International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 /doi:10.14445/22315381/IJETT-V69I6P220
Volume 69 Issue 6, 131-135, June 2021

Aggregate Production Planning of Ethanal-based Hand Sanitizer to Meet Rising Demand During Covid19 Pandemic in Thailand

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Abstract - *Aggregate production planning (APP) is often used in logistic management and has direct effects on manufacturing system. APP is capacity planning which determines suitable levels of amount of worker, production strategy and inventory control. In this study, a ethanal-based hand sanitizer manufacturing company was used as a case study. Key concern of the company was that they were unable to distribute products to customer on schedule which affected customers' satisfaction. In this paper, an optimization model was developed to solve the APP problem in an environment of uncertainty demand. This study used six forecasting methods consisting of the moving average, exponential, double exponential, linear trend, quadratic trend and Winter's method. The accuracy of forecasting was measured by the lowest mean absolute percent error. The computational results show Winter's method was the best forecasting method because of its lowest mean absolute percent error of 18. The demand results from Winter's model was then used for APP with different five demanding scenario. The findings reveal the production cost for normal demand was lowest at 1,116,730 Baht and increased to 1,336,596.00 Baht when increased demand by 20 percent.*

Keywords — *forecasting method, aggregate production planning, cosmetic company*

I. INTRODUCTION

Production planning and control has the main objective to allocate limited resources for maximizing benefit and increasing customer satisfaction. Maximizing use of limited resources is a key responsibility of factory managers through production planning and manage departments and persons with duties involving forecasting, planning, work scheduling, analysis, inventory control and production operations control. These production control basics and techniques can be used in other areas of service work such as department store inventory control and sales forecasting techniques.[1]

The manufacturing has experienced difficulties in business operations due to economic changes, causing businesses to face problems ranging from employment problems to investment problems. Therefore, businesses or organizations need to improve and increase capacity to be able to compete in various fields such as price, quality and use technology to improve operations in order to meet customer needs and satisfaction as much as possible to provide quality goods and services and be able to compete with competitors.

The outbreak of Covid19 has impacted health systems, created economic crisis, and disrupted supply chains. There has been a great surge in demand for alcohol-based hand sanitization products resulting in supply shortages. A case study of ethanal-based hand sanitizer manufacturing company in Thailand faced problems of limited supply to meet huge demand during pandemic; however, demand might drop sharply once the pandemic is over. APP is a promising method to forecast suitable inventory levels relative to customer demand and Covid19 situation.

II. THEORY AND LITERATURE REVIEW

A. Aggregate Production Planning

Aggregate Production Planing (APP) is production planning to meet expected demand in a specific time horizon ranged from 2 to 12 or 18 months with the objective of specifying production plan and capacity to be used for the next year by making consideration from data on demand, inventory levels, production capability, costs of materials and policies of each company including overtime and worker limit or new products or processes in the production line.

APP can support information for using in production schedules. APP is related to the organizations' activities and operations in the manufacturing. APP is often used for planning resources such as labor management, raw material optimalization and machine utilization [2]. The objective of APP consists of lowest production costs, maximize utilization and inventory control. The generic aggregate production planning model based on integer linear programming proposed by Anand Jayakumar et.al. in 2017. [3] Components of the model included material costs, labor and overtime costs, hiring and laying labor cost, inventory and product shortage cost as shown in Equation (1). Equations (2) – (7) are production, labor, overtime cost and variable constrain.[4].

$$Min\ Z = \sum_{t=1}^{6} RcW_t + \sum_{t=1}^{6} OcO_t + \sum_{t=1}^{6} HcH_t + \sum_{t=1}^{6} LcL_t + \sum_{t=1}^{6} ScS_t + \sum_{t=1}^{6} McP_t + \sum_{t=1}^{6} CcC_t + \sum_{t=1}^{6} IcI_t \quad (1)$$

Constraints

$$Min\ W \leq W \leq MaxW \quad (2)$$
$$Ot_t \leq Otmax \quad (3)$$
$$P_t = (W_h * W_i + Ot_i) * P_r \quad (4)$$
$$W_t = W_{t-1} + H_t - L_t \quad (5)$$
$$I_{i-1} + P_t + C_t = D_t + S_{t-1} + I_t - S_t \quad (6)$$
$$W_t, O_t, H_t, L_t, I_t, S_t, P_t\ and\ C_i \geq 0 \quad (7)$$

