Calculation of Safety Stock and Bottleneck Minimization with Theory of Constraints Method Approach on Sand Coated Metal Roof Production in XYZ Ltd.

Jason Nathanael Chandra, Lina Gozali, Lilyana Jap
Department of Industrial Engineering
Tarumanagara University
Jakarta, Indonesia
jasonnchan97@gmail.com , ligoz@ymail.com, lilyjaplily@gmail.com

Abstract

Inventory and production planning is one of important aspects that has to be considered in manufacturing industry. This aspect must be well executed for the continuity of manufacturing activities so that the company becomes profitable. This research focuses on safety stock planning and bottleneck that occurs on sand coated metal roof production at PT. XYZ. Occurring risk costs from non-optimal safety stock quantity and failures to achieve production target as occurring bottleneck on production are the main problems. Based on the chosen best forecasting method by analyzing the data, the optimal safety stock for maroon, black, green, brown, red, and blue sand coated metal roofs are 6098, 2196, 1585, 1796, 1267, and 604 consecutively. By using Theory of Constraint to minimize the occurring bottleneck on production line, the chosen best alternative is by recruiting 2 additional workers and 10 drying racks for production thus increasing company's profits.

Keywords

Planning, Forecasting, Safety Stock, Bottleneck, Theory of Constraints

1. Introduction

An ideal manufacturing company must have good management system, such as in organization, planning, administration, and supervision. One of important sections of manufacturing activity is production planning and control division. Many company are still having bad inventory management so that cause inevitable cost such as shortage on raw material inventory, inventory cost for overstocks, and lost sales due to inventory stock-outs. These costs could be reduced, even eliminated by implementing appropriate inventory and production management system. Production obstacles could also emerge due to bad production planning so that the production target could not be achieved.

XYZ Ltd. is a roofing material manufacturing company and coated sand metal roof is one of its products. Its production takes quite long time due to two steps drying which causes limitation in production capacity. Intuitively used safety stock quantity could cause risk cost such as overstocks, inventory stock-outs, and even aggravated by limited production capacity. Seasonal pattern on demand and preferred metal roof color.

Calculation of optimal safety stock for each of metal roof color and bottleneck minimization is needed to solve these problems. Demand data, company operational cost, and its production process will be analyzed as data resources that can be used to help the company in the future.

2. Literature review

Inventory management is defined as controlling responsibility and decision-making function that correlated with company inventory. A manufacturing company also needs appropriate production management to support the production continuity.

2.1. Forecasting

Forecasting is defined as a systematic process that analyzes past history data and forecasts the future data with corresponding chosen method.

2.2. Safety Stock

Safety stock is material stock, such as raw material, work-in-process goods, or finished goods which is preserved by the company to avoid risk cost and stock-out. Safety stock is needed to meet the demand at the right time sufficiently. The formula used to calculate the safety stock quantity can be shown as below:

$SS = Z \times S_d$ ....(1)

Where:

SS is safety stock (units).

Z is the value of probability where stock-out is not occurring.

S_d is forecasting and actual data standard deviation (units).

2.3. Time Motion Study

Time motion study was pioneered by Frederick W. Taylor in 19^{th} century. One of the method in this study is stopwatch time study. This method is used to get the standard time of completing any jobs or production process. This method is chosen when the process that will be measured is repetitively done in short time.

Standard time measurement steps using stopwatch time study in flowchart can be seen in Figure 1.

