series of cylinder kits are considered to have the stationary pattern.

3.4 Formulation of Forecasting Technique and Error Measurement

From the results of data patterns examined by using the autocorrelation technique, the historical data of customer request of the 3 selected forklift spare parts are considered to have the stationary pattern. Therefore, according to the guide to select the time series forecasting method in Table 3.9, the suitable forecasting techniques for this project are the moving average, simple exponential smoothing and multiple linear regression in order to investigate and predict the new series of customer requests for those selected items.

Table 3.9: A Guide for Selection of Forecasting Method

Forecasting Method	Description	Data Pattern	Forecast Horizon
Moving Average	Create the average value over the specified set of observations	Stationary	Short
Simple Exponential Smoothing	Use the weighting factor of historical data	Stationary	Short
Holt's Exponential Smoothing	Extend simple exponential smoothing by including trend in the data	Trend	Short, Medium
Winter's Exponential Smoothing	Extend Holt's exponential smoothing by including seasonality in the data	Trend and Seasonal	Short, Medium
Time Series Decomposition	Identify component factors separately that affect each of the values in the time series	Trend, Seasonal and Cyclical	Short, Medium, Long
Regression	Estimate the relationship between dependent and independent variables	All data patterns	Short, Medium, Long

Source: Hanke et al. (2001); Wilson & Keating (2002)

After the outcomes of proposed forecasting methods are represented, the measurement methods of forecast error, MAPE and tracking signal, are applied to evaluate the impact of each forecasting method. Since there are three forecasting techniques formulated in this project, the values of forecast error of these different forecasting methods are compared to find out the most suitable forecasting method. Thus, the forecasting technique which provides the least forecast error is selected to predict the customer request of the 3 selected items in the future for the CY Company.

3.5 Summary

All methodologies are described to forecast the future customer requests of major forklift spare parts in this chapter. Then, the top 3 items of total company sales like gear kits, torque kits and cylinder kits, are selected and historical data from 2007 to 2009 which is a total of 36 periods is gathered. After that, the autocorrelation technique is utilized to examine whether the pattern of customer request data is stationary, trend, seasonal, or cyclical. According to the results of data pattern examination with autocorrelation technique, the customer request data of the 3 selected forklift spare parts are considered to have the stationary pattern. Hence, the moving average, simple exponential smoothing and multiple linear regression forecasting techniques are applied to investigate and make predictions in this project. In addition, the forecast error measurement methods, MAPE and tracking signal, are finally calculated on the basis of these different forecasting methods, and then compared in order to choose the most suitable forecasting method that provides the least forecast error for the prediction.

CHAPTER IV

PRESENTATION AND CRITICAL DISCUSSION OF RESULTS

This project focuses on the forecast accuracy improvement of the major items for the CY Company. According to the autocorrelation examination results of customer request data in chapter 3, the forecasting technique results of moving average, simple exponential smoothing and multiple linear regression models are presented. Then, forecast error measurement results and choice of the suitable forecasting method for each item are discussed. After that, the comparison of forecast accuracy and performance measurement, the inventory cost and opportunity loss, between the current and proposed forecasting methods is analyzed.

4.1 Forecasting Technique Results

Since the historical data of customer request of the 3 selected forklift spare parts are considered to have the stationary pattern with autocorrelation technique, the suitable forecasting techniques of this project are the moving average, simple exponential smoothing and multiple linear regression. The details of forecasting procedure for each technique will be presented as follows.

4.1.1 Moving Average Model

Moving average model is obtained by calculating the mean for specified set of observations in order to forecast the next period. The amount of past observations must be equal the amount of periods in the moving average. The most recent observation is added and the earliest observation is discarded for forecasting the average of the coming period. The characteristic of moving average model is the larger the amount of periods used in the moving average, the larger the smooth forecasting

The monthly customer request data of 3 selected items during 2007 and 2009, which is a total of 36 months, are utilized to compute the moving average based on Equation 2.2. To identify the suitable moving average period, forecasting is implemented by utilizing the different average periods. Therefore, the forecast of gear kits, torque kits and cylinder kits that starts from two-period moving average to twelve-period moving average is represented in Table 4.1, 4.2 and 4.3 respectively.

Table 4.1: Forecast Value of Moving Average Model for Gear Kit

Period	Actual Customer Request (Unit)	Forecast Value (Unit)										
		MA* (2)	MA (3)	MA (4)	MA (5)	MA (6)	MA (7)	MA (8)	MA (9)	MA (10)	MA (11)	MA (12)
1	118	-	-	-	-		-	-	-	-	-	-
2	88	-	-	-	-	-	-	-	-	-	-	-
3	95	103	-	-	-	-	-	-	-	-	-	-
4	106	92	100	-	-	-	-	-	-	-	-	-
5	115	101	96	102	-	-	-	-	-	-	-	-
6	104	111	105	101	104	-	-	-	-	-	-	-
7	97	110	108	105	102	104	-	-	-	-	-	-
8	120	101	105	106	103	101	103	-	-	-	-	-
9	83	109	107	109	108	106	104	105	-	-	-	-
10	117	102	100	101	104	104	103	101	103	-	-	-
11	125	100	107	104	104	106	106	105	103	104	-	-
12	77	121	108	111	108	108	109	108	107	105	106	-
13	107	101	106	101	104	103	103	105	105	104	102	104
14	137	92	103	107	102	105	104	104	105	105	104	103
15	102	122	107	112	113	108	109	108	107	108	108	107
16	107	120	115	106	110	111	107	109	107	107	108	108
17	106	105	115	113	106	109	110	107	108	107	107	108
18	124	107	105	113	112	106	109	110	107	108	107	107
19	86	115	112	110	115	114	109	111	111	109	110	109
20	93	105	105	106	105	110	110	106	108	109	106	108
21	114	90	101	102	103	103	108	108	104	106	107	105
22	108	104	98	104	105	105	105	109	108	105	107	108
23	126	111	105	100	105	105	105	105	109	108	106	107
24	95	117	116	110	105	109	108	108	107	110	110	107
25	131	111	110	111	107	104	107	107	107	106	109	109
26	128	113	117	115	115	111	108	110	109	109	108	111
27	112	130	118	120	118	117	114	110	112	111	111	110
28	74	120	124	117	118	117	116	113	110	112	111	111
29	118	93	105	111	108	111	111	111	109	107	108	108
30	93	96	101	108	113	110	112	112	112	110	108	109
31	109	106	95	99	105	109	107	110	109	110	108	107
32	103	101	107	99	101	106	109	108	110	109	110	108
33	83	106	102	106	99	102	105	109	107	109	109	109
34	94	93	98	97	101	97	99	103	106	105	107	107
35	111	89	93	97	96	100	96	98	102	105	104	106
36	101	103	96	98	100	99	102	98	100	103	105	104

Remark: * MA is moving average.

