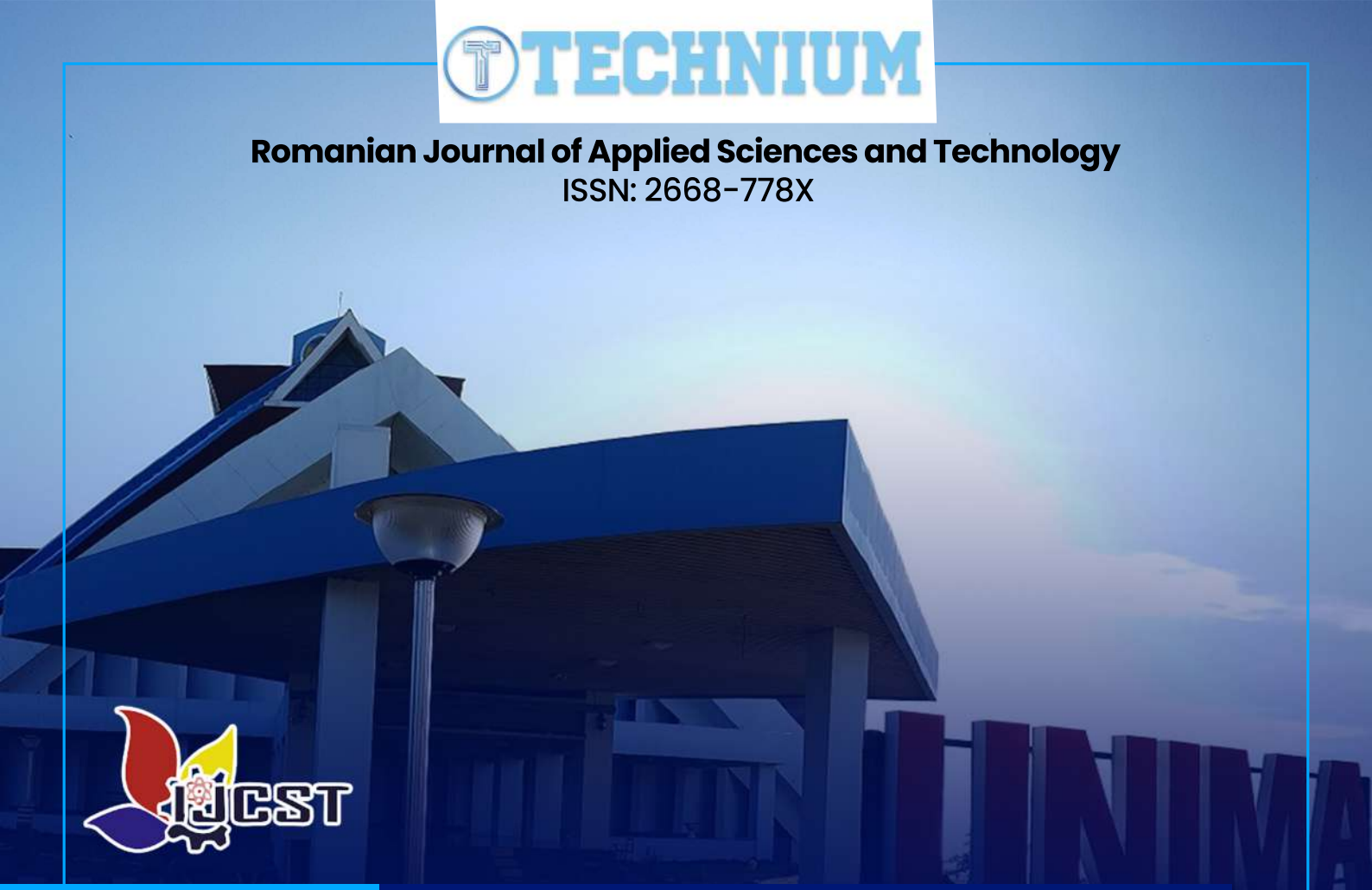
TECHNIUM

Romanian Journal of Applied Sciences and Technology
ISSN: 2668-778X



vol. 16 / 2023

The 7th International Conference on Science Technology

organized by
Faculty of Social Science and
Law Universitas Negeri Manado and
Consortium of International Conference
on Science and Technology

The Innovation Breakthrough in Digital and Disruptive Era

Technium: Romanian Journal of
Applied Sciences and Technology
Vol. 16, 397-404, October, 2023
ISSN: 2668-778X
www.techniumscience.com

Production Planning and Control of Flooring Using Aggregate Planning Method

Rusindiyanto[1], *Rr.* Rochmoeljati[2], *Yekti* Condro Winursito[3], *Isna* Nugraha[4*], *Hafid* Syaifullah[5]

[1,2,3,4,5] Industrial Engineering, Faculty of Engineering, Universitas Pembangunan Nasional "Veteran" Jawa Timur, Surabaya 60294, Indonesia
Email: rusindiyanto4@gmail.com[1], rochmoeljati@gmail.com[2], yekti.condro.ti@upnjatim.ac.id[3], isna.nugraha.ti@upnjatim.ac.id[4*], hafid.s.ti@upnjatim.ac.id[5]