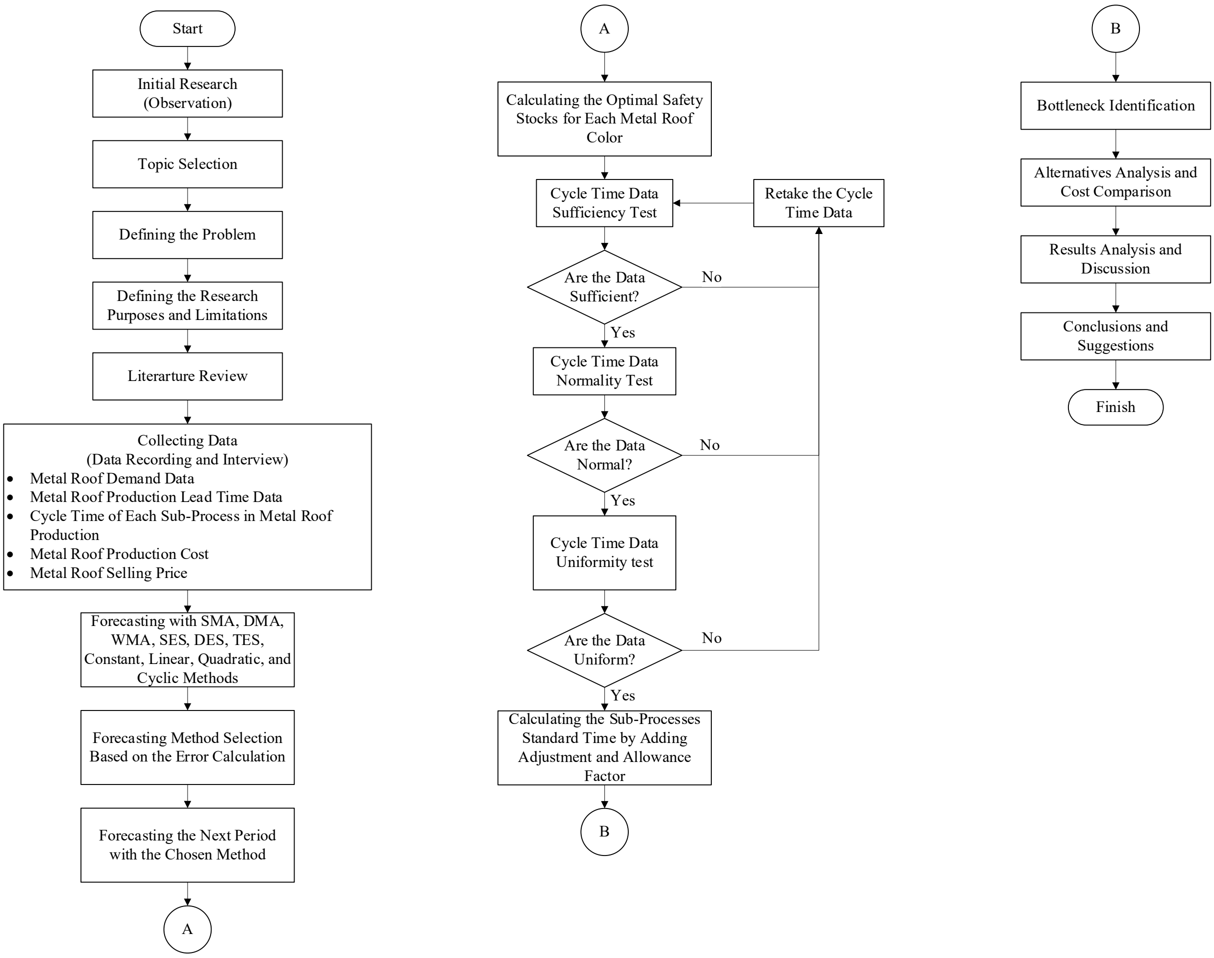

Figure 1. Standard Time Measurement Steps using Stopwatch Time Study

2.4. Theory of Constraints

Theory of constraints introduced by Goldratt which is a management philosophy based on continuous improvement focusing on the system constraints. In the TOC view, the goal of an organization to make money is accomplished by increasing throughput while at the same time reducing inventory and operating expenses.