Table 4.2: Forecast Value of Moving Average Model for Torque Kit

Period	Actual Customer Request (Unit)	Forecast Value (Unit)										
		MA* (2)	MA (3)	MA (4)	MA (5)	MA (6)	MA (7)	MA (8)	MA (9)	MA (10)	MA (11)	MA (12)
1	128	-	-	-	-	-	-	-	-	-	-	-
2	149	-	-	-	-	-	-	-	-	-	-	-
3	131	139	-	-	-	-	-	-	-	-	-	-
4	107	140	136	-	-	-	-	-	-	-	-	-
5	97	119	129	129	-	-	-	-	-	-		-
6	101	102	112	121	122	-	-	-	-	-	-	-
7	121	99	102	109	117	119	-	-	-	-	-	-
8	144	111	106	107	111	118	119	-	-	-	-	-
9	117	133	122	116	114	117	121	122	-	-	-	-
10	92	131	127	121	116	115	117	121	122	-	-	-
11	126	105	118	119	115	112	111	114	118	119	-	-
12	132	109	112	120	120	117	114	113	115	119	119	-
13	137	129	117	117	122	122	119	116	115	117	120	120
14	110	135	132	122	121	125	124	121	119	117	119	121
15	135	124	126	126	119	119	123	122	120	118	117	118
16	94	123	127	129	128	122	121	124	124	122	119	118
17	129	115	113	119	122	122	118	118	121	121	119	117
18	99	112	119	117	121	123	123	119	119	122	122	120
19	148	114	107	114	113	117	119	120	117	117	120	120
20	127	124	125	118	121	119	122	123	123	120	120	122
21	97	138	125	126	119	122	120	122	123	124	121	121
22	141	112	124	118	120	116	118	117	120	121	121	119
23	101	119	122	128	122	124	119	121	120	122	123	123
24	126	121	113	117	123	119	120	117	119	118	120	121
25	83	114	123	116	118	123	120	121	118	120	119	120
26	125	105	103	113	110	113	118	115	117	115	116	116
27	144	104	111	109	115	112	114	119	116	118	115	117
28	121	135	117	120	116	120	117	118	121	119	120	118
29	142	133	130	118	120	117	120	117	118	121	119	120
30	90	132	136	133	123	124	120	123	120	121	123	121
31	133	116	118	124	124	118	119	117	119	117	118	120
32	98	112	122	122	126	126	120	121	118	121	118	119
33	115	116	107	116	117	121	122	117	118	116	119	117
34	138	107	115	109	116	117	120	121	117	118	116	118
35	93	127	117	121	115	119	120	123	123	119	120	118
36	117	116	115	111	115	111	116	116	119	120	117	117

Remark: * **MA** is moving average.

Table 4.3: Forecast Value of Moving Average Model for Cylinder Kit

Period	Actual Customer Request (Unit)	Forecast Value (Unit)										
		MA* (2)	MA (3)	MA (4)	MA (5)	MA (6)	MA (7)	MA (8)	MA (9)	MA (10)	MA (11)	MA (12)
1	173	-	-	-	-	-	-	-	-	-	-	-
2	171	-	-	-	-	-	-	-	-	-	-	-
3	129	172	-	-	-	-	-	-	-	-	-	-
4	136	150	158	-	-	-	-	-	-	-	-	-
5	164	133	145	152	-	-	-	-	-	-	-	-
6	128	150	143	150	155	-	-	-	-	-	-	-
7	153	146	143	139	146	150	-	-	-	-	-	-
8	126	141	148	145	142	147	151	-	-	-	-	-
9	165	140	136	143	141	139	144	148	-	-	-	-
10	120	146	148	143	147	145	143	147	149	-	-	-
11	162	143	137	141	138	143	142	140	144	147	-	-
12	150	141	149	143	145	142	145	144	143	145	148	-
13	158	156	144	149	145	146	143	146	145	143	146	148
14	137	154	157	148	151	147	148	145	147	146	145	147
15	160	148	148	152	145	149	145	146	144	146	145	144
16	152	149	152	151	153	148	150	147	148	146	148	147
17	154	156	150	152	151	153	148	151	148	148	146	148
18	130	153	155	151	152	152	153	149	151	148	149	147
19	144	142	145	149	147	149	149	150	147	149	147	147
20	124	137	143	145	148	146	148	148	150	147	148	147
21	163	134	133	138	141	144	143	145	145	147	145	146
22	135	144	144	140	143	145	147	146	147	147	149	146
23	151	149	141	142	139	142	143	145	144	146	146	147
24	117	143	150	143	143	141	143	144	146	145	146	147
25	128	134	134	142	138	139	138	140	141	143	142	144
26	174	123	132	133	139	136	137	137	138	140	142	141
27	158	151	140	143	141	145	142	142	141	142	143	144
28	156	166	153	144	146	144	147	144	144	142	143	144
29	170	157	163	154	147	147	146	148	145	145	144	145
30	133	163	161	165	157	151	151	149	150	148	147	146
31	157	152	153	154	158	153	148	148	147	149	146	146
32	122	145	153	154	155	158	154	149	149	148	149	147
33	140	140	137	146	148	149	153	150	146	147	146	147
34	114	131	140	138	144	146	148	151	149	146	146	145
35	169	127	125	133	133	139	142	144	147	145	143	143
36	145	142	141	136	140	139	144	145	147	149	147	145

Remark: ***MA** is moving average.

According to Table 4.1, 4.2 and 4.3, the forecast of two-period moving average is computed by aggregating the last two observations and then dividing it by two periods in order to find the forecast value. Thus, the forecast value of three-period moving average until the twelve-period moving average is also calculated in the same method but the number of observations will change based on the number of periods in the moving average.

4.1.2 Simple Exponential Smoothing Model

Simple exponential smoothing model is calculated from the series of historical observations in order to predict the future observations of the same series. The smoothing constant or a is assigned as the weighting factor that is the key component in the analysis. As the value of *a* in exponential smoothing form is between zero and one, when a is the small value, the new forecast will be similar to the previous forecast. On the other hand, when a is a large value, the new forecast will adjust some errors that occurred in the previous forecast.