Decision Variables

t = Forecasting time
N = Number of Product
W_t = workforce size
O_t = overtime hours per month
H_t = employees hired per month
L_t = employees laid off per month
S_t = number of units stocked out/backlogged
P_t = number of units produced
C_t = number of units subcontracted
I_t = number of inventories at the end

B. Forecasting Methods

To predict customer demand, a time series forecasting method was analyzed using the Minitab program. The forecasting methods consisted of moving average, simple exponential smoothing, double exponential smoothing, winter's and seasonal exponential smoothing, linear trend and quadratic trend method. Accuracy of forecasting methods were measured using mean absolute percent error (MAPE), a value for comparing forecasting efficiency as shown in Equation 8, which compared effectiveness of forecasting methods. [5]

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\frac{|A_t - F_t|}{A_t} \quad (8)$$

MAPE = mean absolute percentage error
n = number of times the summation iteration happens
A_t = actual value
F_t = forecast value

Mean absolute percent error is a measurement of forecasting deviations compared to real values. Lower MAPE indicated high forecasting accuracy.

APP is often used in many industries. For example, a previous study conducted by Paiva and Morabito in 2009 applied the mixed integer APP programming to sugar and ethanol milling industries. [6] In automotive industries, Sillekens, et.al proposed a mixed integer linear programming model for an APP solve by linear approximation method. [7] César rosero-mantilla *et.al. on 2017* increased the production capacities by applying the APP model to enhance production efficiency in the rubber line industry.[8] Antonio Campo et al. [9] proposed an aggregate production planning model to determine appropriate strategies for a textile company. Endah Rahayu Lestari et.al. [10] applied dynamic programming approach solving aggregate production planning in scenario study of biscuit factory.

In solving aggregate production planning problems, several researchers applied meta-heuristic methods. The meta-heuristics for solving complex optimization problems is an important in the area of minimize cost and maximum profit. The solutions of metaheuristic methods may not be the most suitable and best solutions cannot be guaranteed from every data processing. Solutions were accepted and found in an appropriate time. [11] Therefore, meta-heuristic methods were widely accepted in many fields of research. Meta-heuristic methods such as genetic algorithm [12], particle swarm optimization [13], harmony search algorithm, [14] firefly algorithm[15] and elevator kinematic optimization [16] were used to solve aggregate production planning problems. APP is key system for business operations for increasing manufactorers' capacity to prioritization and machine utilization. Therefore, this research explored APP to recommend methods with the lowest production cost and being able to meet customer demand on schedule.

III. RESEARCH METHODOLOGY

A. Data Collection

Retrospective demand data from 29 weeks were collected for aggregate production planning for the company in the case study as shown as scatter plot in Fig. 1 and box plot in Fig. 2.

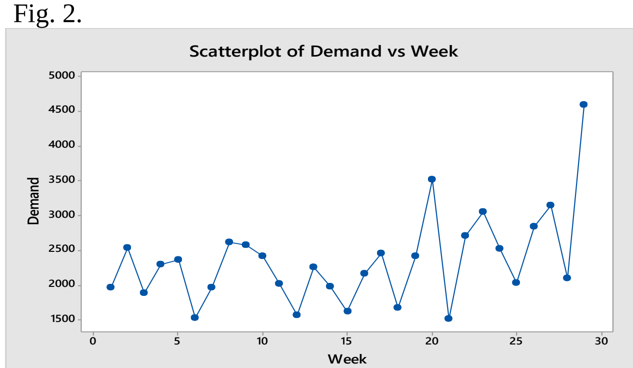

Fig. 1 The graphical plot of demand from 29 weeks

In Fig. 1, demand was fluctuating across time period. This could be situation of Covid19 infection in Thailand and economic crisis.

