Engng.J.CMU.(2016) 23 (3), 33-43

วารสารวิศวกรรมศาสตร์
มหาวิทยาลัยเชียงใหม่
Engineering Journal
Chiang Mai University

Applied Methodologies of Work Study, Forecasting and Inventory Management Techniques for Pharmaceutical's Warehouse Management: Atlanta Medicare Co.,Ltd

Sasarose Jaijit and Punnamee Sachakamol*
Department of Industrial Engineering, Faculty of Engineering, Kasetsart University,
Bangkok 10900, Thailand.
E-mail: *fengpmsa@ku.ac.th

ABSTRACT

This research is a case study of the Atlanta Medicare Company Limited, a company with business operations in the form of a distribution center for pharmaceuticals. The distribution center has significant limitations in areas of shelf life, storage area, and employee work rate. Moreover, the business is in a sector that enjoys rapid growth caused by increasing consumer demand. Consequently, efforts are aimed at the improvement of working methods to eliminate the various problematic limitations and to capably and efficiently support increased work volumes in the areas of time and capital. The data in this research is obtained from observation of work practices. This includes the application of general problem-solving skills to identify bottlenecks in work operations, which links to industrial work study techniques, forecasting techniques, and inventory management techniques to analyze solutions for problems encountered in work methods at the bottleneck point. Timing data was recorded and mapped onto work process charts and workflow diagrams. The analyzed results is obtained by means of industrial study techniques, assisted in a comparative visualization prior to, and following, the improvement of work practices. Additional forecasting techniques are applied to assess consumer needs of certain items from a list of 47 pharmaceutical products, for Numerical Scoring combined with ABC Analysis principles. Monthly sales volume data is gathered from the past 18 months to analyze via the Minitab 15 program. Moreover, data obtained from forecasting is used to conduct an analysis of sales order volume with further inventory management techniques. The aforesaid methods reveals current problems in the pharmaceutical distribution center, particularly in the product categorization, sorted by items ordered. Moreover, the results from this analysis shows an solutions and improvements rendered to the working methods by means of industrial work study techniques include increase of 422 orders per month (24.10%), with a working time reduction of 1.74 min per order (19.42%) and an operating cost reduction of 489,032.02 baht per year (0.58%). The results from forecasting and product inventory management techniques also help minimize losses incurred in the inventory.

1. Introduction

From the past until present, the 4 factors fundamental to human existence are food, housing, clothing, and medicine. Business operators within these various sectors, who are capable of meeting consumer demand, currently enjoy a high business growth rate – especially in businesses relevant to medicine. According to [3], data from the Office of Policy and Strategy at the Ministry of Public Health indicates that the number of patients is likely to increase substantially every year.

To optimize the response to consumer demand and enhance potential competitiveness pharmaceutical distribution enterprises must have management systems that prevents against losses that may incur as a result from both internal and external factors. This could include lack of volume due to exceeding consumer demand, poor order process management, storage and distribution processes, as well as medicine shelf-life, etc. These various factors rely on industrial work operation research principles and inventory system design, which

Received 16 July 2015
Accepted 10 November 2015

involves volume forecasting with uncertain demand.

This research work originates from the aforesaid overview and is a case study of Atlanta Medicare Company Limited. The company has pharmaceutical distribution centers, handling pharmaceuticals that have significant limitations on storage life. Thus, to capably and efficiently respond to consumer demand while creating maximum benefits to the organization, efforts are aimed at improving work practices. These practices must support the increasing work volume while increasing the speed of work operations, at minimum operational cost and minimizing losses.

To create efficient consumer demand response capabilities and maximize benefits to the organization, various techniques have been applied. These include Industrial Work Study Techniques, Forecasting Techniques, and Inventory Management Techniques. The Industrial Work Study Techniques assist in generating results of maximum response capabilities for increasing consumer demand, through the implementation of new work systems that further reduce operational costs, [2]. The Forecasting Techniques are applied to assess consumer needs in advance, using a selection of certain items from the list of 47 pharmaceutical products. This will assist in predicting consumer demand and enable us to set the ideal order volume to meet consumer demand. Finally, Inventory Management Techniques in this research are focused on order forms that are consistent with pharmaceutical products. The results include order amounts or quantities obtained from Forecasting Techniques as a value for appropriate order calculation. This will enhance delivery certainty of pharmaceuticals to clients and reduce the total annual inventory costs, [12]. Ultimately, this increases opportunities to utilize saved funds for profit generation elsewhere.

2. Research Methodology

This research applies 3 methods i.e. Industrial Work Study, Forecasting, and Inventory Management.

2.1 Industrial Work Study

1. Specify and analyze the problem for the applicable management approach in the case study of Atlanta Medicare Company Limited, using general problem-solving procedures, [6] comprised of the following.

1.1 Define the problem.

1.2 Specify the criteria for decision.

1.3 Analyze the problem.

1.3.1 Specify which work division has a bottleneck in the overall work process. The overall work process is categorized in 3 portions and 6 main jobs. Main job number one is order receiving. Main job number two is drug returning that two sections are within portion 1 (defined below). Main job number three is drug receiving. Main job number four is box receiving. Main job number five is organize customer orders which three sections are within portion 2. Main job number six is transportation of drug that within portion 3 as follows:

- Portion 1: receive orders from customers.
- Portion 2: organize customer orders.
- Portion 3: deliver customer orders.