The monthly customer request data of 3 selected items during 2007 and 2009, a total of 36 months, are utilized to compute the simple exponential smoothing based on Equation 2.3. To obtain more correct forecasting results with the optimal smoothing constant, the forecast of gear kits, torque kits and cylinder kits where the a value starts from 0.1 to 0.9 is illustrated in Table 4.4, 4.5 and 4.6 respectively.

Table 4.4: Forecast Value of Simple Exponential Smoothing Model for Gear Kit

Period	Actual Customer Request (Unit)	Forecast Value (Unit)								
		SES a=0.1	SES a=0.2	SES a=0.3	SES a=0.4	SES a=0.5	SES a=0.6	SES a=0.7	SES a=0.8	SES a=0.9
1	118	106	106	106	106	106	106	106	106	106
2	88	107	108	110	111	112	113	114	116	117
3	95	105	104	103	102	100	98	96	94	91
4	106	104	102	101	99	98	96	95	95	95
5	115	104	103	102	102	102	102	103	104	105
6	104	105	106	106	107	108	110	111	113	114
7	97	105	105	105	106	106	106	106	106	105
8	120	105	104	103	102	102	101	100	99	98
9	83	106	107	108	109	111	112	114	116	118
10	117	104	102	101	99	97	95	92	90	86
11	125	105	105	105	106	107	108	110	112	114
12	77	107	109	111	114	116	118	120	122	124
13	107	104	103	101	99	96	93	90	86	82
14	137	104	104	103	102	102	102	102	103	104
15	102	108	110	113	116	119	123	126	130	134
16	107	107	109	110	110	111	110	109	108	105
17	106	107	108	109	109	109	108	108	107	107
18	124	107	108	108	108	107	107	107	106	106
19	86	109	111	113	114	116	117	119	120	122
20	93	106	106	105	103	101	98	96	93	90
21	114	105	103	101	99	97	95	94	93	93
22	108	106	106	105	105	105	106	108	110	112
23	126	106	106	106	106	107	107	108	108	108
24	95	108	110	112	114	116	119	121	122	124
25	131	107	107	107	106	106	104	103	100	98
26	128	109	112	114	116	118	120	123	125	128
27	112	111	115	118	121	123	125	126	127	128
28	74	111	114	116	117	118	117	116	115	114
29	118	107	106	104	100	96	91	87	82	78
30	93	109	109	108	107	107	107	109	111	114
31	109	107	106	103	102	100	99	98	97	95
32	103	107	106	105	105	104	105	106	107	108
33	83	107	106	104	104	104	104	104	104	103
34	94	104	101	98	96	93	91	89	87	85
35	111	103	100	97	95	94	93	93	93	93
36	101	104	102	101	101	102	104	105	107	109

Remark: * SES is simple exponential smoothing.

Table 4.5: Forecast Value of Simple Exponential Smoothing Model for Torque Kit

Period	Actual Customer Request (Unit)	Forecast Value (Unit)								
		SES a=0.1	SES a=0.2	SES a=0.3	SES a=0.4	SES a=0.5	SES a=0.6	SES a=0.7	SES a=0.8	SES a=0.9
1	128	119	119	119	119	119	119	119	119	119
2	149	120	121	122	123	124	124	125	126	127
3	131	123	126	130	133	136	139	142	144	147
4	107	124	127	130	132	134	134	134	134	133
5	97	122	123	123	122	120	118	115	112	110
6	101	119	118	115	112	109	105	102	100	98
7	121	118	115	111	108	105	103	101	101	101
8	144	118	116	114	113	113	114	115	117	119
9	117	121	122	123	125	128	132	135	139	141
10	92	120	121	121	122	123	123	123	121	119
11	126	117	115	112	110	107	104	101	98	95
12	132	118	117	117	116	117	117	119	120	123
13	137	120	120	121	123	124	126	128	130	131
14	110	121	123	126	128	131	133	134	136	136
15	135	120	121	121	121	120	119	117	115	113
16	94	122	124	125	127	128	129	130	131	133
17	129	119	118	116	114	111	108	105	101	98
18	99	120	120	120	120	120	121	122	123	126
19	148	118	116	114	111	109	108	106	104	102
20	127	121	122	124	126	129	132	135	139	143
21	97	121	123	125	126	128	129	130	129	129
22	141	119	118	116	115	112	110	107	103	100
23	101	121	123	124	125	127	129	131	133	137
24	126	119	118	117	116	114	112	110	107	105
25	83	120	120	120	120	120	120	121	122	124
26	125	116	112	109	105	101	98	94	91	87
27	144	117	115	114	113	113	114	116	118	121
28	121	120	121	123	125	129	132	136	139	142
29	142	120	121	122	124	125	125	125	125	123
30	90	122	125	128	131	133	135	137	139	140
31	133	119	118	117	115	112	108	104	100	95
32	98	120	121	122	122	122	123	124	126	129
33	115	118	116	115	112	110	108	106	104	101
34	138	118	116	115	113	113	112	112	113	114
35	93	120	121	122	123	125	128	130	133	136
36	117	117	115	113	111	109	107	104	101	97

Remark: * SES is simple exponential smoothing.