Abstract. PT. X a is a private company engaged in the wood processing industry. To avoid production excesses or shortages in the company, production planning using the Aggregate Planning Method can be utilized to meet all consumer demands. The variables used include demand data, production costs, setup costs, and manufacturing time. Through this research, the company can fulfill consumer demands and minimize production costs by implementing aggregate planning. Additionally, the company can forecast future demand, enabling them to anticipate fluctuations in consumer demand. By using aggregate production planning, a total production time of 8657 hours can be scheduled to fulfill a demand of 7121 m^3. The cost savings achieved after implementing aggregate planning. The total proposed production cost using aggregate planning is IDR.1.383.921.682 and actual cost is IDR 1.477.900.968. So that the company can save production costs of IDR 93,979,286 or 6.35%. For the total production cost of the upcoming year 2023 by implementing aggregate planning based on the forecasting data, the cost is IDR 1.534.711.812.

1 Introduction

Currently, the industrial sector is experiencing rapid growth and development. This growth has led to an increase in demand for products in large quantities. Therefore, companies must adapt to these developments and follow current trends to ensure smooth production and business sustainability [1].

PT. X is a company operating in the wood processing industry. Its main activities involve manufacturing wooden flooring for houses and decking for ships, as well as various types of furniture. The company follows three stages of wood processing: sawmill for cutting the wood, kiln dry for drying, and moulding to shape the wood into desired products.

PT. X faces challenges due to the continuous increase in consumer demand, while the existing production cannot meet their needs. To address this issue, it is necessary to forecast future demand and develop strategies to reduce production costs, ensuring consumer demand is met with minimal production expenses. Employing aggregate planning in the production process can prevent overproduction or underproduction [2]. This way, the company strives to meet consumer demand with optimal production costs and proactively tackles the current challenges .

Aggregate Planning is an operational activity aimed at calculating the quantity and schedule of production for the future [3]. It can be defined as an effort to align supply and demand for a product or service by determining the appropriate quantities and schedules for input, transformation processes, and output [2].

Through this research, it is expected that the company can better accommodate consumer demand and reduce production costs by implementing aggregate planning methods. Additionally, the company can forecast future demand, enabling effective anticipation of consumer demand fluctuations [4].

2 Literature Review

2.1 Production Planning

Production planning is a process that involves the planning and determination of necessary steps to produce goods or services in the desired quantity and schedule. Production planning is a process to establish initial steps to be taken in the future, including what actions should be taken, how much should be done, and when it should be done [5]. This planning is related to the future period, thus based on forecasts made from past data and some assumptions [6]. The goal of production planning is to achieve efficiency and effectiveness in managing resources, optimizing the use of raw materials, organizing labor, and managing production capacity to meet market demand effectively [7][8].

Every plan made must be periodically evaluated through control to ensure smooth implementation. Thus, the company can measure how far the planning is going according to plan and make corrections if necessary [9]. In production planning, various factors are considered, such as demand forecasting, availability of raw materials, production capacity, and labor capabilities

[10][11]. The result of production planning is a production schedule that outlines the types of products, quantities, and production time schedules for a certain period [12]. Production planning is important to achieve a balance between supply and demand, avoid excess or shortage of inventory, and optimize the use of company resources. With good production planning, companies can improve operational efficiency, reduce production costs, and enhance customer satisfaction with timely and demand-driven products.

2.2 Production Control

The implementation of the planned production requires control to proceed according to the plans that have been made. Production plans are based on forecasts, which may not always be accurate [13]. Production control is a function carried out by staff and is not directly the responsibility of the company's management line. Production control can be carried out at every level of management, depending on the needs and characteristics of the factory [14].

Production Control is a management process that involves supervision and regulation of production activities to ensure that production proceeds in accordance with the plans and standards that have been set. The goal of production control is to achieve efficiency, productivity, and optimal quality in the production process [9].

Production control involves continuous monitoring and evaluation of production processes, including monitoring product quality, the use of raw materials and resources, production timing planning, and scheduling [15]. If there are differences between actual performance and established plans, corrective action will be taken to rectify the situation [16].

In controlling production, companies also seek to identify and resolve issues that may arise during the production process to ensure that production targets are achieved efficiently and effectively. Production control helps minimize the risk of production deviations from standards or meeting market demands, thereby maintaining customer satisfaction and business sustainability [17][18].

2.3 Forecasting

Forecasting is the process of projecting future needs, which includes information about the quantity, quality, time, and location of goods or services needed to meet demand [19]. Forecasting is used to estimate future demand for a company. By knowing the estimated future demand, companies can determine strategies and policies for material planning and scheduling that need to be done [20].