2.5. Theory of Constraints Steps

The continuous improvement with TOC consists of five-step methodology:

1. Identify the Constraint
   This step requires the identification of the weakest link or element of the system, which is limiting the performance of the system.
2. Exploit the Constraint
   This step requires the identification of the different ways for exploring the possibility for the improvement of the constraint.
3. Subordinate Everything Else to the Constraint
   After exploiting the constraint effectively, it is required to set the pace of every non-constraint in accordance with the pace of the constraint in order to make utilization of the constraint efficient.
4. Elevate the System's Constraint
   This step requires to increase the capacity of the constraint in order to make it non-constraint.
5. If a Constraint is Broken, Repeat the Cycle

This step is the most important step of any continuous process improvement methodology. If the constraint chosen for the improvement of the system has been broken with the help of initial four steps, the system is required to monitor again for identifying another constraint of the system.

2.6. Bottleneck

Bottleneck is a resource which limits the entire process as its capacity becomes the constraint. It limits the system's throughput. With TOC, the bottleneck can be minimized from its system. Bottleneck also related to capacity constraint resource (CCR) which is the process capacity that can also limit the throughput. Bottleneck and CCR identification table is shown in Table 1.

Table 1. CCR-Bottleneck Identification

Category	Bottleneck	Non-Bottleneck
CCR	Will constraint actual flow, both in quantity and time. Must be considered in planning the production flow.	Will constraint the timing of the actual flow, but not the quantity. Must be considered in planning the production flow.
Non-CCR	May constraint actual flow, both in quantity and time. Need not be considered in planning the production flow.	Does not constraint the flow, either in quantity or in timing. Need not be considered in planning the production flow.

3. Research Methodology

Methodology consists of steps that must be planned before doing research so that the research is done systematically.

These all steps consist of initial research, topic selection, defining the problem, defining the research purposes and limitation, literature review, collecting data, data processing, results analysis and discussion, and conclusion with suggestion. These steps in flowchart can be shown in Figure 2.

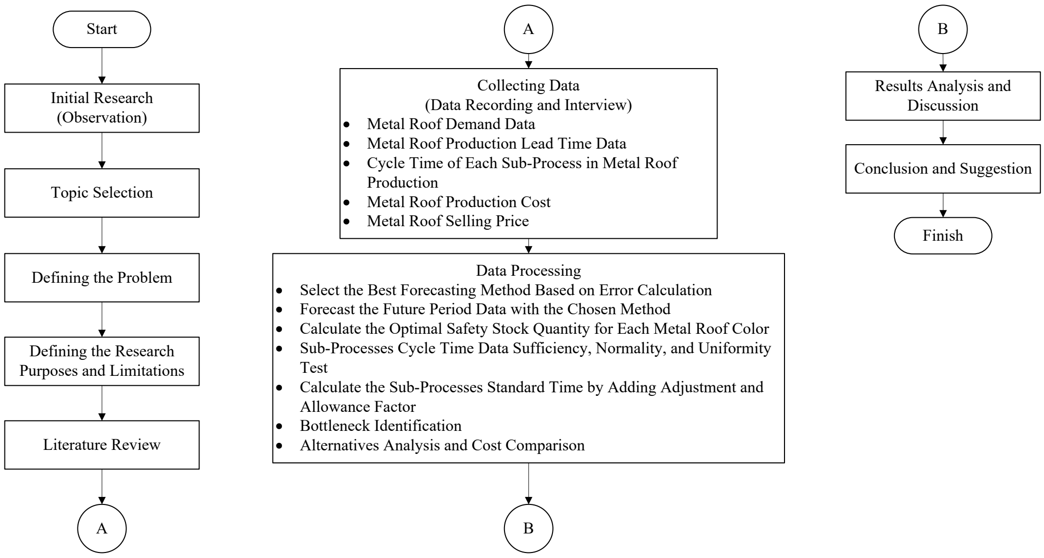

Figure 2. Methodology

4. Result and discussion

The calculation of optimal safety stock quantity for each metal roof color requires historical demand data. The historical demand data from January 2017 until September 2018 is shown in Table 2.