This research takes into account bottlenecks that arise, during work operations, from minimum work volume obtained within one hour. Time and work volume in each main job is randomly analyzed which consists of 5 random samples obtained per section as illustrated in Figure 1.

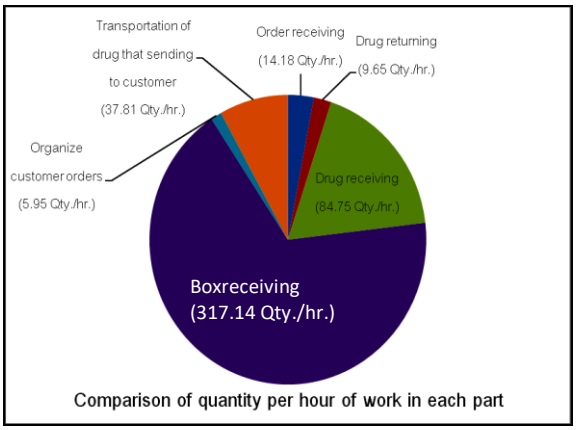

Figure 1 comparison of quantity per hour of work in each division

1.3.2 From section 1.3.1, bottlenecks in work operation are identified during portion 2: organize customer orders, when products are arranged to fulfill orders. The aforesaid work operation has problematic limitations i.e. pharmaceutical storage life, employee work rate, and product storage area capacity.

1.3.3 Tools applied to analyze current work practices during portion 2: organize customer orders include the following in the Operation Process Charts and Flow Process Charts as shown in Figure 2 and Figure 3.

- Operation Process Charts

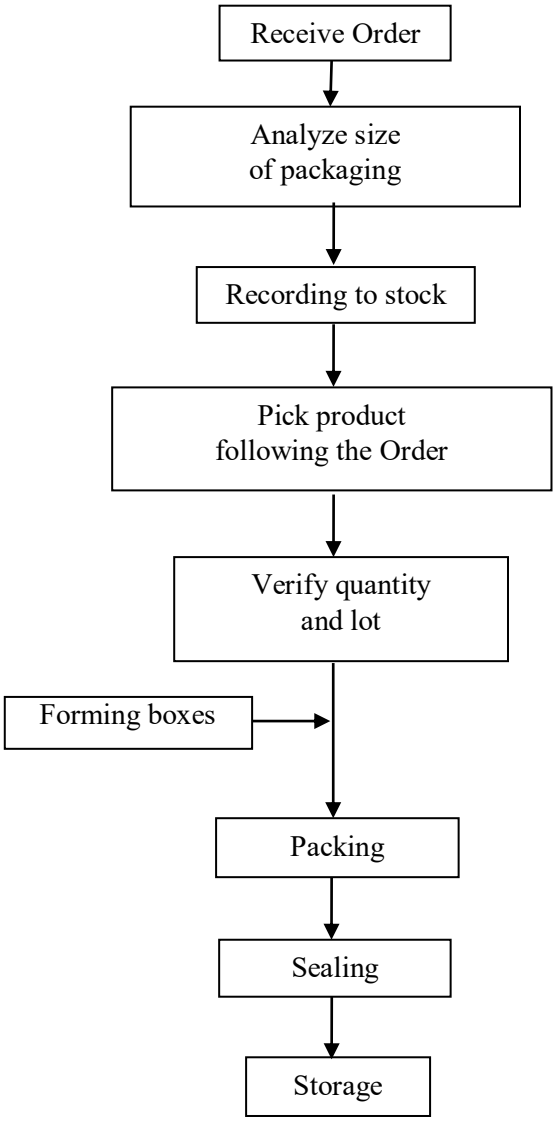

Figure 2 Operation Process Charts of work in portion 2

- Flow Process Charts

Flow Process Charts

Present √ **Proposed method** **7 Employees**
Work Organize customer orders **Part** Warehouse
Researcher Sasarose Jaijit **Atlanta Medicare Co.,Ltd**

Process	Operation	Transportation	Inspection	Delay	Storage	Notes	Distance (metre)	Time (min/order)
1	●	⇨	□	D	▽	Forming boxes		0.53
2	○	⇨	■	D	▽	Verify order papers with source document		0.08
3	●	⇨	□	D	▽	Screen orders		0.24
4	●	⇨	□	D	▽	Key data for printing crate labels		0.50
5	●	⇨	□	D	▽	Key ddata for saving to life		0.41
6	●	⇨	□	D	▽	Including crate labels and orders together		0.16
7	●	⇨	□	D	▽	Packaging size analysis		0.80
8	○	➪	□	D	▽	Send all of document (order papers, crate labels) to picking part	11	0.23
9	●	⇨	□	D	▽	Record orders into stock card		0.69
10	●	⇨	□	D	▽	Consider orders from order papers		0.02
11	○	➪	□	D	▽	Pick packaging and walk to product shelf	10.62	0.37
12	●	⇨	□	D	▽	Pick products		0.78
13	○	➪	□	D	▽	Walk to packing part	6.78	0.48
14	○	⇨	■	D	▽	Verify quantity and lot of product		0.62
15	●	⇨	□	D	▽	Packing products and order papers into box		0.65
16	○	➪	□	D	▽	Sent to sealing part	1.2	0.07
17	●	⇨	□	D	▽	Put order papers into envelope		0.64
18	●	⇨	□	D	▽	Sealing packaging		0.70
19	●	⇨	□	D	▽	Paste crate labels in front of packaging		0.80
20	●	⇨	□	D	▽	Sign signature of packer in front of packaging		0.30
21	○	➪	□	D	▽	Send the box to storage part	4.94	0.08
22	○	⇨	□	D	▼	Storage		