Demand forecasting is an estimation or projection of the expected level of demand for products that will occur within a specific period in the future [21]. Demand forecasting focuses on predicting demand for independent products or those not influenced by other factors, such as forecasting for finished products that are not dependent on the demand for other products [22].

Demand forecasting has certain common characteristics that must be considered in evaluating a demand forecasting process and the forecasting methods used [23]. The characteristics of demand forecasting are as follows:

- Causal factors that occurred in the past are assumed to remain relevant in the future.
- Forecasts are never perfect, meaning actual demand will always differ from the projected demand.
- The accuracy of forecasts will decrease over longer time spans.

These characteristics serve as important reference points in analyzing and evaluating the results of demand forecasting, helping to understand the limitations of demand forecasting.

2.4 Aggregate Planning

Aggregate Planning is an operational activity aimed at calculating the quantity and schedule of production in the future [3]. Another definition of Aggregate Planning is an effort to match the supply and demand of a product or service by determining the appropriate quantities and schedules for inputs, transformation processes, and outputs [24]. In the process of Aggregate Planning, decisions are made to determine production, workforce requirements (staffing), inventory, and the level of unmet demand (backorder level) [25].

The process of aggregate planning includes determining the production level, required inventory, workforce levels, as well as backorder policies or customer order rejection policies. The ultimate goal is to achieve a balance between supply and demand in the most economical and efficient way [4].

In aggregate planning, companies need to consider various factors such as demand fluctuations, production costs, factory capacity, inventory, and labor [26]. By conducting effective aggregate planning, companies can avoid excess or shortage of inventory, minimize production costs, and enhance operational efficiency in their business.

3 Methodology

This research was conducted at PT. X, a company engaged in the wood processing industry. Variables can be interpreted as factors or concepts that have varying values and magnitudes. The variables used in the current problem are: demand data, production cost, set up cost, manufacturing time. If the collected data is complete, the next step is aggregate planning. In the forecasting process, the forecasting method will be determined based on the available data. The method used is the one with the smallest Mean Squared Error (MSE) value. After determining the method with the smallest MSE value, the next step is to perform forecast method testing.

Four forecasting methods are used from several available forecasting methods, including single

TECHNIUM
Technium: Romanian Journal of Applied Sciences and Technology
Vol. 16, 397-404, October, 2023
ISSN: 2668-778X
www.techniumscience.com

exponential smoothing with trend, linear regression, double exponential smoothing with trend. Select the best forecasting method using statistical tests to calculate the level of error for each forecasting method, specifically by calculating the smallest MSE value for each forecasting method.

$$MSE = \sum \frac{\left(y_1 - y_1^{\ 1}\right)^2}{N} \quad (1)$$

MSE = Mean Squared Error

Verification test is conducted with the purpose of determining whether the method to be used is acceptable or not.

$$MR = [(dt - d1t) - d)-(dt-1 - d1t-1)] \quad (2)$$

d_{t-1} = demand at (t-1)
d_{1t-1} = forecast at (t-1)

The purpose of knowing the average daily production is to determine the monthly production capacity. Calculating monthly production capacity based on working days. This calculation is done to determine the wood production capacity for one month based on the available working days. This production capacity consists of regular time production capacity and overtime production capacity.

The allocation of demand quantities with capacity based on the transportation model. The purpose of this allocation is to adjust the demand quantity according to the production capacity for month. The process can be accomplished by employing the matrix formulation of aggregate planning.

Table 1. The Matrix Formulation of Aggregate Planning

Source		Demand Period				Idle	Production
		1	2	3	4		
l_0		0	C_I	$2C_I$	$3C_I$	0	Pt_0
1	RT_1	C_r	C_r+C_i	C_r+2C_i	C_r+3C_i	0	Pt_1
	OT_1	C_o	C_o+C_i	C_r+3C_i	C_r+3C_i	0	Ot_1
2	RT_2		C_r	C_r+C_i	C_r+3C_i	0	Pt_2
	OT_2		C_o	C_o+C_i	C_o+3C_i	0	Ot_2
3	RT_3			C_r	C_r+3C_i	0	Pt_3
	OT_3			C_o	C_o+3C_i	0	Ot_3
4	RT_4				C_r	0	Pt_4
	OT_4				C_o	0	Ot_4
Forecast		Y_1	Y_2	Y_3	Y_4	R	

4 Discussion

4.1 Product Demand Data

In this aggregate planning, only high-volume demands will be used in this research. The demand data used includes E2E, E4E, S2S, and S4S types of flooring.

Table 2. Demand Data Used in Aggregate Planning

Months	E2E	E4E	S2S	S4S
January	50	60	65	55
February	45	50	60	50
March	65	80	80	70
April	50	50	60	60
May	85	75	80	65
June	80	80	70	70
July	70	70	75	80
August	50	60	60	55
September	80	75	85	75
October	30	25	35	40
November	75	65	60	70
December	80	80	85	85

The machines used by PT. X are facilities that can be used for one type of product and another type of product with the same processing.