Table 4.6: Forecast Value of Simple Exponential Smoothing Model for Cylinder Kit

Period	Actual Customer Request (Unit)	Forecast Value (Unit)								
		SES a=0.1	SES a=0.2	SES a=0.3	SES a=0.4	SES a=0.5	SES a=0.6	SES a=0.7	SES a=0.8	SES a=0.9
1	173	146	146	146	146	146	146	146	146	146
2	171	149	151	154	157	160	162	165	168	170
3	129	151	155	159	162	165	167	169	170	171
4	136	149	150	150	149	147	144	141	137	133
5	164	147	147	146	144	142	139	138	136	136
6	128	149	151	151	152	153	154	156	158	161
7	153	147	146	144	142	140	138	136	134	131
8	126	148	147	147	147	147	147	148	149	151
9	165	145	143	141	138	136	134	133	131	128
10	120	147	148	148	149	151	153	155	158	161
11	162	145	142	140	137	135	133	131	128	124
12	150	146	146	146	147	149	150	153	155	158
13	158	147	147	147	148	149	150	151	151	151
14	137	148	149	151	152	154	155	156	157	157
15	160	147	147	147	146	145	144	143	141	139
16	152	148	149	151	152	153	154	155	156	158
17	154	149	150	151	152	152	153	153	153	153
18	130	149	151	152	153	153	153	154	154	154
19	144	147	147	145	144	142	139	137	135	132
20	124	147	146	145	144	143	142	142	142	143
21	163	145	142	139	136	133	131	129	128	126
22	135	146	146	146	147	148	150	153	156	159
23	151	145	144	143	142	142	141	140	139	137
24	117	146	145	145	146	146	147	148	149	150
25	128	143	140	137	134	132	129	126	123	120
26	174	141	137	134	132	130	128	127	127	127
27	158	145	145	146	149	152	156	160	165	169
28	156	146	147	150	152	155	157	159	159	159
29	170	147	149	152	154	155	156	157	157	156
30	133	149	153	157	160	163	165	166	167	169
31	157	148	149	150	149	148	146	143	140	137
32	122	149	151	152	152	152	152	153	154	155
33	140	146	145	143	140	137	134	131	128	125
34	114	145	144	142	140	139	138	137	138	139
35	169	142	138	134	130	126	123	121	119	116
36	145	145	144	144	145	148	151	155	159	164

Remark: * SES is simple exponential smoothing.

According to Table 4.4, 4.5 and 4.6, the forecast of simple exponential smoothing at a = 0.1 is computed by aggregating between the actual value of the previous period, multiplied with 0.1, and the forecast value of the previous period, multiplied with 0.9, in order to find the forecast value of the next period. The forecast value of the first period is assumed to be the average of all actual customer request data owing to the lack of the data before the first period. Thus, the forecast value at $a = 0.2$ until $a = 0.9$ is also calculated in the same method but the multiple with smoothing constant will be changed based on the different a values in the simple exponential smoothing.

4.1.3 Multiple Linear Regression Model

Multiple linear regression is the statistical procedure which estimates the relationship between the dependent variable and more than one independent variable. Forecasting by this model is appropriate when there are several predictor variables involved. As the customer request data of the major forklift spare parts fluctuate in each month, the economic factors are expected to have an affect on these requests of customers. The increase in the number of forklift requirements in the present business, especially in an industry, is expected to highly impact the variation of customer request of forklift spare parts for the repair because the forklift is normally used in the warehouse of an industry. Thus, to analyze whether general factors have an affect on customer request for forecasting, the import value of forklift, industrial production index, industrial confidence index and quantity of industrial factory are gathered from the bank of Thailand, the office of industrial economics and Thai customs department during 2007 and 2009 which is a total of 36 months as presented in Table 4.7. Import value of forklift explains the expansion of forklift import in Thailand. Industrial production index is the economic indicator that represents the expansion of real industrial production. Industrial confidence index is the economic indicator that shows the expansion of industrial investment and buying intentions.

Table 4.7: General Factors Affecting Customer Request in 2007-2009

Year	Period	Import Value of Forklift (Million Baht)	Industrial Production Index	Industrial Confidence Index	Quantity of Industrial Factory
2007	Jan	340	170.53	44.80	341
2007	Feb	360	168.10	44.60	345
2007	Mar	320	177.45	46.50	355
2007	Apr	416	165.15	47.80	339
2007	May	353	168.00	44.70	360
2007	Jun	288	167.77	46.70	364
2007	Jul	313	167.31	41.10	368
2007	Aug	436	168.94	46.70	371
2007	Sep	249	170.83	47.80	391
2007	Oct	439	181.84	44.70	430
2007	Nov	458	183.76	46.40	348
2007	Dec	374	185.52	44.50	265
2008	Jan	335	186.78	46.60	314
2008	Feb	336	181.96	45.70	365
2008	Mar	395	188.57	47.60	355
2008	Apr	452	168.27	43.20	327
2008	May	372	181.76	45.40	405
2008	Jun	386	182.48	41.10	458
2008	Jul	422	184.42	46.70	348
2008	Aug	342	185.36	45.60	358
2008	Sep	513	184.79	41.30	528
2008	Oct	406	181.11	45.00	334
2008	Nov	431	167.73	44.60	275
2008	Dec	550	148.97	40.70	289
2009	Jan	270	139.13	41.80	269
2009	Feb	199	139.79	36.70	242
2009	Mar	261	159.71	40.50	275
2009	Apr	209	145.85	39.50	260
2009	May	177	159.57	46.50	293
2009	Jun	208	170.01	48.60	363
2009	Jul	348	168.10	46.00	387
2009	Aug	242	169.45	47.00	345
2009	Sep	287	183.31	49.70	335
2009	Oct	222	180.32	51.00	369
2009	Nov	269	180.24	49.00	317
2009	Dec	308	185.07	49.20	326

Source: Bank of Thailand (2008); Office of Industrial Economics (2010); Thai Customs Department (2010)

For this project, the dependent variable is the actual customer request for each item and the independent variables are the import value of forklift, industrial production index, industrial confidence index and quantity of industrial factory. Therefore, the factors of independent variables are analyzed to check whether these factors cause the fluctuation of the customer request for these selected forklift spare parts before the forecast value of this model is computed.

The actual customer request during 2007 and 2009 which is a total of 36 months is shown in Table 3.2, 3.3 and 3.4 respectively. The monthly general factors affecting customer request that are shown in Table 4.7 are utilized to compute the multiple linear regression by using the SPSS program. Hence, the analysis results of this model for gear kits, torque kits and cylinder kits are presented in Table 4.8, 4.9 and 4.10 respectively.

Table 4.8: Analysis Results of Multiple Linear Regression Model for Gear Kit

Model	Coefficients Beta		t	Sig.
	Unstandardized	Standardized		
(Constant)	151.806		3.607	0.001
Import Value of Forklift	0.024	0.138	0.689	0.496
Industrial Production Index	-0.244	-0.207	-0.765	0.450
Industrial Confidence Index	-0.629	-0.127	-0.545	0.589
Industrial Factory Quantity	0.047	0.172	0.816	0.420

Remarks: Dependent variable is actual customer request of gear kit.

$F = 0.814$; $Sig > 0.05$; Adjusted $R^2 = 0.022$

As demonstrated in Table 4.8, it can conclude that, first, the value of adjusted R^2 which is 0.022 indicates that only 2.2 percent of the fluctuation of customer request data for gear kits can be explained by this model. Secondly, the relative F-statistic shows that all variables in the model have no effect of relationship and are not statistically significant because the significance value is higher than 0.05. Thirdly, the relative t-statistic represents that all independent variables, import value of forklift, industrial production index, industrial confidence index and quantity of industrial factory, have no impact on customer request data of gear kits and are not statistically significant at 95 percent level because the p-value is higher than 0.05. Consequently, the forecast value of this model is not appropriate to develop additional analysis.