Conclusion

Process	Qty.		
Operation	14	**Total process**	22
Transportat	5		
Inspection	2	**Total distance (metre)**	34.54
Delay	0		
Storage	1	**Total time (min/order)**	9.15

Figure 3 Flow Process Charts of work in portion 2 (before improving or present)

Flow Process Charts

Present **Proposed method** √ **7 Employees**
Work Organize customer orders **Part** Warehouse
Researcher Sasarose Jaijit **Atlanta Medicare Co.,Ltd**

Process	Operation	Transportation	Inspection	Delay	Storage	Notes	Distance (metre)	Time (min/order)
1	●	⇨	□	D	▽	Forming boxes		0.53
2	○	⇨	■	D	▽	Verify order papers with source document		0.08
3	●	⇨	□	D	▽	Key data for printing crate labels		0.19
4	●	⇨	□	D	▽	Including crate labels and orders together		0.16
5	●	⇨	□	D	▽	Packaging size analysis		0.45
6	●	⇨	□	D	▽	Scan barcode and print picking order paper		0.12
7	○	➪	□	D	▽	Send all of document (order papers, crate labels) to picking part	4.2	0.14
8	●	⇨	□	D	▽	Consider orders from order papers		0.02
9	○	➪	□	D	▽	Pick packaging and walk to product shelf	10.62	0.37
10	●	⇨	□	D	▽	Pick products		0.78
11	○	➪	□	D	▽	Walk to packing part	10.4	0.57
12	●	⇨	□	D	▽	Separate product follow order papers		0.49
13	●	⇨	□	D	▽	Verify quantity and lot of product		0.62
14	●	⇨	□	D	▽	Packing products and order papers into box		0.65
15	○	➪	□	D	▽	Sent to sealing part	1.2	0.07
16	●	⇨	□	D	▽	Put order papers into envelope		0.64
17	●	⇨	□	D	▽	Sealing packaging		0.21
18	●	⇨	□	D	▽	Paste crate labels in front of packaging		0.80
19	●	⇨	□	D	▽	Sign signature of packer in front of packaging		0.30
20	●	⇨	□	D	▽	Sealing packaging by tying machine		0.27
21	○	➪	□	D	▽	Send the box to storage part	3.57	0.08
22	○	⇨	□	D	▼	Storage		

Conclusion

Process	Qty.		
Operation	14	**Total process**	22
Transportat	5		
Inspection	2	**Total distance (metre)**	29.99
Delay	0		
Storage	1	**Total time (min/order)**	7.53

Figure 4 Flow Process Charts of work in portion 2 (proposed method)

Before timing can take place, the number of rounds timed must be calculated. This research requires the number of rounds timed set at 95% level of trust and no more than 15% level of error, [8] calculated using at the following formula.

$$N = (13.33\sqrt{n\sum X^2 - (\sum X)^2} / \sum X)^2 \qquad (1)$$

1.3.4 Determine areas for improvement.

- Improve the methodology.

- Apply an ERP system to facilitate and increase speed in printing crate labels and packaging size analysis. [14] study the implementation of Enterprise Resource Planning (ERP) in the Peoples' Republic of China which entails Triple Play installation of ERP or an integrated process among personnel, technology, and process.

- Improve tools and facilitation equipment.

- Apply box tying machines to assist in sealing instead of transparent tape.

- Improve employees' work environment.

- Arrange pharmaceuticals on shelves for convenience in retrieval.

- Improve the layout of shelves to make it easier to pick up pharmaceuticals.

2. Consider and seek solutions by means of brainstorming techniques.

3. Assess various comparisons to seek the optimal answer.

3.1 Compare time results during work operations from the Flow Process Chart before and after improvement.

3.2 Compare the increased or reduced costs incurred and further analyze the breakeven point in case of additional purchased equipment to replace original materials or equipment.

3.3 Compare the original walking route to retrieve pharmaceuticals with the new shelf type.

3.4 Compare the amount of returned pharmaceuticals prior to notification of return policy issued to clients with after the notification of return policy or conditions issued to clients.

4. Provide suggestions and follow-up results.

2.2 Forecasting

Forecasting is the use of historic data to determine the direction of future trends, [10]. From the list of 47 pharmaceutical products certain items will be selected by Numerical Scoring method combining with ABC Analysis principles.

1. Gather consumer demand data of pharmaceuticals and consider past data over a period of 18 months.

2. Rank the importance of pharmaceuticals by 3 decision factors as follows.

- Profit per unit.
- Storage area utilized per unit.
- Sales volume over the period of 18 months.

The Numerical Scoring Model is applied with the following details.

2.1 Determine the weight values in each factor whereby Profit Per Unit carries a weight percentage value equal to 0.2; Storage Area Per Unit equal to 0.02; and Sales Volume equal to 0.78, [11].

2.2 Each pharmaceutical item is scored in each factor by a range divided into 5 equal periods whereby the scores in Period 1 to Period 5 contain values equal to 20 40 60 80 and 100 respectively.

2.3 Each pharmaceutical item in each factor is considered to determine the factor's score period, after which each pharmaceutical item in each factor is scored accordingly.