Table 3. Machine Data

No.	Machine name	Total	No.	Machine name	Total
1	Hoist	1	6	Single Rate	2
2	BandSaw	5	7	Multi Rate	3
3	Ponny	2	8	Planner	2
4	Cross Cut	9	9	Moulding	3
5	Boiler	2			

The costs incurred during the production process by PT. X consist of finished data, divided into Unit cost, Set-up Cost, and Holding Cost.

Table 4. Unit Cost Data, Set-Up Cost and Holding Cost

No.	Product	Unit Cost (IDR)/m^3	Set – up Cost (IDR)/m^3	Holding Cost (IDR)/m^3/ month
1	E2E	IDR 2.025.430	IDR 110.786	IDR 1000
2	E4E	IDR 2.025.430	IDR 110.786	IDR 1000
3	S2S	IDR 1.535.260	IDR 64.507	IDR 1000
4	S4S	IDR 1.535.260	IDR 64.507	IDR 1000

4.2 Calculation of Proposed Aggregate Planning

4.2.1 Determining Safety Stock Quantity

To determine the safety stock for each product type, the formula used is:

$$SS = k.\sigma_D$$

Note :
SS = Safety stock
K = Safety factor for normal distribution =1,645 (For a confidence level of 95%)

σ_D =Standard deviation of the demand for each product type

$$\sigma_D = \sqrt{\frac{\sum(xi - \bar{x})^2}{N-1}}$$

Note :
x_i =Forecasted demand adjusted for defect percentage
$\bar{x}$ =Average demand adjusted for defect percentage
N =Total number of demand data
An example calculation for the E2E product type:
1. Total demand = 845 m^3
2. Average demand = $\frac{845}{12}$ = 70,41 ≈ 70 m^3/month

TECHNIUM
Technium: Romanian Journal of Applied Sciences and Technology
Vol. 16, 397-404, October, 2023
ISSN: 2668-778X
www.techniumscience.com

3. Standard Deviation

$$= \sqrt{\frac{(56-70)^2+(67-70)^2+.....+(89-70)^2}{12-1}}$$

$$= \sqrt{\frac{4253}{11}} = 19{,}663$$

4. Safety stock (pcs) = Safety factor x standard deviation

=1,645 x 19,663

=32,34 ≈ 32 m^3

The summary of safety stock calculations for each product type can be seen in Table 5, as follows:

Table 5. Safety Stock for Each Product Type

Product Type	Total Demand (m^3/year)	Average Demand (m^3/ month)	Safety Factor (k)	Standard Deviation	Safety stock (SS) (m^3)
E2E	845	70	1,645	19,663	32
E4E	857	71	1,645	18,193	30
S2S	906	75	1,645	15,806	26
S4S	861	72	1,645	14,488	24

4.2.2 Converting All Demands For Each Product Type Into Hours

The demand for each product type, which has been adjusted for defect percentage, is converted into hours using production time.

Formula :

$D_t = W_{pij} \times D_{ij}, t$

Note :

D_{ij}, t = Demand

W_{pij} = Production Time

D_t = Total demand in period t in hours

The summary of the calculation results for the conversion of demand for each product type can be seen in Table 6.

Table 6. Results of Demand Conversion into Hours

Month	Demand (Hours)				Total
	E2E	E4E	S2S	S4S	
January	83	99	107	90	379
February	74	83	99	83	339
March	107	132	132	116	487
April	83	83	99	99	364
May	139	123	132	107	501
June	132	132	116	116	496
July	116	116	123	132	487
August	83	99	99	90	371
September	132	123	139	123	517
October	49	41	58	65	213
November	123	107	99	116	445
December	132	132	139	139	542
Total	1376	1407	1478	1399	5141

4.2.3 Total Production Requirement Calculation

The next step for the total production requirement is to sum up the demand with the safety stock. The total production requirement for the 12 planning periods is:

$$P_t = \sum (D_t + I_t - I_{t-1})$$

Note :

P_t =Total production requirement for period t.

D_t =Total demand for each product in period t is converted into hours

I_t =Inventory akhir pada periode I dikonversikan ke dalam satuan jam

I_{t-1} = The initial inventory at period t-1 is converted into hours.

An example for January 2022, the total production requirement for E2E is:

P_t =379 + 165 – 37 = 507 hours

The results of the calculation are as follows:

Table 7. Determination of Total Production Requirement

Period	Demand (hours)	Safety stock	Total Production Requirement (hours)
0		37	
1	379	165	507
2	339	165	339
3	487	165	487
4	364	165	364
5	501	165	501
6	496	165	496
7	487	165	487
8	371	165	371
9	517	165	517
10	213	165	213
11	445	165	445
12	542	165	542
Total	5141		5269

4.2.4 Planning for the Number of Workers

The total available working hours during the 12 production planning periods.

Total production time = 5269 hours (table 6.)

