DEMAND FORECASTING USING TIME SERIES ANALYSIS AND ECONOMIC ORDER QUANTITY MODEL FOR INVENTORY CONTROL: A CASE STUDY OF A CONSTRUCTION COMPANY

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DEDICATION

For my beloved father and my late mother,

My supervisor and my friends.

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ABSTRACT

Inventory management, is the process of ensuring the right amount supply is available in a company. It helps the company to maintain inventory level and fulfill the customers' needs and wants. But unfortunately, there are still many construction companies fail to practice a systematic inventory management process in this fast-growing industrial era. Apart from that, they are also lack of proper forecasting techniques for predicting accurate demand. Therefore, the purpose of this study is to identified a suitable inventory management model by integrating the monthly order system, Economic Order Quantity (EOQ) and forecasting techniques. This study is conducted as a case study based on a construction company located in Singapore. Numerical data from the year 2014 to year 2017 for the raw materials is collected from the company's inventory record. The raw materials are diesel, quarry dust, concrete dan industrial gas. All the data are analysed by Microsoft Excel add-in tool (Xrealstats), QM for Windows and Microsoft Excel. The data from 2014 until 2016 is used by six main forecasting techniques and three performance measure to predict the best forecasted data for 2017. After identifying the most accurate forecasted demand quantity, it is used in the monthly order system and EOQ to compute the minimum total inventory cost. Decisions tree analysis is used to compare minimum total inventory cost in identifying the suitable inventory management model. As a final result, after analysing the minimum total inventory cost, the best suitable forecasting technique and inventory model for all the raw materials is linear regression and EOQ respectively. The EOQ and forecasting techniques proposed in this research are potential to predict the budget for the raw materials efficiently. This will enable the management of the construction company to prevent any financial issues in raw material purchasing in the future.

ABSTRAK

Pengurusan inventori, adalah proses memastikan jumlah bekalan yang betul tersedia dalam syarikat. Ia membantu syarikat mengekalkan tahap inventori dan memenuhi keperluan dan kehendak pelanggan. Namun malangnya, masih terdapat banyak syarikat pembinaan yang gagal mengamalkan proses pengurusan inventori yang sistematik dalam era perindustrian yang berkembang pesat ini. Selain itu, mereka juga kekurangan teknik ramalan yang betul untuk meramal permintaan yang tepat. Oleh itu, tujuan kajian ini adalah untuk mengenal pasti model pengurusan inventori yang sesuai dengan mengintegrasikan sistem pesanan bulanan, Kuantiti Pesanan Ekonomi (EOQ) dan teknik peramalan. Kajian ini dijalankan sebagai kajian kes berdasarkan sebuah syarikat pembinaan yang terletak di Singapura. Data berangka dari tahun 2014 hingga tahun 2017 untuk bahan mentah dikumpul daripada rekod inventori syarikat. Bahan mentahnya ialah diesel, habuk kuari, konkrit dan gas industri. Semua data dianalisis oleh alat tambah Microsoft Excel (Xrealstats), QM untuk Windows dan Microsoft Excel. Data dari 2014 hingga 2016 digunakan oleh enam teknik ramalan utama dan tiga ukuran ketepatan untuk meramal data ramalan terbaik untuk 2017. Selepas mengenal pasti kuantiti permintaan ramalan yang paling tepat, ia digunakan dalam sistem pesanan bulanan dan EOQ untuk mengira jumlah minimum kos inventori. Analisis pokok keputusan digunakan untuk membandingkan jumlah kos inventori minimum dalam mengenal pasti model pengurusan inventori yang sesuai. Hasil akhir, selepas menganalisis jumlah kos inventori minimum, teknik ramalan dan model inventori yang terbaik untuk semua bahan mentah adalah regresi linear dan EOQ masing-masing. EOQ dan teknik peramalan yang dicadangkan dalam penyelidikan ini berpotensi untuk meramalkan bajet untuk bahan mentah dengan cekap. Ini akan membolehkan pengurusan syarikat pembinaan untuk mengelakkan sebarang isu kewangan dalam pembelian bahan mentah pada masa hadapan.