Table 2. Historical XYZ Ltd. Sand Coated Metal Roof Demand Data January 2017-September 2018

Month	Sand Coated Metal Roof						Total
	Maroon	Black	Green	Brown	Red	Blue	
42.736	6.752	2.540	1.285	800	920	50	12.347
42.767	5.501	6.420	660	333	846	50	13.810
42.795	4.646	1.771	1.841	1.510	1.299	30	11.097
42.826	4.868	3.692	585	1.043	1.370	1.070	12.628
42.856	9.317	3.293	2.344	828	577	280	16.639
42.887	4.593	2.010	2.343	1.348	270	50	10.614
42.917	10.103	5.680	1.887	4.084	1.180	75	23.009
42.948	21.605	6.297	4.695	4.436	1.755	457	39.245
42.979	12.570	5.010	3.365	1.959	1.525	845	25.274
43.009	11.615	5.632	1.865	4.031	1.327	50	24.520
43.040	12.901	4.327	2.446	1.663	672	656	22.665
43.070	5.831	3.002	1.300	669	3.555	488	14.845
43.101	9.627	3.950	2.680	1.375	2.558	25	20.215
43.132	3.750	3.540	730	790	366	726	9.902
43.160	5.218	3.422	1.176	1.031	1.721	321	12.889
43.191	5.877	2.852	872	1.301	1.270	965	13.137
43.221	8.118	3.677	3.466	1.396	859	350	17.866
43.252	1.988	1.909	556	993	1.250	50	6.746
43.282	4.933	4.366	2.117	1.751	1.489	796	15.452
43.313	9.879	5.513	1.772	3.181	715	70	21.130
43.344	7.538	1.485	1.391	700	2.950	1.267	15.331
Total	**167.230**	**80.388**	**39.376**	**35.222**	**28.474**	**8.671**	**359.361**

4.1. Cost and Production Capacity Data

Each of metal roof color selling price is shown in Table 3. Its production cost is shown in Table 4. Production capacity for each day is 8 hour with 1 hour rest.

Table 3. Selling Price

Sand Coated Metal Roof	Selling Price/Pcs
Maroon	Rp. 25.700,-
Black	Rp. 25.700,-
Green	Rp. 26.500,-
Brown	Rp. 26.500,-
Red	Rp. 28.000,-
Blue	Rp. 28.000,-

Table 4. Production Cost

Production Cost Data (Rp)		
Electricity (I3)	Per kWh	1.035,78
Water (4A)	Per m^3	6.825
Raw Material	Per Pcs	19.000
Salary	Monthly	2.500.000

4.2. Calculation of Safety Stock

Based on the chosen best forecasting method, maroon, green, and brown metal roofs use cyclic method, the black one uses 10 month single moving average, red and blue metal roofs use quadratic method. The results of optimal safety stock calculation per month for each color are shown in Figure 3.

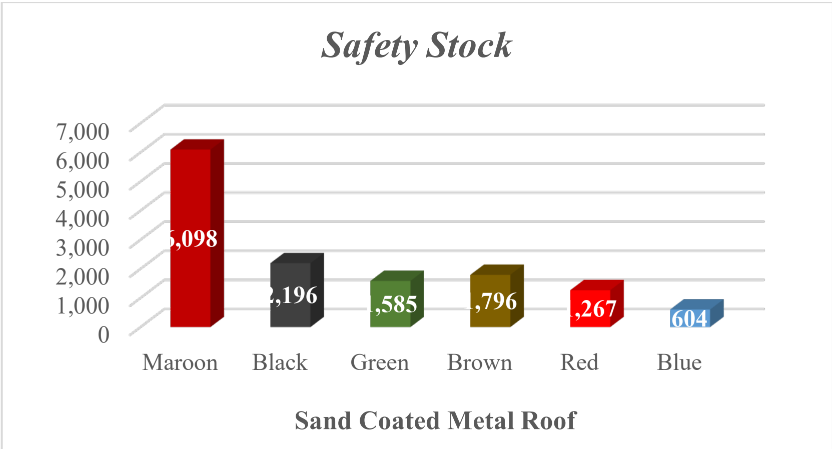

Figure 3. Optimal Safety Stock

4.3. Calculation of Standard Time

TOC implementation to minimize bottleneck in production process needs each sub-process standard time data. The calculation of standard time with adjustment and allowance factor consideration is shown in Table 5.