Table 4.9: Analysis Results of Multiple Linear Regression Model for Torque Kit

Model	Coefficients Beta		t	Sig.
	Unstandardized	Standardized		
(Constant)	94.128		1.865	0.072
Import Value of Forklift	0.001	0.006	0.029	0.977
Industrial Production Index	0.594	0.411	1.554	0.130
Industrial Confidence Index	-0.660	-0.109	-0.477	0.637
Industrial Factory Quantity	-0.139	-0.414	-2.003	0.054

Remarks: Dependent variable is actual customer request of torque kit.

$F = 1.169$; $Sig > 0.05$; Adjusted $R^2 = 0.019$

Table 4.9 indicates that, firstly, the value of adjusted R^2 which is 0.019 indicates that only 1.9 percent of the fluctuation of customer request data for torque kits can be explained by this model. Secondly, the relative F-statistic shows that all variables in the model have no effect of relationship and are not statistically significant because the significance value is higher than 0.05. Thirdly, the relative t-statistic represents that all independent variables, import value of forklift, industrial production index, industrial confidence index and quantity of industrial factory, have no impact on customer request data of torque kits and are not statistically significant at 95 percent level because p-value for those variables are higher than 0.05. Therefore, the forecast value of this model is not appropriate to develop additional analysis.

Table 4.10: Analysis Results of Multiple Linear Regression Model for Cylinder Kit

Model	Coefficients Beta		t	Sig.
	Unstandardized	Standardized		
(Constant)	206.294		4.339	0.000
Import Value of Forklift	-0.045	-0.230	-1.165	0.253
Industrial Production Index	0.428	0.317	1.189	0.244
Industrial Confidence Index	-2.207	-0.390	-1.694	0.100
Industrial Factory Quantity	-0.054	-0.173	-0.828	0.414

Remarks: Dependent variable is actual customer request of cylinder kit.

$F = 1.006$; $Sig > 0.05$; Adjusted $R^2 = 0.001$

According to Table 4.10, it can conclude that, firstly, the value of adjusted R^2 which is 0.001 indicates that only 0.1 percent of the fluctuation of customer request data for cylinder kits which can be explained by this model. Secondly, the relative F-statistic shows that all variables in the model have no effect of relationship and are not statistically significant because significance value is higher than 0.05. Thirdly, the relative t-statistic represents that all independent variables, import value of forklift, industrial production index, industrial confidence index and quantity of industrial factory, have no impact on customer request data of cylinder kits and are not statistically significant at 95 percent level because p-value of those variables are higher than 0.05. Hence, the forecast value of this model is not appropriate to develop additional analysis.

4.2 Forecast Error Measurement Results

After the forecast value of moving average model from two to twelve periods and that of simple exponential smoothing model at $a = 0.2$ until $a = 0.9$ is represented, the measurement methods of forecast error, MAPE and tracking signal, are applied to evaluate the impact of each forecasting method. Since there are the different average periods and smoothing constant values formulated in this project, the values of forecast error are compared to determine the appropriate average period for moving average method and the optimal smoothing constant for simple exponential smoothing method. Thus, the average period and a value which provide the least MAPE value and tracking signal of $\pm$ 6 range are selected to forecast for each forecasting method. The forecast error measurement results of MAPE and tracking signal for moving average and simple exponential smoothing techniques are summarized in Table 4.11 and 4.12 respectively.

Table 4.11: Forecast Error Measurement of Moving Average Model

Gear Kit			**Torque Kit**			**Cylinder Kit**		
MA (k)*	**MAPE (%)**	**TS*****	**MA (k)**	**MAPE (%)**	**TS**	**MA (k)**	**MAPE (%)**	**TS**
2	16.7	0.6	2	18.3	-2.4	2	11.6	-1.7
3	14.9	0.9	3	18.9	-2.3	3	12.1	-0.3
4	14.3	0.1	4	17.8	-1.4	4	11.5	0.1
5	13.7	-1.1	5	15.8	-0.4	5	12.0	-1.4
6	14.2	-1.2	6	16.4	0.5	6	11.4	-0.4
7	14.3	-0.9	7	15.9	-0.1	7	12.0	-1.1
8	14.1	-2.1	8	16.3	-1.6	8	11.4	0.1
9	13.5	-0.8	9	16.2	-1.5	9	11.7	-1.2
10	13.5	-2.0	**10**	**15.6**	**0.2**	**10**	**10.6**	**0.6**
11	13.5	-3.5	11	15.8	-0.2	11	10.8	-0.3
12	**12.3**	**-1.2**	12	15.7	-1.1	12	10.7	-0.5

Remarks: * MA (k) is moving average of the number of periods used.

** MAPE is mean absolute percentage error.

*** TS is tracking signal.

Table 4.11 obviously indicates that the least MAPE value of moving average model is twelve-period moving average for gear kits and ten-period moving average for both torque kits and cylinder kits. Furthermore, the tracking signal of the least MAPE value for all 3 selected items is in the range of ± 6, so these average periods are acceptable.

Table 4.12: Forecast Error Measurement of Simple Exponential Smoothing Model

Gear Kit			Torque Kit			Cylinder Kit		
SES (a)	**MAPE (%)**	**TS*** **	**SES (a)**	**MAPE (%)**	**TS**	**SES (a)**	**MAPE (%)**	**TS**
0.1	**12.9**	**-1.7**	**0.1**	**15.3**	**-1.1**	**0.1**	**11.4**	**-0.7**
0.2	13.5	-1.6	0.2	16.0	-1.0	0.2	11.7	-0.5
0.3	14.2	-1.2	0.3	16.8	-0.8	0.3	11.9	-0.3
0.4	14.8	-0.8	0.4	17.7	-0.7	0.4	12.0	-0.1
0.5	15.5	-0.6	0.5	18.6	-0.6	0.5	12.3	0.0
0.6	16.3	-0.4	0.6	19.6	-0.5	0.6	12.8	0.1
0.7	16.9	-0.3	0.7	20.6	-0.4	0.7	13.5	0.1
0.8	17.7	-0.3	0.8	21.6	-0.3	0.8	14.5	0.1
0.9	18.7	-0.2	0.9	22.8	-0.2	0.9	15.6	0.0

Remarks: * SES is simple exponential smoothing.