Number of working days = 297 days per year

Reguler time = 7 hours/person/day

Over time = 4 hours/person/day

Absence rate = 10 %

Total effective working hours :

= (1 - % absence) x ∑ working days x regular time

= (1 - 10 %) x 297 x 7

= 1871,1 hours

$$\text{Required workforce quantity} = \frac{\text{Total Production}}{\text{Total effective working hours}}$$

$$= \frac{5269}{1871{,}1} = 2{,}815 \approx 3 \text{ persons}$$

4.2.5 Production Cost Calculation

The production cost processing calculated in this research includes:

a. Regular time labor cost: IDR 4000 / hour / person

Regular time labor wage = 3 persons x IDR 4000

= IDR 12.000 / hour

b. Overtime labor cost : IDR 4200 / hour / person

Overtime labor wage = 3 persons x IDR 4200

= IDR 12.600 / hour

c. Production cost for E2E / E4E products:

IDR 2.025.430/m^3. There are 15 pieces of wood in 1m^3, so the production cost calculation is:

Production cost = IDR 2.025.430 :15= IDR 135.028 / pcs

For regular time production cost:

= Production cost + regular time labor wage

= IDR 135.028 + IDR 12.000

= IDR 147.028

TECHNIUM
Technium: Romanian Journal of Applied Sciences and Technology
Vol. 16, 397-404, October, 2023
ISSN: 2668-778X
www.techniumscience.com

For overtime production cost:
= Production cost + overtime labor wage
= IDR 135.028 + IDR 12.600
= IDR 147.628
d. Production cost for S2S/S4S products: IDR 1.535.260/m^3
Production cost = IDR 1.535.260 : 15 = IDR 102.350/pcs
For regular time production cost:
= Production cost + regular time labor wage
= IDR 102.350 + IDR 12.000
= IDR 114.350
For overtime production cost:
= Production cost + overtime labor wage
= IDR 102.350 + IDR 12.600
= IDR 114.950

4.2.6 Determining the Capacity of Production Alternatives

The calculations for production requirements and capacity for aggregate planning can be seen in Table 8 as follows:

Table 8. Production Requirements and Capacity for Aggregate Planning

Period	Demand (hours)	Safety stock (hours)	Total production requirement (hours)	Working days (days)	Regular time capacity (hours)	Overtime capacity (hours)	Total demand (hours)
0		37					
1	379	165	507	25	525	300	544
2	339	165	339	24	504	288	504
3	487	165	487	25	525	300	652
4	364	165	364	24	504	288	529
5	501	165	501	26	546	312	666
6	496	165	496	25	525	300	661
7	487	165	487	26	546	312	652
8	371	165	371	25	525	300	536
9	517	165	517	25	525	300	682
10	213	165	213	22	462	264	378
11	445	165	445	26	546	312	610
12	542	165	542	24	504	288	707
Total	5141	2017	5269	297	6237	3564	7121

4.2.7 Aggregate Planning Matrix

Based on the calculations of production requirements and capacity above, an aggregate planning matrix can be created using the transportation method for the 12 planning periods. From the production calculations in the aggregate planning matrix, the total production cost incurred is as follows:
Total Cost =

1. Period 1: (37 x 1000) + (507 x 261378)= IDR.132.555.646
2. Period 2: (165 x 1000) + (18 x 262378) + (321 x 261378) = IDR.88.790.142
3. Period 3: (165 x 1000) + (183 x 262378) + (304 x 261378) = IDR.127.639.086
4. Period 4: (165 x 1000) + (221 x 262378) + (143 x 261378) = IDR.95.527.592
5. Period 5: (165 x 1000) + (361 x 262378) + (140 x 261378) = IDR.131.476.378
6. Period 6: (165 x 1000) + (406 x 262378) + (90 x 261378) = IDR.130.214.488
7. Period 7: (165 x 1000) + (435 x 262378) + (52 x 261378) = IDR.127.891.086
8. Period 8: (165 x 1000) + (371 x 262378) = IDR.97.507.238
9. Period 9: (165 x 1000) + (123 x 263378) + (394 x 262378) = IDR.135.937.426
10. Period 10: (165 x 1000) + (131 x 263378) + (82 x 262378) = IDR.56.182.514
11. Period 11: (165 x 1000) + (443 x 263378) + (2 x 262378) = IDR.117.366.210
12. Period 12: (165 x 1000) + (460 x 263378) + (82 x 262378) = IDR.142.833.876

Total = IDR.1.383.921.682
So, the total proposed production cost using aggregate planning is IDR.1.383.921.682.

4.3 Existing Condition Aggregate Planning

The company implements production alternatives, including regular time and overtime work hours.

Table 9. Working Hours Data for January - December 2022.