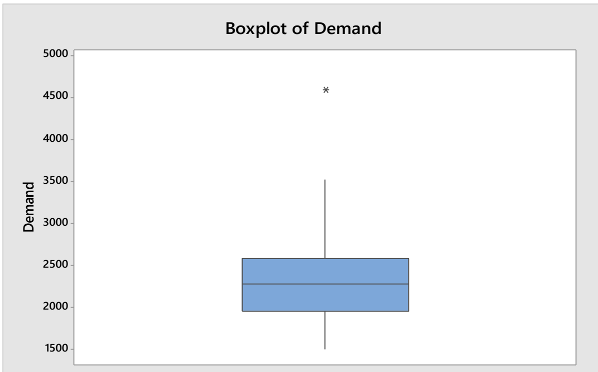

Fig. 2 The graphical plot of demand from 29 weeks

B. Aggregate Production Planning Problems

Production planning and control is the first process of production system management. Furthermore, production planning and control is a decision-making strategy in estimating and allocating resources such as manpower, machines, and materials. Aggregate production planning is planning to determine the number of products and times when products should be manufactured in relation to customer demand while remaining consistent with the company's production capacity according to information shown in TABLE I.

TABLE I
DATA FOR AGGREGATE PRODUCTION PLANNING

Data	Quantity
Materials cost	42 Baht/kg
Production volume in normal time	50 kg /work/day/person
The amount of production during overtime	20 kg work/day/person
The largest number of combined overtime hours	$\leq$ 24 hour/week
Inventory Cost (Ic)	50 Baht/kg
Stocked out Cost (Sc)	120 Baht/kg
Hired Cost (Hc)	500 Baht/person
Laid off Cost (Lc)	1500 Baht/person
Recruitment Cost (Rc)	4000 Baht/week
Overtime Cost (Oc)	60 Baht/hour
Subcontracted Cost (Ct)	120 Baht/kg
Inventory quantity	50 kg
Final inventory amount	50 kg
The amount of product shortage in the last month	0 kg
Workforce size	5 persons
Working time	5 day/week

According to TABLE I, necessary data for aggregate production planning consisted of data on capacity, aggregate units and expenses such as raw material costs, labor costs, overtime wages, contract hiring, costs from hiring more employees and costs from dismissing employees, etc.

IV. COMPUTATION RESULTS AND ANALYSES

TABLE II Table 2 shows forecasting errors (MAPE) form different method using the Minitab program.

TABLE II
FORECASTION ERRORS

Forecasting Models	MAPE
Moving Average N=3	21.00
Moving Average N=5	23.00
Single Exponential Smoothing α = 0.175	20.00
Double Exponential Smoothing α = 0.11 and γ = 0.41	20.00
winter's method α = 0.25 , β = 0.25 and γ = 0.25 (Multiplicative Method)	18.00
Linear Trend Model (Y_t = 1841 + 3.42×t)	20.00
Quadratic Trend Model (Y_t = 2389 - 71.8×t + 3.54×t^2)	18.00

Demand from forecasting obtained from the winter's method and quadratic trend method shows the lowest mean absolute percent error (MAPE) as shown in TABLE II, Fig. 3 and 4.

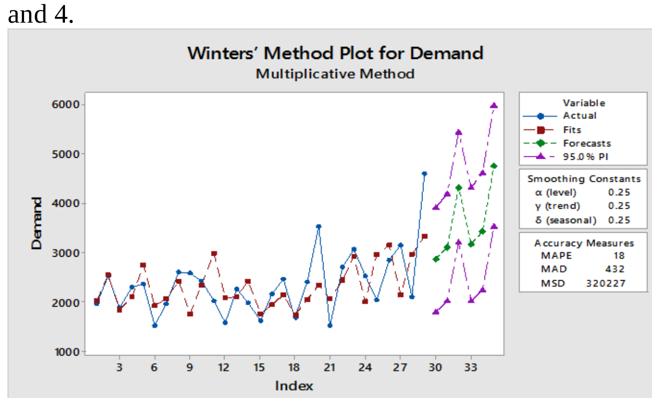

Fig. 3 The graphical plot of demand with winter's method

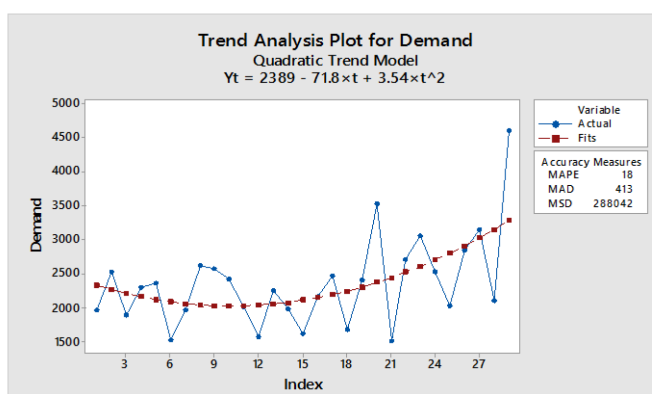

Fig. 4 The graphical plot of demand with quadratic trend method

Therefore, the researchers used forecasting method from the quadratic equation model in aggregate production planning for the case study company. This study applied mathematical programs to calculate appropriate production planning by creating hypothetical situations to determine solution models before comparing costs in each option. This study designed comparisons in the following 5 scenarios:

Scenario A – Forecasting demand by the winter's method
Scenario B – Forecasting demand at 10% Lower
Scenario C - Forecasting demand at 10% Higher
Scenario D - Forecasting demand at 20% Lower
Scenario E - Forecasting demand at 20% Higher

Analysis of lowest production cost was performed by applying the LINGO program, Version 13, to solve problems in each scenario as shown in TABLE III.

TABLE III.
SIMULATION FOR AGGREGATE PRODUCTION PLANNING

Demand	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Week1	2,860	257	315	229	343
Week2	3,104	279	341	248	372
Week3	4,320	389	475	346	518
Week4	3,170	285	349	254	380
Week5	3,427	309	377	274	412
Week6	4,756	428	524	381	571
Total Cost	1,116,730	1,003,172	1,228,288	896,864	1,336,596

TABLE IV - VII show the number of workers per month, total overtime per month, number of workers hired and number of workers laid off each week in Scenarios A-E.

TABLE IV.
NUMBER OF WORKERS

Scenario	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Scenario A	5	5	7	5	6	11
Scenario B	4	5	6	5	5	10
Scenario C	5	6	8	6	6	12
Scenario D	4	4	6	4	5	9
Scenario E	6	6	8	6	7	13

TABLE V.
TOTAL OVERTIME

Scenario	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Scenario A	78	92	128.5	96	96.5	206
Scenario B	76.2	77	119.4	80.15	91.85	183.4
Scenario C	92.3	95.5	137.6	99.35	113.65	228.6
Scenario D	61.9	74	97.8	76.8	74.7	160.8
Scenario E	94.1	111	159.2	115.2	118.3	251.2

TABLE VI.
NUMBER OF HIRING WORKER

Scenario	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Scenario A	1	0	2	0	1	5
Scenario B	0	1	1	0	0	5
Scenario C	1	1	2	0	0	6
Scenario D	0	0	2	0	1	4
Scenario E	2	0	2	0	1	6

TABLE VII.
NUMBER OF LAYOFF WORKER

Scenario	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Scenario A	0	0	0	2	0	0
Scenario B	0	0	0	1	0	0
Scenario C	0	0	0	2	0	0
Scenario D	0	0	0	2	0	0
Scenario E	0	0	0	2	0	0

V. CONCLUSION AND FUTURE WORK

This study applied forecasting methods and APP to obtain lowest production cost in various scenarios. The computational results show Winter's and Quadratic Trend method were the most efficient forecasting method because of theirs lowest mean absolute percent errors of 18. The scenario A caused cheapest production cost (1,116,730 Baht) based on forcasting demand values by the winter's method. In Scenario B, decreasing demand by 10 percent, production cost was equal to 1,003,172 Baht. In Scenario C, increasing demand by 10 percent, production cost was increased to1,228,288 Baht. In Scenario D, decreasing demand by 20 percent, production cost was 896,864 Baht. In Scenario E, rising demand by 20 percent, production cost was 1,336,596 Baht. As a result, the company was able to increase efficiency and customer satisfaction. Variation of demands in each scenario could be due to a variety of production models and different production factors. Therefore, design of experiments can be used to develop suitable production systems and other methods such as meta-heuristic method can be applied to find solutions for complex problems. This study suggested application of multi-objective optimization a study conducted by Pongchanun [17]. and the Fuzzy Set Theory study conducted by Phruksaphanrat et al [18] as well as experimental design to develop proper production systems and reduce cycle time. Therefore, consideration should be given to uncertain demand [19] , more diverse inventory [19] and application of other programs for solving problems to obtain values quickly with the lowest deviation.

ACKNOWLEDGMENT

The authors would like to thank Faculty of Engineering, King Mongkut's University of Technology North Bangkok (Research Grant No. ENG-63-84)

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