** MAPE is mean absolute percentage error.

*** TS is tracking signal.

Table 4.12 indicates that the MAPE value increases consecutively at the smoothing constant from 0.1 to 0.9. Therefore, the least MAPE value of simple exponential smoothing model is the smoothing constant value at 0.1 for gear kits, torque kits and cylinder kits. Moreover, the tracking signal of the least MAPE value for all 3 selected items is in the range of ± 6, so this smoothing constant is acceptable.

4.3 Forecast Evaluation Analysis

Based on the comparison of forecast error among proposed forecasting methods, moving average and simple exponential smoothing, in Table 4.13, the most suitable forecasting technique which provides the least MAPE is selected to predict the customer request of the 3 selected items in the future for the CY Company. Thus, twelve-period moving average should be used to forecast gear kits, simple exponential smoothing at a = 0.1 for torque kits and ten-period moving average for cylinder kits with the forecast error at 12.3 percent, 15.3 percent and 10.6 percent respectively.

Table 4.13: Comparison of Forecast Error among Proposed Forecasting Methods

Item	Forecasting Method	MAPE (%)*	TS**
Gear Kit	**Twelve-Period Moving Average**	**12.3**	**-1.2**
	Simple Exponential Smoothing (a = 0.1)	12.9	-1.7
Torque Kit	Ten-Period Moving Average	15.6	0.2
	Simple Exponential Smoothing (a = 0.1)	**15.3**	-1.1
Cylinder Kit	**Ten-Period Moving Average**	**10.6**	0.6
	Simple Exponential Smoothing (a = 0.1)	11.4	-0.7

Remarks: MAPE is mean absolute percentage error.

**TS is tracking signal.

According to the comparison of forecast accuracy between current and proposed forecasting methods in Table 4.14, the percentage of forecast accuracy equals to converting the forecast error with the formula of 1 – MAPE. The forecast accuracy of proposed forecasting method, twelve-period moving average for gear kits, improves from 75 percent to 88 percent when compared to the current forecasting method. Similarly, there are improvements in forecast accuracy of proposed forecasting methods, simple exponential smoothing at a = 0.1 for torque kits and ten-period moving average for cylinder kits, which is around 10 percent and 13 percent respectively.

Table 4.14: Comparison of Forecast Accuracy Improvement between Current and Proposed Forecasting Methods

Item	Error (%)		Accuracy (%)		Improvement (%)
	Current Method	Proposed Method	Current Method	Proposed Method	
Gear Kit	25	12	75	88	13
Torque Kit	25	15	75	85	10
Cylinder Kit	24	11	76	89	13

Remarks: Proposed method for gear kits is twelve-period moving average.

Proposed method for torque kits is simple exponential smoothing at a=0.1.

Proposed method for cylinder kits is ten-period moving average.

4.4 Performance Measurement Analysis

After the most suitable forecasting method for each selected item is applied to forecast, the performance measurement analysis which is the opportunity loss and inventory cost between the current and proposed forecasting methods is compared in order to assess the advantage in monetary term. The unit price is used to compute the opportunity loss of sales when the forecast value is lower than actual customer request data. On the other hand, when the forecast value is higher than actual customer request data, the inventory cost is computed by aggregating the total unit cost and the inventory holding cost of 1 percent per month. The calculation of opportunity loss and inventory cost for both current and proposed forecasting methods of gear kits, torque kits and cylinder kits is represented in Table 4.15, 4.16 and 4.17 respectively.

Table 4.15: Opportunity Loss and Inventory Cost of Current and Proposed Forecasting Methods for Gear Kit

Twelve-Period Moving Average Method							Current Method	
Period	Actual Customer Request (Unit)	Forecast Value (Unit)	Error (Unit)	Cost / Unit **(Baht)**	Opportunity Loss **(Baht)**	Inventory Cost **(Baht)**	Opportunity Loss **(Baht)**	Inventory Cost **(Baht)**
Jan,07	118	-	-	4,420	-	-	93,492	-
Feb,07	88	-	-	4,420	-	-	-	120,533
Mar,07	95	-	-	4,420	-	-	88,298	-
Apr,07	106	-	-	4,420	-	-	109,074	-
May,07	115	-	-	4,420	-	-	132,125	-
Jun,07	104	-	-	4,420	-	-	-	58,035
Jul,07	97	-	-	4,420	-	-	58,135	-
Aug,07	120	-	-	4,420	-	-	79,275	-
Sep,07	83	-	-	4,420	-	-	-	111,605
Oct,07	117	-	-	4,420	-	-	107,460	-
Nov,07	125	-	-	4,420	-	-	123,579	-
Dec,07	77	-	-	4,420	-	-	-	80,356
Jan,08	107	104	-3	4,650	16,404	-	-	61,055
Feb,08	137	103	-34	4,650	185,912	-	191,380	
Mar,08	102	107	5	4,650	-	23,483	-	75,144
Apr,08	107	108	1	4,650	-	4,697	150,012	-
May,08	106	108	2	4,650	-	9,393	88,896	-
Jun,08	124	107	-17	4,650	94,452	-	105,564	-
Jul,08	86	109	23	4,650	-	108,020	-	103,323
Aug,08	93	108	15	4,650	-	70,448	-	112,716
Sep,08	114	105	-9	4,650	50,688	-	107,008	-
Oct,08	108	108	0	4,650	-	-	-	65,751
Nov,08	126	107	-19	4,650	107,008	-	191,488	-
Dec,08	95	107	12	4,650	-	56,358	56,320	-
Jan,09	131	109	-22	4,900	126,016	-	108,832	-
Feb,09	128	111	-17	4,900	97,376	-	137,472	-
Mar,09	112	110	-2	4,900	11,456	-	137,472	-
Apr,09	74	111	37	4,900	-	183,113	-	103,929
May,09	118	108	-10	4,900	58,070	-	145,175	-
Jun,09	93	109	16	4,900	-	79,184	-	103,929
Jul,09	109	107	-2	4,900	11,614	-	69,684	-
Aug,09	103	108	5	4,900	-	24,745	110,333	-
Sep,09	83	109	26	4,900	-	128,674	-	108,878
Oct,09	94	107	13	4,900	-	64,337	-	128,674
Nov,09	111	106	-5	4,900	29,570	-	106,452	-
Dec,09	101	104	3	4,900	-	14,847	124,194	-
				Total	**788,566**	**767,297**	**2,621,720**	**1,233,927**