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LIST OF ABBREVIATIONS

ANN	-	Artificial Neural Network
C	-	Cycles
D	-	Annual Demand
EMV	-	Expected Monetary Values
EOQ	-	Economic Order Quantity
EPCC	-	Engineering, Procurement, Construction, and Commissioning
FIT	-	Forecast Including Trend
H	-	Holding cost per unit per year
MAD	-	Mean Absolute Deviation
MAPE	-	Mean Absolute Percent Error
MRO	-	Maintenance/Repair/Operating Supply
MSE	-	Mean Squared Error
N	-	Number of inventory order
POQ	-	Period Order Quantity
Q	-	Number of units of order
Q_s	-	Number of safety stocks
R	-	Random variation
ROP	-	Reorder Point
S	-	Seasonality
SME	-	Small-Medium Enterprises
T	-	Trend
TIC	-	Total Inventory Cost
WIP	-	Work-In-Process

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Materials are an essential requirement in every construction industry. Usually, materials cost consists fifty to sixty percent of the total cost for the entire project (Song, 2005). This is very particular when it comes to large and complex construction projects, whereby a great financial investment is done in every single process of the works. However, inappropriate handling and management of materials on construction sites have the potential to hamper project performance (Ogunlana *et al.*, 1996). This could be due to several factors such as inadequate storage space (Sardroud, 2012), over-ordering and double handling (Donyavi & Flanagan, 2009), and incomplete and lack of up-to-date information regarding on-site stock (Navon & Berkovich, 2006).

Therefore, planning and implementing material inventory management is very important throughout construction works. It is vital in the control of materials and goods that have to be held (or stored) for effective later use in the case of production or efficient later exchange activities in the case of services (Adeyemi & Salami, 2010). Bell and Stukhart (1987) supported this statement by claiming that, effective inventory management can ensure that the right quantity with great quality of materials can be easily supplied on time. They also concluded that by having such an inventory management system the materials are easily obtained at a reasonable cost and are available when needed. Apart from that, having effective inventory management can make a significant contribution to a company's profitability as well as increase its return rate on total asset investment (Adeyemi & Salami, 2010). Despite the different kinds of inventory items of a business, the proper inventory control technique can help

to determine the sustainability of any goal-focused business efficiently (Haribhai-Pitamber & Dhurup, 2014).

Inventory management can be improved by collaborating with the forecasting process. Most of the inventory systems have always focused on the right forecasting techniques, even though it is only a minor part of the overall inventory management problem. (Supply chain 247, Feb 23, 2015). Forecasting is the art and science of predicting future events (Heizer & Render, 2011). It has been used to predict the uncertain nature of business trends to help managers make better decisions and plans (Je *et al.*, 2005). This activity is necessary because all the organizations operate in an atmosphere of uncertainty, but decisions must be made today that affect the future of the organization (Render *et al.*, 2011).

The purpose of this research is to propose and evaluate an inventory control model by using the Economic Order Quantity (EOQ) and forecasting techniques for a construction company. It is expected that the proposed model will minimize the inventory cost and resolved material shortage issues for the company. This chapter explains the background of the study, the problem statement, objectives of the study, research questions, and significance of the study.

1.2 Background of the study

The construction company is a established civil and infrastructure construction company in Singapore since 1972. The company is principally a specialist in providing EPCC (Engineering, Procurement, Construction, and Commissioning) services for infrastructure projects of transmission and storage of commodities, such as oil, gas, and water. Their services encompass the full spectrum of engineering works from engineering design, sourcing, and procurement, construction, fabrication, installation, testing, and commissioning. They also possess the expertise to phase and integrate new systems with existing facilities such that existing operations are not disrupted whilst works are being carried out. Furthermore, they have the provision of maintenance services to their customers for their existing infrastructure facilities. They have worked on a variety of specialised projects over the years, including offshore oil and gas production facilities and petrochemical plants.

In 1994, the company was awarded the engineering designs, and construction of a plastic compounding plant for GE Plastics China Ltd (part of the General Electric

group of USA) in Nansha, Guangdong Province, China. Since 1997, they have secured projects in Singapore, Hong Kong, Indonesia, Vietnam, and China. Their customers include government bodies, public utility companies, airport service providers, and international engineering and construction contractors. Their operation centers are currently established in the South East Asian region, China and India. These strong bases indicate that the company is moving into the Greater Asia Region, Middle East, and beyond.

The management and staff constantly strive to meet customers' satisfaction through continual improvements. Through their dedication, the company has achieved the ISO 9001:2008, ISO 14001:2004, OHSAS 18001:2007, Green & Gracious Builders Scheme, and BizSafe Star Certifications. The other award attained is Singapore Quality Class and they are also Member of the Association of Process Industry, Singapore Business Federation, Singapore Contractors Association Ltd, Gas Association of Singapore, Singapore Chinese Chamber of Commerce & Industry, Singapore Welding Society, and Singapore National Employers Federation.

1.3 Problem statement

Mismanagement of inventories might result in significant financial problems for an organization, such as inventory glut issues or shortage of inventories. Mwansele *et al.* (2011), claimed that poor inventory management may result in understocking, overstocking as well as high inventory cost.