2.4 The weight score value of each factor is calculated from the formula.

$$S_W = S \times W \qquad (2)$$

2.5 Seek the total weight score of 3 factors from the formula.

$$T_{S \times W} = S_1W_1 + S_2W_2 + S_3W_3 \qquad (3)$$

3. Rank the total weight score value of each product from highest to lowest then group according to importance by application of ABC Analysis and consider specific forecasting of products in Group A with the following grouping conditions, [5]

- Group A consists of 10 percent of all product items.
- Group B consists of 30 percent of all product items.
- Group C consists of 60 percent of all product items.

4. Select forecasting methods consistent with data characteristics measured from MAPE values lower than the forecasted values by contrasting techniques, [7]. This research compares MAPE results from two forecasting techniques i.e. Simple Exponential Smoothing

and Double Exponential Smoothing. Use of these two techniques arises from the data characteristics of demand from the graph shown in Figure 5 to Figure 9. The result is shown in randomness form. However, some items of pharmaceuticals such as A1 A2 and A3 pharmaceuticals are not clear to show in the trend characteristics. So, this is the reason for using two techniques that mentioned before.

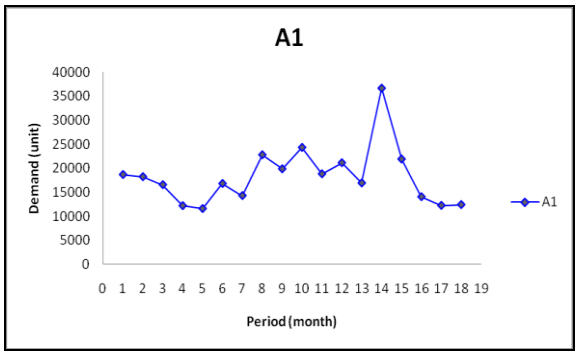

Figure 5 Characteristics of demand A1

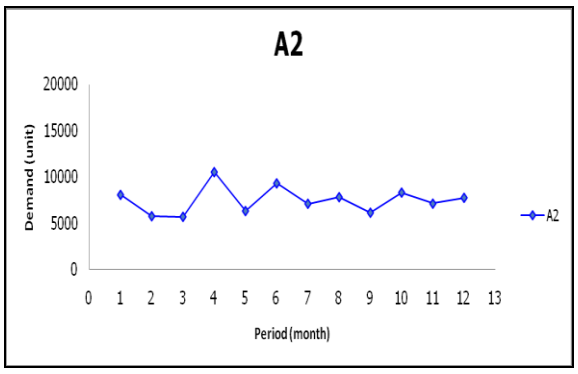

Figure 6 Characteristics of demand A2

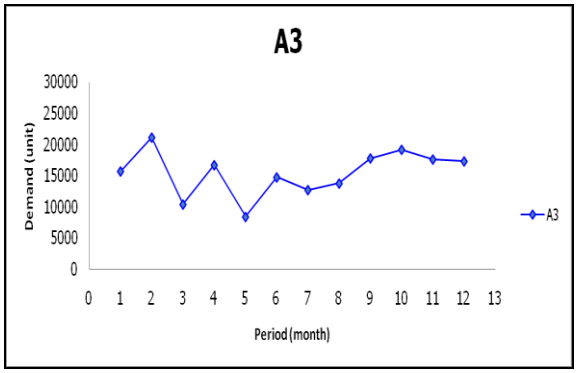

Figure 7 Characteristics of demand A3

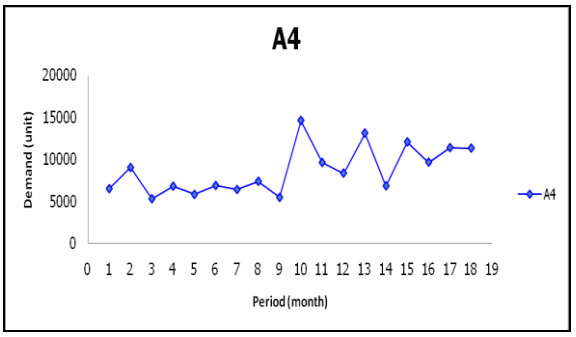

Figure 8 Characteristics of demand A4

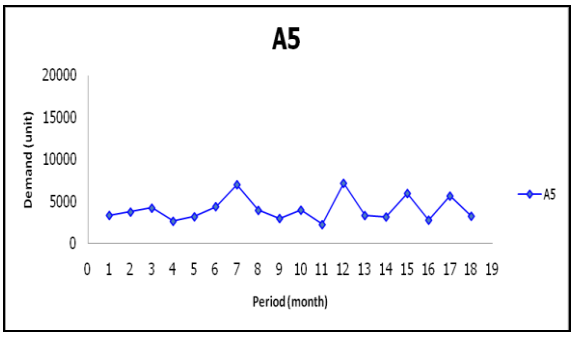

Figure 9 Characteristics of demand A5

Using Minitab program version 15 for analyze MAPE value of two techniques that show the result in Figure 10 to Figure 14.