Period	Regular Working Days	Working Hours/Day	Overtime Hours	Regular Working Hours	Overtime Working Hours
1	25	7	4	175	100
2	24	7	4	168	96
3	25	7	4	175	100
4	24	7	4	168	96
5	26	7	4	182	104
6	25	7	4	175	100
7	26	7	4	182	104
8	25	7	4	175	100
9	25	7	4	175	100
10	22	7	4	154	88
11	26	7	4	182	104
12	24	7	4	168	96

4.3.1 Production Capacity Based on Available Working Hours

An example calculation for Period 1 is as follows:
Total demand = 507 hours
Regular Time Production = 175
Overtime Production = 100
Production Shortage = Total demand - (regular time production + overtime production) = 507 – (175 + 100) = 232 hours
Production Surplus = (Regular time production + Overtime production) - Total demand = (175 + 100) – 507 = - 232
Since the result is negative, it means there is a production shortage, so the production surplus is considered 0.
Here are the results of production capacity calculations based on available working hours, as shown in Table 10:

Table 10. Production Capacity Based on Available Working Hours

Period	Total Demand (hours)	Regular Time Production	Overtime Production	Production Shortage (hours)	Production Surplus

Technium: Romanian Journal of Applied Sciences and Technology
Vol. 16, 397-404, October, 2023
ISSN: 2668-778X
www.techniumscience.com

					(hours)
1	507	175	100	232	0
2	339	168	96	75	0
3	487	175	100	212	0
4	364	168	96	100	0
5	501	182	104	215	0
6	496	175	100	221	0
7	487	182	104	201	0
8	371	175	100	96	0
9	517	175	100	242	0
10	213	154	88	0	29
11	445	182	104	159	0
12	542	168	96	278	0
		2079	1188	2031	29

So, the production cost of the company's actual data can be calculated as follows:
Total Cost = Regular Time Cost + Overtime Cost + Production Shortage Cost + Production Surplus Cost
Total Cost = IDR 543.400.704 + IDR 311.586.264 + IDR 622.895.000 + IDR 19.000 = IDR 1.477.900.968

4.4 Demand Forecasting

The forecasting methods used are:

1. Single Exponential Smoothing with Trend (SEST) method.
2. Linear Regression (LR) method.
3. Double Exponential Smoothing with Trend (DEST) method.

Through the calculation results obtained from the Win QSB program, the Mean Squared Error (MSE) values for each forecasting method are as follows:

Table 11. Mean Squared Error (MSE) values for each Forecasting Method.

Product Type	MSE		
	SEST	LR	DEST
E2E	380,6437	266,7298	387,6845
E4E	290,8094	249,0724	290,9091
S2S	215,9091	189,3186	215,9091
S4S	190,6493	137,7161	204,7076

From Table 11, it can be observed that the best method used to forecast the next periods is Linear Regression. To calculate the demand forecast for the next 12 periods through Win QSB, the results are as follows:

Table 12. Forecast Results for the Next 12 Periods

Period	Demand Forecast			
	E2E	E4E	S2S	S4S
January	71	65	72	73
February	73	65	74	74
March	75	65	75	75
April	77	65	76	76
May	79	66	78	78
June	81	66	79	79
July	83	66	80	80
August	85	66	82	81
September	87	66	83	83
October	89	66	84	84
November	91	66	86	85
December	93	67	87	86

4.5 Aggregate Planning for January - December Based on Forecasting Data

The summary of production requirements and capacity calculations for aggregate planning can be seen in Table 13 as follows:

Table 13. Production Requirements and Capacity for Aggregate Planning

Period	Demand (hours)	Safety stock (hours)	Total production requirement (hours)	Working days (days)	Regular time capacity (hours)	Overtime capacity (hours)	Total demand (hours)
0		165					
1	463	45	343	25	525	300	508
2	471	45	471	24	504	288	516
3	476	45	476	25	525	300	521
4	483	45	483	24	504	288	528
5	496	45	496	26	546	312	541
6	501	45	501	25	525	300	546
7	508	45	508	26	546	312	553
8	515	45	515	25	525	300	560
9	524	45	524	25	525	300	569
10	531	45	531	22	462	264	576
11	538	45	538	26	546	312	583
12	548	45	548	24	504	288	593
Total	6054	705	5934	297	6237	3564	6594

Based on the calculations of production requirements and capacity above, an aggregate planning matrix can be created using the transportation method for the 12 planning periods. From the production calculations in the aggregate planning matrix, the total production cost incurred is as follows:
Total Cost =

1. Period 1 : [(165 x 1000) + (343 x 261378)] = IDR 89.817.654
2. Period 2 : [(45 x 1000) + (182 x 262378) + (289 x 261378)] = IDR 123.336.038
3. Period 3 : [(45 x 1000) + (215 x 262378) + (261 x 261378)] = IDR 124.675.928
4. Period 4 : [(45 x 1000) + (264 x 262378) + (219 x 261378)] = IDR 126.554.574
5. Period 5 : [(45 x 1000) + (285 x 262378) + (211 x 261378)] = IDR 129.973.488
6. Period 6 : [(45 x 1000) + (335 x 262378) + (166 x 261378)] = IDR 131.330.378
7. Period 7 : [(45 x 1000) + (359 x 262378) + (149 x 261378)] = IDR 133.184.024
8. Period 8 : [(45 x 1000) + (397 x 262378) + (118 x 261378)] = IDR 135.051.670
9. Period 9 : [(45 x 1000) + (407 x 263378) + (117 x 261378)] = IDR 137.821.072
10. Period 10 : [(45 x 1000) + (408 x 262378) + (123 x 261378)] = IDR 139.244.718
11. Period 11 : [(45 x 1000) + (339 x 262378) + (199 x 261378)] = IDR 120.095.124
12. Period 12 : [(45 x 1000) + (347 x 262378) + (201 x 261378)] = IDR 143.627.144