Table 4.16: Opportunity Loss and Inventory Cost of Current and Proposed Forecasting Methods for Torque Kit

Simple Exponential Smoothing Method (a = 0.1)							Current Method	
Period	Actual Customer Request (Unit)	Forecast Value (Unit)	Error (Unit)	Cost / Unit (Baht)	Opportunity Loss (Baht)	Inventory Cost (Baht)	Opportunity Loss (Baht)	Inventory Cost (Baht)
Jan,07	128	119	-9	3,340	35,325	-	58,875	-
Feb,07	149	120	-29	3,340	113,825	-	113,825	-
Mar,07	131	123	-8	3,340	31,400	-	94,200	-
Apr,07	107	124	17	3,340	-	57,348	54,950	-
May,07	97	122	25	3,340	-	84,335	-	67,468
Jun,07	101	119	18	3,340	-	60,721	-	84,335
Jul,07	121	118	-3	3,340	11,961	-	91,701	-
Aug,07	144	118	-26	3,340	103,662	-	103,662	-
Sep,07	117	121	4	3,340	-	13,494	47,844	-
Oct,07	92	120	28	3,340	-	94,455	-	94,455
Nov,07	126	117	-9	3,340	36,612	-	105,768	-
Dec,07	132	118	-14	3,340	56,952	-	113,904	-
Jan,08	137	120	-17	3,515	70,431	-	116,004	-
Feb,08	110	121	11	3,515	-	39,052	-	88,754
Mar,08	135	120	-15	3,515	63,210	-	105,350	-
Apr,08	94	122	28	3,515	-	99,404	-	74,553
May,08	129	119	-10	3,515	42,140	-	71,638	-
Jun,08	99	120	21	3,515	-	74,553	-	85,204
Jul,08	148	118	-30	3,515	126,420	-	139,062	-
Aug,08	127	121	-6	3,515	25,284	-	122,206	-
Sep,08	97	121	24	3,515	-	85,204	-	95,854
Oct,08	141	119	-22	3,515	94,072	-	119,728	-
Nov,08	101	121	20	3,515	-	71,003	-	92,304
Dec,08	126	119	-7	3,515	29,932	-	94,072	-
Jan,09	83	120	37	3,700	-	138,269	-	108,373
Feb,09	125	116	-9	3,700	39,168	-	117,504	-
Mar,09	144	117	-27	3,700	117,504	-	126,208	-
Apr,09	121	120	-1	3,700	4,352	-	73,984	-
May,09	142	120	-22	3,700	97,570	-	106,440	-
Jun,09	90	122	32	3,700	-	119,584	-	138,269
Jul,09	133	119	-14	3,700	62,090	-	110,875	-
Aug,09	98	120	22	3,700	-	82,214	-	93,425
Sep,09	115	118	3	3,700	-	11,211	79,830	-
Oct,09	138	118	-20	3,700	88,700	-	93,135	-
Nov,09	93	120	27	3,700	-	100,899	-	48,581
Dec,09	117	117	0	3,700	-	-	99,616	-
				Total	**1,250,610**	**1,131,745**	**2,360,381**	**1,071,575**

Table 4.17: Opportunity Loss and Inventory Cost of Current and Proposed Forecasting Methods for Cylinder Kit

Ten-Period Moving Average Method							Current Method	
Period	Actual Customer Request (Unit)	Forecast Value (Unit)	Error (Unit)	Cost / Unit (Baht)	Opportunity Loss (Baht)	Inventory Cost (Baht)	Opportunity Loss (Baht)	Inventory Cost (Baht)
Jan,07	173	-	-	2,290	-	-	75,376	-
Feb,07	171	-	-	2,290	-	-	72,684	-
Mar,07	129	-	-	2,290	-	-	-	62,448
Apr,07	136	-	-	2,290	-	-	53,840	-
May,07	164	-	-	2,290	-	-	82,710	-
Jun,07	128	-	-	2,290	-	-	-	62,448
Jul,07	153	-	-	2,290	-	-	77,196	-
Aug,07	126	-	-	2,290	-	-	-	32,381
Sep,07	165	-	-	2,290	-	-	90,981	-
Oct,07	120	-	-	2,290	-	-	-	60,135
Nov,07	162	147	-15	2,290	42,570	-	90,816	-
Dec,07	150	145	-5	2,290	14,190	-	73,788	-
Jan,08	158	143	-15	2,420	43,695		90,303	-
Feb,08	137	146	9	2,420	-	21,998	-	43,996
Mar,08	160	146	-14	2,420	41,790	-	89,550	-
Apr,08	152	146	-6	2,420	17,910	-	101,490	-
May,08	154	148	-6	2,420	17,910	-	77,610	-
Jun,08	130	148	18	2,420	-	43,996	-	48,884
Jul,08	144	149	5	2,420	-	12,221	71,640	-
Aug,08	124	147	23	2,420	-	56,217	-	56,217
Sep,08	163	147	-16	2,420	49,312	-	110,952	-
Oct,08	135	147	12	2,420	-	29,330	67,804	-
Nov,08	151	146	-5	2,420	15,410	-	95,542	-
Dec,08	117	145	28	2,420	-	68,438	-	75,770
Jan,09	128	143	15	2,550	-	38,633	-	56,661
Feb,09	174	140	-34	2,550	107,984	-	98,456	-
Mar,09	158	142	-16	2,550	50,816	-	73,048	-
Apr,09	156	142	-14	2,550	44,464	-	114,336	-
May,09	170	145	-25	2,550	81,600	-	117,504	-
Jun,09	133	148	15	2,550	-	38,633	-	38,633
Jul,09	157	149	-8	2,550	26,112	-	104,448	-
Aug,09	122	148	26	2,550	-	66,963	-	90,143
Sep,09	140	147	7	2,550	-	18,029	52,224	-
Oct,09	114	146	32	2,550	-	82,416	-	61,812
Nov,09	169	145	-24	2,550	80,112	-	90,126	-
Dec,09	145	149	4	2,550	-	10,302	83,450	-
				Total	**633,875**	**487,174**	**2,055,874**	**627,079**

Table 4.18: Comparison of Performance Measurement between Current and Proposed Forecasting Methods in 2008-2009

Item	Performance Measurement	Current Method (Baht)	Proposed Method (Baht)	Savings (Baht)
Gear Kit	Inventory Cost	863,399	767,297	96,102
	Opportunity Loss	1,830,282	788,566	1,041,716
	Total	**2,693,681**	**1,555,863**	**1,137,818**
Torque Kit	Inventory Cost	825,317	821,393	3,924
	Opportunity Loss	1,575,652	860,873	714,779
	Total	**2,400,969**	**1,682,266**	**718,703**
Cylinder Kit	Inventory Cost	472,116	487,176	-15,060
	Opportunity Loss	1,438,483	577,115	861,368
	Total	**1,910,599**	**1,064,291**	**846,308**
			Grand Total	**2,702,829**

Remarks: Proposed method for gear kit is twelve-period moving average.
Proposed method for torque kit is simple exponential smoothing at a = 0.1.
Proposed method for cylinder kit is ten-period moving average.