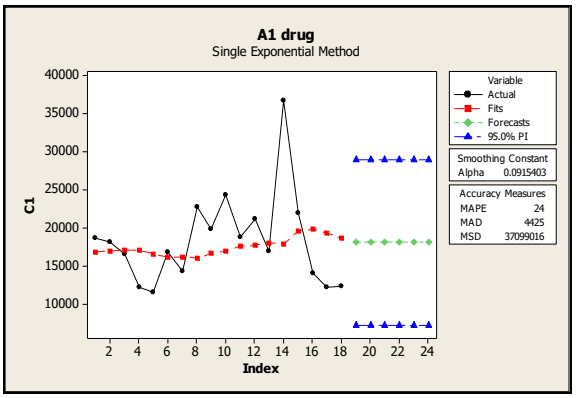

Figure 10 (a) data characteristics of demand from plotted graph by Minitab15 for A1 pharmaceutical

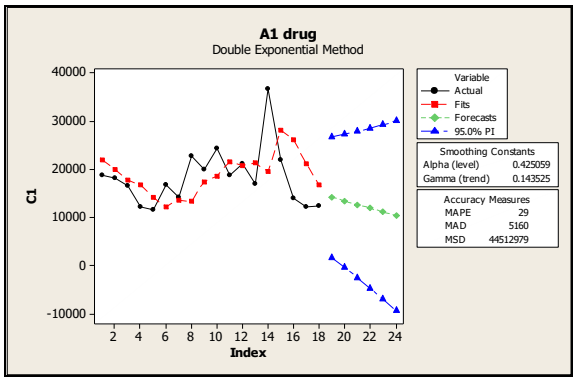

Figure 10 (b) data characteristics of demand from plotted graph by Minitab15 for A1 pharmaceutical

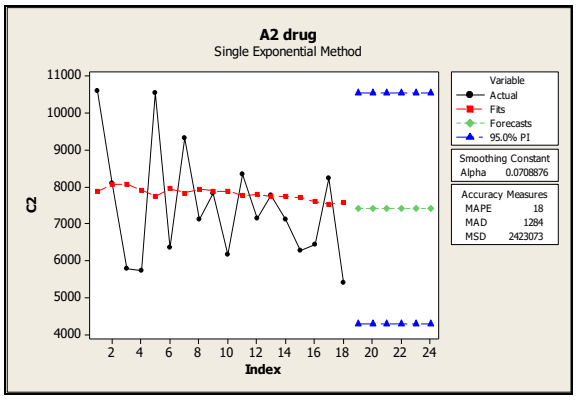

Figure 11 (a) data characteristics of demand from plotted graph by Minitab15 for A2 pharmaceutical

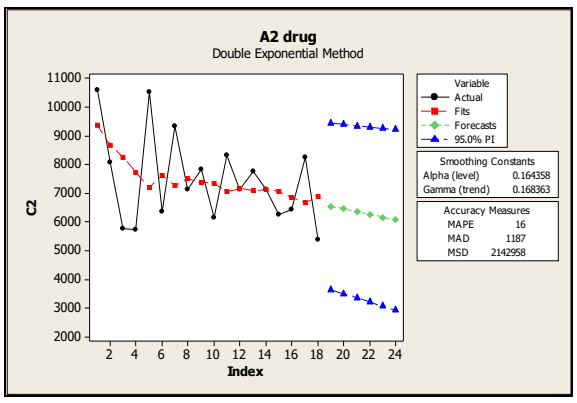

Figure 11 (b) data characteristics of demand from plotted graph by Minitab15 for A2 pharmaceutical

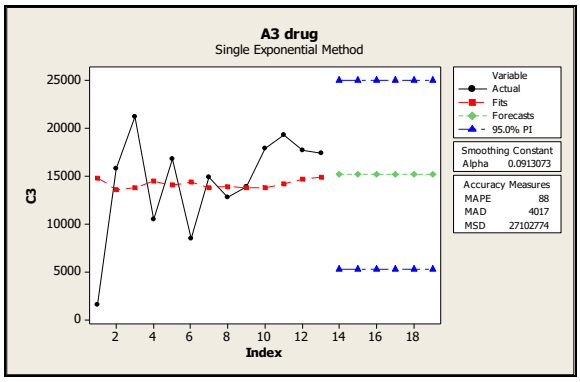

Figure 12 (a) data characteristics of demand from plotted graph by Minitab15 for A3 pharmaceutical

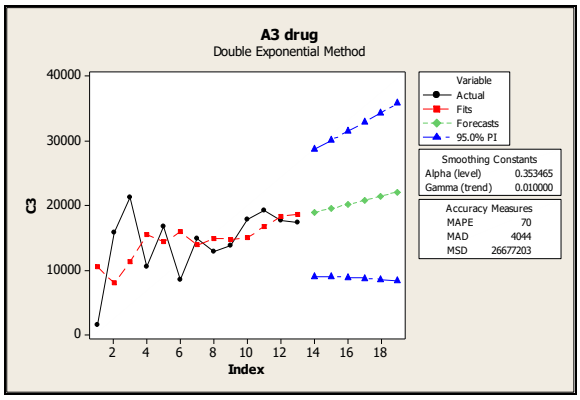

Figure 12 (b) data characteristics of demand from plotted graph by Minitab15 for A3 pharmaceutical

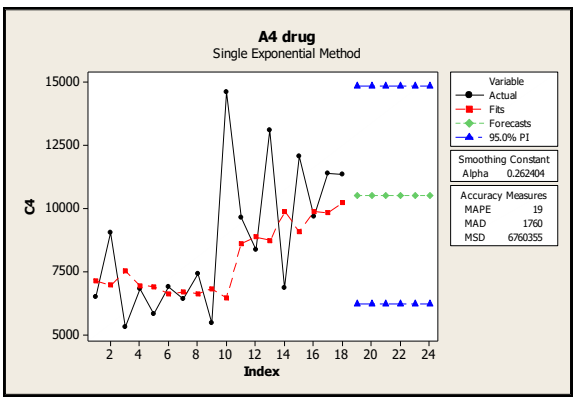

Figure 13 (a) data characteristics of demand from plotted graph by Minitab15 for A4 pharmaceutical