Total = IDR 1.534.711.812

So, the total production cost for the upcoming year (2023) by implementing aggregate planning based on the forecasting data is IDR. 1,383,921,682.

4.6 Cost Comparison

Based on the calculations using aggregate planning, the existing cost of the company can be compared to the proposed cost. A summary of the cost savings is as follows:

Existing cost/ Actual Cost = IDR 1.477.900.968
Aggregate planning Cost = IDR 1.383.921.682
Cost Savings = Actual Cost - Aggregate planning Cost
= IDR 1.477.900.968 – IDR 1.383.921.682
= IDR 93.979.286
= 6.35 %

By using aggregate planning, the company can minimize production costs and effectively meet consumer demand. On the other hand, for the total production cost of the upcoming year 2023 by implementing aggregate planning based on the forecasting data, the cost is IDR 1.534.711.812.

5 CONCLUSION

By using aggregate production planning, a total production time of 8657 hours can be scheduled to fulfill a demand of 7121 m^3. On the other hand, for the upcoming 12 periods, a production time of 5934 hours is needed to meet a demand of 6594 m^3. The cost savings achieved after implementing aggregate planning. PT. X is encouraged to adopt aggregate planning for production to minimize production costs, which will ultimately lead to increased profitability. The total proposed production cost using aggregate planning is IDR.1.383.921.682 and actual cost is IDR 1.477.900.968. So that the company can save production costs of IDR 93,979,286 or 6.35%. For the total production cost of the upcoming year 2023 by implementing aggregate planning based on the forecasting data, the cost is IDR 1.534.711.812. This approach will also enable the company to meet future consumer demands effectively.

For further research, can use the Interval Programming Approach for Multi-period and Multiproduct Aggregate Production Planning. This approach is a mathematical optimization technique that can help efficiently plan production activities over multiple time periods and with multiple products, considering various constraints and objectives. It enables better decision-making in resource allocation, production scheduling, and cost optimization in a complex production environment.

References

[1] W. Zheng and P. P. Walsh, “Economic growth, urbanization and energy consumption—A provincial level analysis of China,” *Energy Econ.*, vol. 80, pp. 153–162, 2019.

[2] A. Bueno, M. Godinho Filho, and A. G. Frank, “Smart production planning and control in the Industry 4.0 context: A systematic literature review,” *Comput. Ind. Eng.*, vol. 149, p. 106774, 2020.

[3] C. Nivasanon, I. Srikun, and P. Aungkulanon, “Aggregate production planning: A case study of installation elevator company,” *Proc. Int. Conf. Ind. Eng. Oper. Manag.*, pp. 5357–5365, 2021.

[4] N. Pang and Y. Ning, “An uncertain aggregate production planning model for vegetables,” *ICNC-FSKD 2017 - 13th Int. Conf. Nat. Comput. Fuzzy Syst. Knowl. Discov.*, pp. 1386–1395, 2018, doi: 10.1109/FSKD.2017.8392968.

[5] N. S. Aydin and E. B. Tirkolaee, “A systematic review of aggregate production planning literature with an outlook for sustainability and circularity,” *Environ. Dev. Sustain.*, pp. 1–42, 2022.

[6] W. G. Rohmah, I. Purwaningsih, and E. F. S. M. Santoso, “Applying linear programming model to aggregate production planning of coated peanut products,” *IOP Conf. Ser. Earth Environ. Sci.*, vol. 131, no. 1, 2018, doi: 10.1088/1755-1315/131/1/012035.

[7] E. Noegraheni and H. Nuradli, “Aggregate Planning to Minimize Cost of Production in Manufacturing Company,” *Binus Bus. Rev.*, vol. 7, no. 1, p. 39, 2016, doi: 10.21512/bbr.v7i1.1448.

[8] B. Zhu, J. Hui, F. Zhang, and L. He, “An Interval Programming Approach for Multi-period and Multi-product Aggregate Production Planning by Considering the Decision Maker’s Preference,” *Int. J. Fuzzy Syst.*, vol. 20, no. 3, pp. 1015–1026, 2018, doi: 10.1007/s40815-017-0341-y.

[9] J. P. Usuga Cadavid, S. Lamouri, B. Grabot, R. Pellerin, and A. Fortin, “Machine learning applied in production planning and control: a state-of-the-art in the era of industry 4.0,” *J. Intell. Manuf.*, vol. 31, pp. 1531–1558, 2020.