Although the company received various awards and recognitions from professional bodies, it still faced mismanagement issues of inventories or materials for over 20 years. The company failed to keep track of their orders records, which cause them to engage in duplicate orders frequently over a short period. This leads to the lack of sense in the cost-saving monitoring process as well. Lack of monitoring and tracking of inventory or material status may result in a shortage of materials when it is required for any particular construction process. Eventually, the progress of the project will be delayed due to the shortage of materials. This results in a long lead-time of the procurement process and high material costs for the entire construction project.

Besides that, one of the major issues the company facing is the shortage of construction material while projects are still going on. This leads the company to purchase the materials, or in other words, fulfill the demand quantity on an urgent

basis, which always ends up in high purchasing costs. Due to the high purchasing cost, the company tends to have some reluctance in practicing such a purchasing manner. Consequently, its warehouse is having high expenses, which affect the profit of the company. High maintenance of the company's warehouse was reflected by its high operating cost. The data in Table 1.1 proved material cost increasing compare on yearly basis works.

Table 1.1: Yearly material cost (SGD) spent by the company on period year 2014 until 2017

Years	Diesel	Quarry Dust	Concrete	Industrial Gas	Total Yearly Material Cost ($)
Y2014	$ 115,924.09	$173,662.06	$35,640.00	$10,092.00	$335,318.15
Y2015	$123,658.00	$217,517.33	$56,040.00	$10,063.00	$407,278.33
Y2016	$224,847.68	$209,248.91	$86,992.69	$12,673.00	$533,762.28
Y2017	$424,173.62	$223,835.38	$104,889.66	$13,862.00	$766,760.66
Grand Total	$ 888,603.39	$824,263.67	$283,562.35	$46,690.00	$2,043,119.41

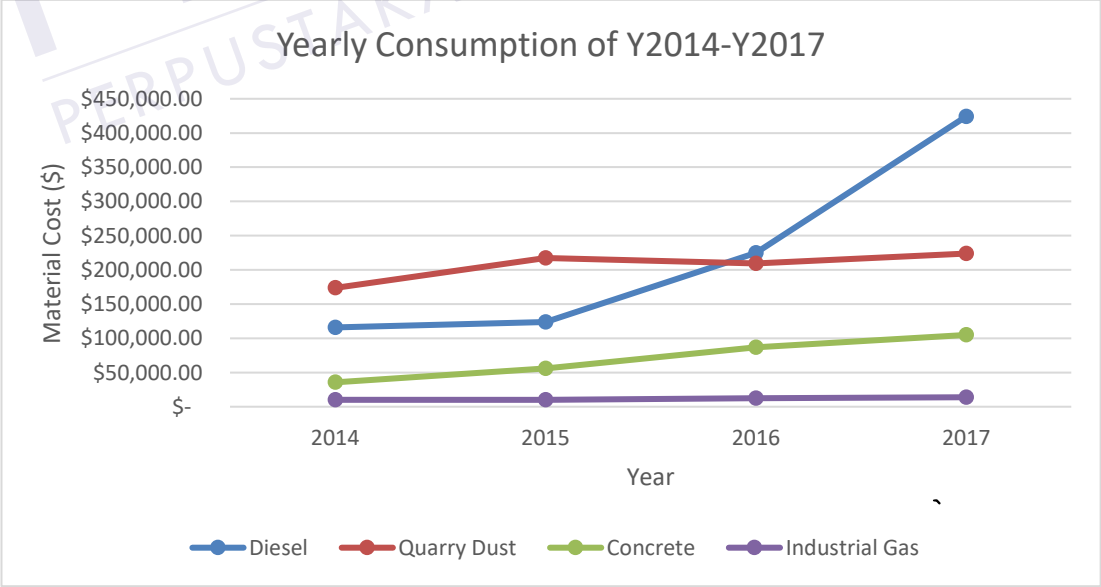

Figure 1.1: Graph of Yearly Material Consumptions Cost Line Trend

It is very clear that all the above mention problems rise due to the absence of a systematic inventory management process within their in-house inventory or warehouse system. In addition to that, the company also did not implement any forecasting techniques in purchasing process which lead to an inaccurate quantity of materials for its construction projects.

1.4 Research questions

This study seeks to answer the following specific research questions regarding the above-mentioned problem and purpose:

1. What is the forecasted demand for the selected raw materials?
2. What is the EOQ for the selected raw materials?
3. What is the optimum total cost of inventory?
4. What is the best decision alternative in the inventory management?