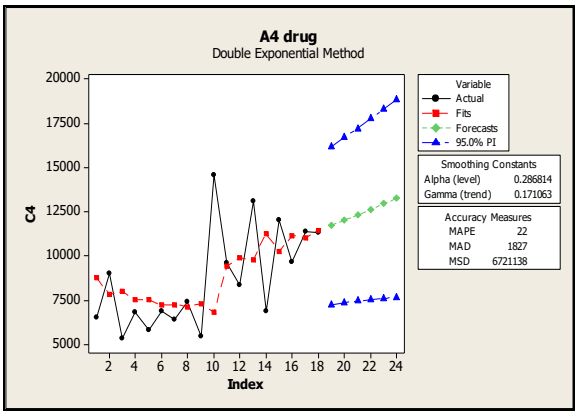

Figure 13 (b) data characteristics of demand from plotted graph by Minitab15 for A4 pharmaceutical

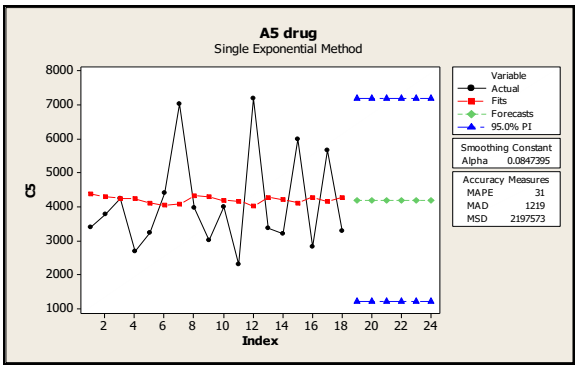

Figure 14 (a) data characteristics of demand from plotted graph by Minitab15 for A5 pharmaceutical

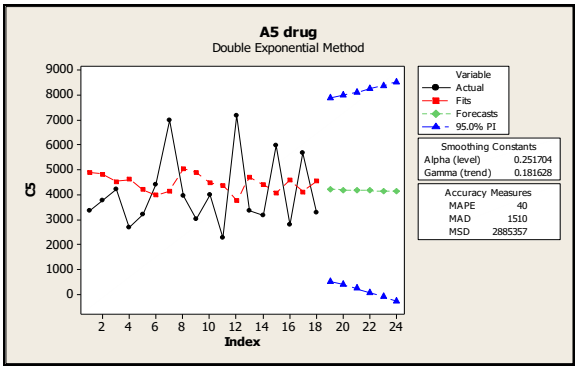

Figure 14 (b) data characteristics of demand from plotted graph by Minitab15 for A5 pharmaceutical

2.3 Inventory Management

The purpose of inventory management is to determine optimization. This model identifies the variables requiring attention. It includes calculations of cost and estimate of stock, [1].

1. Consider the specific data of product items in Group A.
2. Examine the manufacturing sources of pharmaceuticals in Group A to determine if they originated from single manufacturer or not.
3. Select the methods of considering sales order that are appropriate to the data.

Since the pharmaceutical data under consideration is comprised of data with independent and constant demand within a constant lead times, consideration under assumption of constant demand can be explained by coefficient of variation (c.v.) value and is not over 0.2, [4]. Coefficient of variation is calculated from the formula.

$$\text{c.v.} = \frac{\text{estimate var D}}{\bar{d}^2} \qquad (4)$$

The value of c.v. in each pharmaceutical are as follows in Table1

Table 1 Value of coefficient of variation (c.v.)

Item	Coefficient of variation value
A1	0.05
A2	0.02
A3	0.06
A4	0.11
A5	0.14

Considering the c.v. value of each pharmaceutical was found not to exceed 0.2 on the terms described above. Therefore, a model inventory of the constant demand or deterministic model can be applied. So, there are two models to consider and compare, namely the Fixed Order Quantity System and the Fixed Order Period System, [13] as follows:

3.1 Fixed Order Quantity (FOQ: EOQ), [9]

- Calculation of size of model ordered (Q^*) must be equal each time during each order period:

$$Q^* = \sqrt{2SD/H} \qquad (5)$$

- Calculation of order distance (T^*):

$$T^* = Q^*/D = \sqrt{2S/HD} \qquad (6)$$

- Calculation of order cost ($TC(Q^*)$):

$$TC(Q^*) = \sqrt{2SHD} + CD \quad (7)$$

- Calculation of reorder point (ROP):

$$ROP = D \times LT \quad (8)$$

- Calculation of safe stock level (ss):

$$ss = Z_\alpha \times \sigma_d \sqrt{LT} \quad (9)$$

Where：

- α is the value of chance of lack of goods obtained from:

$$SL_c = 1 - \mathrm{P}(M > B) \quad (10)$$

when the company sets a customer service level policy at 95%.