To present the improvement of proposed forecasting methods, moving average and simple exponential smoothing, for the 3 selected items, the comparison of performance measurement between the current and proposed forecasting methods is shown in Table 4.18. The total inventory cost and opportunity loss during 2008 and 2009 of current forecasting method are 2,693,681 baht for gear kits, 2,400,969 baht for torque kits and 1,910,599 baht for cylinder kits. For proposed forecasting methods, the total inventory cost and opportunity loss are 1,555,863 baht for gear kits, 1,682,266 baht for torque kits and 1,064,291 baht for cylinder kits. When the performance measurement is compared to the current forecasting method, the total inventory cost and opportunity loss of proposed forecasting methods in 2008-2009 decreases by 1,137,818 baht for gear kits, 718,703 baht for torque kits and 846,308 baht for cylinder kits. Hence, after using those proposed forecasting methods, the firm can earn a grand total of savings during 2008 and 2009 which is around by 2,702,829 baht or 61 percent using current forecasting method since the forecast values of proposed methods are closer to actual customer requests than the current methods.

4.5 Summary

The forecasting methods of moving average, simple exponential smoothing and multiple linear regression are applied to forecast the customer request of 3 selected items as the historical data of customer request are considered to have a stationary pattern with the autocorrelation technique. Then, the forecast error measurement methods, MAPE and tracking signals, are calculated on the basis of these different forecasting methods, to choose the most suitable forecasting method for each item that provides the least forecast error. Therefore, the most suitable forecasting method is twelve-period moving average for gear kits, simple exponential smoothing at a = 0.1 for torque kits and ten-period moving average for cylinder kits. After that, the proposed forecasting methods are compared to the current forecasting methods in order to show the percentage of the forecast accuracy improvement. Furthermore, the comparison of the inventory cost and opportunity loss between current and proposed forecasting methods is also compared in order to explore the total number of savings by using proposed methods.

CHAPTER V

SUMMARY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The major purpose of this project is to propose the most suitable forecasting method for major forklift spare parts so as to commit the least forecast error and improve the forecast accuracy when compared to the current forecasting method in order to plan the optimal stock management to satisfy the customer request and also increase the higher profitability for the CY Company. The following details are the findings that are summarized from this project.

1. From the results of data pattern examination with autocorrelation technique, the historical data of customer request are considered to have the stationary pattern. Thus, the forecasting techniques of moving average, simple exponential smoothing and multiple linear regression models are applied in this project. However, according to analysis results of multiple linear regression model, it can noticeably be seen that all independent variables, import value of forklift, industrial production index, industrial confidence index and quantity of industrial factory, have no impact on customer request data of all 3 forklift spare parts. The forecast value of multiple linear regression model is not appropriate to develop additional analysis. This may be because economic factors may have an effect on the number of forklift requirements increasingly in the present business but also each forklift will take several years to require forklift spare parts in order to be repaired. Therefore, economic factors may not directly impact the customer request of forklift spare parts.

2. According to the forecast error measurement analysis, the most suitable forecasting technique which provides the least MAPE value and the tracking signal in the range of ± 6 which is selected to predict the customer request of each major item in the future for the CY Company. Consequently, twelve-period moving average is applied

to forecast for gear kits, simple exponential smoothing at a = 0.1 for torque kits and ten-period moving average for cylinder kits.

3. After the forecast accuracy between current and proposed forecasting methods is compared, the result shows that the percentage of forecast accuracy of proposed forecasting methods improves. Therefore, the application of these proposed forecasting methods to predict future events helps to facilitate successful planning of sales in order to satisfy customer requirements for the company.

4. Based on the comparison of performance measurement between the current and proposed forecasting methods, the result presents that the total inventory cost and opportunity loss of proposed forecasting methods in 2008-2009 decreased. Hence, the firm can save the inventory cost and generate further sales by using these proposed forecasting methods as the forecast values of proposed methods are closer to actual customer request than the current method.

5.2 Managerial Implication

Currently, several firms do not conduct a forecast by using the systematic forecasting technique. The researchers can adapt this project to be a direction for forecasting the future demand in other companies as well. This is because this project has proved that the systematic forecasting technique can develop the business performance by improving the forecast accuracy of customer request, and decreasing the inventory cost and opportunity loss of sales. The improvement in forecast accuracy will result in the better management of optimal inventory level to serve the customer requirement in order to reduce the variation between supply and demand. Therefore, the systematic forecasting technique is helpful for the firm to estimate the number of units that will be produced, stocked, or sold for the future demand to be more accurate. This technique can help the firm to decline the excess and shortage of inventories, and also increase the customer satisfaction and profitability for the firm. Moreover, the firms can improve the creditability in the business and take more advantage for selling their products than competitors by using this systematic forecasting technique. In addition, the company can obtain more knowledge on the examination of demand data patterns and the application of suitable forecasting methods for its data patterns because different forecasting methods will be applied with the different types of data patterns. This will effect the minimization in forecast error, inventory cost and opportunity loss for the firm.

5.3 Recommendations and Further Study

Since some general factors of customer request are not included in the analysis. A survey of customers' buying intention by using a questionnaire can provide better data and reflect real requirement of customers in the present situation. Therefore, the combination of the qualitative technique from survey and quantitative forecasting technique should be studied in the future research in order to develop a forecasting methodology that is more efficient. Moreover, after the proposed forecasting methods predict the customer request in the future, the analysis of economics order quantity or EOQ and safety stock should be further studied to plan optimal stock management in order to minimize inventory costs and maximize the opportunity of sales.

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