1.5 Research objectives

The following are the specific objectives of this study:

1. To determine the forecasted demand for the selected raw materials
2. To compute the EOQ for the selected raw materials
3. To find the optimum total cost of inventory
4. To identify the best decision alternative in the inventory management

1.6 Research scope

This research focused on the company in examining the effectiveness and efficiency of the inventory management system. They are specialists in providing EPCC (Engineering, Procurement, Construction, and Commissioning) services for infrastructure projects especially in the transmission and storage of commodities. The data used in this research is the raw material data from the year 2014 to year 2017. The targeted respondents were general managers or core members of the managerial team or assigned persons by a general manager who have a good understanding of the firm, especially in the inventory system.

The rationale behind the choice of this company is the absence of a systematic inventory management process in a fast-growing construction company. The company also lacks proper forecasting techniques in predicting accurate demand, which is one of the objectives to be achieved through this research.

1.7 Significance of research

This study is expected to provide benefits in terms of business practices and the development of science. It may lead, help, and provide some ideas on inventory system for the company particularly using Economic Order Quantity (EOQ) and forecasting approaches. The company can apply an effective and efficient way of inventory management system for minimizing their total cost and improve the competitiveness of the company in the market.

Apart from that, this study also would be beneficial for Small-Medium Enterprises (SME) who is the key players in commercialization and promoting technology-based companies. The proposed inventory management system can be their guideline in minimizing their total cost and thus increasing their net profit. This indirectly creates more concern and knowledge about the importance of using an effective and efficient way for their inventory management system.

Finally, this study would be a good reference material for similar research or to proceed with further research in the future.

1.8 Organization of the thesis

The writing organization explains the transition of research progress according to chapters. The following is the explanation of the content of each chapter in this thesis.

1.8.1 Chapter 1: Introduction

In this chapter, the background of the research is discussed. Following the research background, the problem statement is identified from the research background. Research questions are formulated, and relevant research objectives are presented. The

suitable scope for the research was selected and the significance of the research was highlighted thoroughly.

1.8.2 Chapter 2: Literature review

This chapter reviews the aspect of inventory, Economic Order Quantity (EOQ), and forecasting so that it can give a clear knowledge of relevant research regarding this research topic. It consists of the understanding of the EOQ model and forecasting related to inventory management. Besides that, earlier works in the literature related to EOQ and forecasting has also been highlighted on in this chapter.

1.8.3 Chapter 3: Methodology

This chapter discusses the methodology that had been used to accomplish the aim of this research. It explains the research design, data collection, inventory models and all the forecasting techniques related to this research. Furthermore, it also explains about decision trees and research flow chart which shows the overall picture of data analysis process.

1.8.4 Chapter 4: Data analysis

This chapter deals with data analysis and interpretation. It starts with inventory data, performance measure of forecasting, forecasting analysis, inventory analysis, and decision tree analysis. The monthly purchasing data of the raw materials of the company throughout 2014-2017 was collected and analyzed to achieve all the research objectives.

1.8.5 Chapter 5: Discussion, recommendations, and conclusion

In this chapter, the final findings and results discuss further and have a short summary at the end of the discussion. The limitations and problems encountered during the whole process of collecting data, suggestions, and further research are also included in this chapter.

1.9 Summary

This chapter explained the basic outline of the research study. It mainly covers the background of the company and also discussed major issues the company is facing. The aim of this research is to propose an inventory management system with a suitable forecasting technique. The effectiveness and efficiency of inventory management could bring impact on any company. It may affect the overall company's profitability and performance of construction projects too.

Furthermore, this study can serve as a guideline for future research for reference purposes. In addition, future researchers can make this thesis a source of reference and learning resource for their postgraduate/undergraduate projects. The results in this study also may serve as a literature base for future researchers.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides an overview of the literature on the inventory and forecasting modeling concepts and theories. It starts with an introduction of the concept of management and operation management. This followed by a thorough description of inventory which includes the function of inventory, types of inventory and importance of inventory management. Apart form this, explanation related to type of inventory model, forecasting techniques, decision analysis and a summary of earlier studies in the literature also given in this chapter.

2.2 Management

Management can be described as coordinating and overseeing the work activities of others so that their activities are completed perfectly. It makes sure that every task within an organization is undertaken by the people responsible for doing them efficiently and effectively. Efficiency refers to getting the most output from the least amount of input. It is also known as “doing things right” or in other words not wasting any resources. Effectiveness is often described as “doing the right things” that is doing those work activities that will help the organization reach its goals. It clearly can be noted that efficiency is concerned with the means of getting things done, whereas effectiveness is concerned with the ends, or attainment of organizational goals (Robbins *et al.*, 2012).

To achieve high efficiency and effectiveness, four functions of management refer to setting goals, establishing strategies, and developing plans to integrate and

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