- σ_d is standard deviation in lead time

3.2 Fixed Order Period System (FOP: EOI), [9]

Cases with multiple pharmaceutical items ordered

Five items of pharmaceuticals that ordered from two suppliers. A1, A3 and A4 are orders from supplier 1. A2 and A5 are orders from supplier 2. These two cases are calculated separately as follows below:

Case 1: Ordered from Supplier 1

- Calculation of distance between multiple orders (T^*):

$$T^* = \sqrt{\frac{2S}{H_1D_1 + H_2D_2 + H_3D_3}} \quad (11)$$

- Calculation of size of model ordered (Q^*):

$$Q^* = D \times T^* \quad (12)$$

- Calculation of multiple order costs ($TC(T^*)$):

$$TC(T^*) = (C_1D_1 + C_2D_2 + C_3D_3) + \sqrt{2S(H_1D_1 + H_2D_2 + H_3D_3)} \quad (13)$$

- Calculation of reorder point (ROP):

$$ROP = D \times LT \quad (14)$$

- Calculation of safe stock level (ss):

$$ss = Z_\alpha \times \sigma_d \sqrt{LT + T^*} \quad (15)$$

Where：

- α is the value of chance of lack of goods obtained from:

$$SL_c = 1 - \mathrm{P}(M > B) \quad (16)$$

when the company sets a customer service level policy at 95%.

- σ_d is standard deviation in lead time

Case 2: Ordered from Supplier 2

- Calculation of distance between multiple orders (T^*):

$$T^* = \sqrt{\frac{2S}{H_1D_1 + H_2D_2}} \quad (17)$$

- Calculation of size of model ordered (Q^*):

$$Q^* = D \times T^* \quad (18)$$

- Calculation of multiple order costs ($TC(T^*)$):

$$TC(T^*) = (C_1D_1 + C_2D_2) + \sqrt{2S(H_1D_1 + H_2D_2)} \quad (19)$$

- Calculation of reorder point (ROP):

$$ROP = D \times LT \quad (20)$$

- Calculation of safe stock level (ss):

$$ss = Z_\alpha \times \sigma_d \sqrt{LT + T^*} \quad (21)$$

Where：

- α is the value of chance of lack of goods obtained from:

$$SL_c = 1 - \mathrm{P}(M > B) \quad (22)$$

when the company sets a customer service level policy at 95%.

- σ_d is standard deviation in lead time

3.3 Compare the total annual cost, by considering the two order forms against the actual selection of the form that incurs the lowest total annual costs (of which at present the Company applies EOQ to orders), [15].

3. Results

Not only the combined application of Industrial Work Study Techniques and Inventory Management Techniques solve problems encountered in the original work model and increase the competitiveness of the organization, but also the following results is obtained:

3.1 Total reduced expenses:

1. Changed box and sealing methods.
2. Less overtime payments when work hours reduce, as a result of improvements.
3. Changed order practices from the Fixed Order Quantity (EOQ) to a Fixed Order Period (EOI) system.

Total savings of 489,032.02 baht/year (0.58%)

3.2 Working hours reduced by (17.70% after) applying the techniques. This comparison is shown in Figure 3 and Figure 4.

- From using ERP system and improving layout of shelves can adjust the third, fourth, fifth seventh eighth and thirteenth process that shown in the Figure 3 to become the new processes in the third, fifth, sixth, seventh, eleventh and twelfth processes which are shown in the Figure 4. The outcome can save 0.71 min/order of the processing time and reduce stock card in the ninth process in the Figure 3 that save 0.69 min/order of the processing time.

- After adjusting pattern to seal from using only tape (process 18 in the Figure 3) for 0.7 min/order using box tying machines (process 20 in the Figure 4) and also using tape (process 17 in the Figure4) in total time of 0.48 min/order. This way can save 0.22 min/order of the processing time.

3.3 Increase order volume efficiency by 422 order per month which is equal to 24.10%.

In areas forecasted by MAPE comparison, we choose to apply forecasting techniques that offer the lowest MAPE value, as shown in the comparison of MAPE value from Minitab program in Table2.

Table 2 Comparison of MAPE value from Minitab program

Item	MAPE value	
	Simple Exponential Smoothing	Double Exponential Smoothing
A1	24	29
A2	18	16
A3	88	70
A4	19	22
A5	31	40

Simple Exponential Smoothing applies an advance demand volume forecast for A1, A4, and A5 pharmaceuticals, whereas Double Exponential Smoothing applies an advance demand volume forecast for A2 and A3 pharmaceuticals.

In the result of inventory management from two models to consider and compare, namely the Fixed Order Quantity System and the Fixed Order Period System as follows in Table 3 to Table 6:

Table 3 Parameters of inventory management (EOQ) for each item

Item	EOQ				
	Q^* (boxes)	T^* (year)	$TC(Q^*)$ (baht/year)	ROP (boxes)	SS (boxes)
A1	3,341	0.016	15,160,562	1,180	2,222
A2	810	0.011	27,598,868	773	2,352
A3	3,470	0.019	10,496,324	1,019	2,596
A4	2,676	0.029	4,346,551	505	1,290
A5	586	0.012	25,669,982	539	3,541

Table 4 Parameters of inventory management (EOI: Supplier 1) for each item

Item	EOI				
	Q^* (boxes)	T^* (year)	$TC(Q^*)$ (baht/year)	ROP (boxes)	SS (boxes)
A1	2,376	0.011		1,180	3,849
A3	2,053	0.011	29,929,319	1,019	4,496
A4	1,017	0.011		505	2,234

Table 5 Parameters of inventory management (EOI: Supplier 2) for each item

Item	EOI				
	Q^* (boxes)	T^* (year)	$TC(Q^*)$ (baht/year)	ROP (boxes)	SS (boxes)
A2	538	0.008	53,208,889	773	3,111
A5	407	0.008		539	4,684

Table 6 Comparison of total annual cost

Item	Supplier	$TC(Q^*)$ (baht/year)	
		EOQ	EOI
A1	Supplier 1	15,160,562	
A3		10,496,324	29,929,319
A4		4,346,551	
A2	Supplier 2	27,598,868	53,208,889
A5		25,669,982	
Total		83,272,287	83,138,208

4. Conclusion

To summarize, after applies three techniques for eliminate the various problematic and optimize the response to consumer demand which enhance potential competitiveness. The research focus on topics of reducing cost and time. The following results have been obtained:

1. Operation times saving with 1.62 min/order (17.70%), as shown in Figure 3 and Figure 4.
2. Cost saving with

- Cost of over time saving with 16,826 baht/month (41.57%).