[10] Y. Ning, N. Pang, and X. Wang, “An Uncertain Aggregate Production Planning Model Considering Investment in Vegetable Preservation Technology,” *Math. Probl. Eng.*, vol. 2019, 2019, doi: 10.1155/2019/8505868.

[11] C. Matos, A. V. H. Sola, G. de S. Matias, F. H. Lermen, J. L. D. Ribeiro, and H. V. Siqueira, “Model for Integrating the Electricity Cost Consumption and Power Demand into Aggregate Production Planning,” *Appl. Sci.*, vol. 12, no. 15, 2022, doi: 10.3390/app12157577.

[12] E. A. Attia, A. Megahed, A. AlArjani, A. Elbetar, and P. Duquenne, “Aggregate production planning considering organizational learning with case based analysis,” *Ain Shams Eng. J.*, vol. 13, no. 2, p. 101575, 2022, doi: 10.1016/j.asej.2021.09.002.

[13] A. Jamalnia, J. B. Yang, A. Feili, D. L. Xu, and G. Jamali, “Aggregate production planning under uncertainty: a comprehensive literature survey and future research directions,” *Int. J. Adv. Manuf. Technol.*, vol. 102, no. 1–4, pp. 159–181, 2019, doi: 10.1007/s00170-018-3151-y.

[14] N. Chiadamrong and N. Sutthibutr, “Integrating

a weighted additive multiple objective linear model with possibilistic linear programming for fuzzy aggregate production planning problems," *Int. J. Fuzzy Syst. Appl.*, vol. 9, no. 2, pp. 1–30, 2020, doi: 10.4018/IJFSA.2020040101.

[15] E. Demirel, E. C. Özelkan, and C. Lim, "Aggregate planning with Flexibility Requirements Profile," *Int. J. Prod. Econ.*, vol. 202, pp. 45–58, 2018, doi: 10.1016/j.ijpe.2018.05.001.

[16] J. Leng, W. Sha, Z. Lin, J. Jing, Q. Liu, and X. Chen, "Blockchained smart contract pyramid-driven multi-agent autonomous process control for resilient individualised manufacturing towards Industry 5.0," *Int. J. Prod. Res.*, vol. 61, no. 13, pp. 4302–4321, 2023.

[17] S. Chinguwa, I. Madanhire, and T. Musoma, "A Decision Framework based on Aggregate Production Planning Strategies in a Multi Product Factory: A Furniture Industry Case Study," *Int. J. Sci. Res.*, vol. 2, no. 2, pp. 2319–7064, 2013, [Online]. Available: www.ijsr.n.

[18] M. Brandenburg and G. J. Hahn, "Sustainable aggregate production planning in the chemical process industry - A benchmark problem and dataset," *Data Br.*, vol. 18, pp. 961–967, 2018, doi: 10.1016/j.dib.2018.03.064.

[19] P. A. Gunawan, L. Gozali, L. Widodo, F. J. Daywin, and C. O. Doaly, "Production planning and capacity control with demand forecasting using artificial neural network (Case study PT. Dynaplast) for industry 4.0," *Proc. Int. Conf. Ind. Eng. Oper. Manag.*, pp. 2722–2732, 2021.

[20] T. Januschowski *et al.*, "Criteria for classifying forecasting methods," *Int. J. Forecast.*, vol. 36, no. 1, pp. 167–177, 2020.

[21] F. Lefta, L. Gozali, and I. A. Marie, "Aggregate and disaggregate produetion planning, material requirement, and capacity requirement in Pt. XYZ," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 852, no. 1, 2020, doi: 10.1088/1757-899X/852/1/012123.

[22] M. Gansterer, "Aggregate planning and forecasting in make-to-order production systems," *Int. J. Prod. Econ.*, vol. 170, pp. 521–528, 2015, doi: 10.1016/j.ijpe.2015.06.001.

[23] N. D. Chaturvedi, "Minimizing energy consumption via multiple installations aggregate production planning," *Clean Technol. Environ. Policy*, vol. 19, no. 7, pp. 1977–1984, 2017, doi: 10.1007/s10098-017-1376-3.

[24] I. Nugraha, M. Hisjam, and W. Sutopo, "Aggregate Planning Method as Production Quantity Planning and Control to Minimizing Cost," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 943, no. 012045, pp. 0–12, 2020, doi: 10.1088/1757-899X/943/1/012045.

[25] A. Cheraghalikhani, F. Khoshalhan, and H. Mokhtari, "Aggregate production planning: A literature review and future research directions," *Int. J. Ind. Eng. Comput.*, vol. 10, no. 2, pp. 309–330, 2019.

[26] L. Liu and X. Yang, "A Multi-Objective Model and Algorithms of Aggregate Production Planning of Multi-Product with Early and Late Delivery," *Algorithms*, vol. 15, no. 6, pp. 1–24, 2022, doi: 10.3390/a15060182.