- Cost of improving operation from create new box's pattern that saving with 1,543 baht/month (7.55%).

In two cases of cost saving that show comparing in Figure 15.

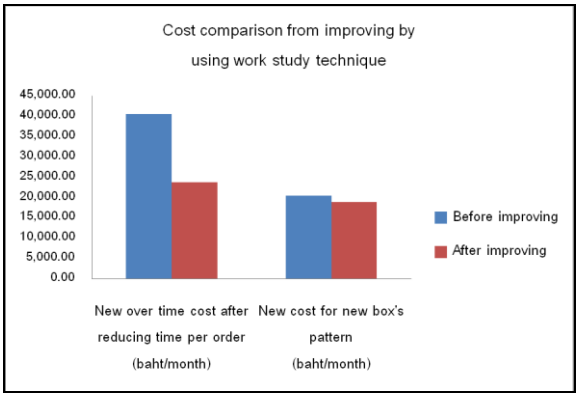

Figure 15 cost comparison from improving by using work study technique

- Cost of inventory saving with 134,079 baht/year (0.16%), that show comparing in Figure 16.

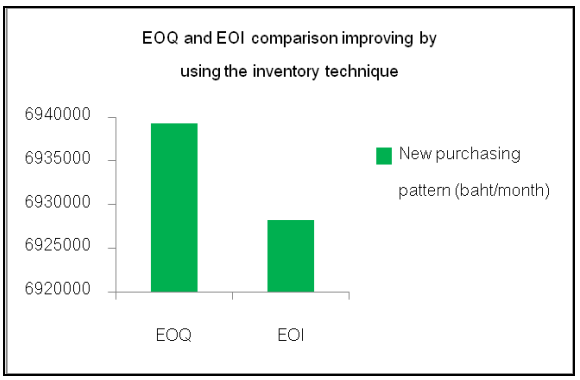

Figure 16 EOQ and EOI comparison, improving by using the inventory technique.

Therefore, this research has helped the organization to increase profit by decreasing cost and reducing the time of the working process. These are the methodologies used to improve and develop the organization and to enhance competitiveness.

5. Acknowledgements

This research was supported by Atlanta Medicare Company Limited and the Department of Industrial Engineering. I would like to express my sincere thanks to my thesis advisor, Dr.Punnamee Sachakamol for his invaluable help and constant encouragement throughout the course of this research. In addition, I am grateful to Asst. Prof. Dr.Nantachai Kantanantha for his suggestions and all his help. Finally, I most gratefully acknowledge my parents and my friends for all their support throughout the period of this research.

REFERENCES

[1] Apiprachyasakul, K. Inventory management. 1st ed. Bangkok, Focus media and publishing, 2010. (In Thai).
[2] Barnes, R.M. Motion and Time Study. New York, John Wiley and Sons Inc, 1980.
[3] About patient reports. Bureau of policy and strategy ministry of public health, Thailand, 2011. [Online] available: http://bps.ops.moph.go.th/Healthinformation/ill54/ill-full2554.pdf
[4] Chetthisong, P. Determining Replenishment Period of Outsourcing Materials with Non-Constant Demands and Uncertain Unit Purchase Costs. M. Eng. Thesis, Kasetsart University, 2004.
[5] Hanke J.E. and J.E. Business forecasting. United States of America: Simon & Schuster Inc, 1940.
[6] Kanjanapanyakom, R. Industrial work study. 1st ed. Bangkok: Top, 2009. (In Thai).
[7] Ren, L.Y., Glasure Y. Revised mean absolute percentage errors (Mape) on errors from simple exponential smoothing methods for some popular non-normal independent time series. *Journal of American Academy of Business*, Cambridge. 2009; 14(2): 357-362.

[8] Rijiravanich, W. Work study. 8th ed. Bangkok, Chulalongkorn University, 2012. (In Thai).
[9] Supithak, W. Inventory theory. Bangkok, Kasetsart University, 2010. (In Thai).
[10] Suvanwong, S. Quantitative forecasting. 1st ed. Nakhon Pathom, Mahidol University, 2013. (In Thai).
[11] Takazawa, K. A weighted even factor algorithm. *Math. Program*, 2008; 115: 223–237.
[12] Tersine, R.J. Principles of Inventory and Materials Management. New Jersey, Prentice Hall, 1994.
[13] Water, D. Inventory Control. England, John Wiley and Sons Inc, 2007.
[14] Yusuf, Y. and Gunasekaran, A. and Wu, C. Implementation of enterprise resource planning in China (Electronic version). *Technovation*, 2006; 26(12): 1324-1336.
[15] Zipkin, P.H. Foundations of Inventory Management. Irwin, McGraw-Hill, 2000.