Table 5. Sand Coated Metal Roof Sub-Processes Standard Time Calculation

Production Process	Cycle Time (s)	Adjustment Factor	Normal Time (s)	Allowance Factor	Standard Time (s)	Amount of Pcs/Cycle	Standard Time (s/pcs)
Glue Mixing	129,50	0,07	138,56	0,39	191,91	50	3,84
Glue Spraying	35,29	-0,02	34,58	0,41	48,70	1	48,70
Sand Mixing	201,66	-0,07	187,55	0,40	262,25	20	13,11
Sand Coating	19,14	0,13	21,63	0,39	29,96	1	29,96
Finishing Paint Mixing	60,57	0,05	63,60	0,39	88,08	50	1,76
Finishing Paint Spraying	14,13	0,21	17,10	0,41	24,08	1	24,08

4.4. Bottleneck Identification

Bottleneck identification is obtained from calculating production targets with available production capacity. If the capacity is insufficient, that sub-process is identified as bottleneck that can hamper overall production. The calculation to identify the bottleneck is shown in Table 6.

Table 6. Calculation Of Bottleneck Identification

Production Process	Standard Time (s)	Capacity Needed (s)						Total Time (s)	Available Capacity (s)	Workload Percentage (%)
		Maroon (399)	Black (192)	Green (94)	Brown (84)	Red (68)	Blue (21)			
Glue Mixing	3,84	1.531,43	736,93	360,79	322,41	261,00	80,60	3.293,16	25.200	13,07
Glue Spraying	**48,70**	**19.431,72**	**9.350,60**	**4.577,90**	**4.090,89**	**3.311,67**	**1.022,72**	**41.785,51**	**25.200**	**165,82**
Sand Mixing	13,11	5.231,84	2.517,58	1.232,56	1.101,44	891,64	275,36	11.250,43	25.200	44,64
Sand Coating	**29,96**	**11.954,82**	**5.752,69**	**2.816,42**	**2.516,80**	**2.037,41**	**629,20**	**25.707,35**	**25.200**	**102,01**
Sand Coating Drying	**40,18**	**16.031,25**	**7.714,29**	**3.776,79**	**3.375,00**	**2.732,14**	**843,75**	**34.473,21**	**28.800**	**119,70**
Finishing Paint Mixing	1,76	702,91	338,24	165,60	147,98	119,79	37,00	1.511,51	25.200	6,00
Finishing Paint Spraying	24,08	9.609,35	4.624,05	2.263,86	2.023,02	1.637,68	505,76	20.663,71	25.200	82,00
Finishing Paint Drying	**40,18**	**16.031,25**	**7.714,29**	**3.776,79**	**3.375,00**	**2.732,14**	**843,75**	**34.473,21**	**28.800**	**119,70**

4.5. Bottleneck Minimization

Based on the result of bottleneck identification, the classification of sub-processed which are categorized as bottleneck and capacity constraints is shown in Table 7.

Table 7. Bottleneck-CCR Classification

	Bottleneck	**Non-Bottleneck**
Capacity Constraint Resource (CCR)	Glue Spraying Sand Coating Drying Finishing Paint Drying	Finishing Paint Spraying
Non-Capacity Constraint Resource (Non-CCR)	Sand Coating	Glue Mixing Sand Mixing Finishing Paint Mixing

Sub-processes which are categorized as bottleneck will be minimized with the production priority of highest contribution margin ratio. The other non-bottleneck sub-processed production quantity then will be set in accordance to the bottleneck ones. The results of bottleneck minimization which show that all of the processes are under capacity is shown in Table 8.

Table 8. Bottleneck Minimization Results

Production Process	Standard Time (s)	Capacity Needed (s)						Total Time (s)	Available Capacity (s)	Workload Percentage (%)
		Maroon (58)	Black (192)	Green (94)	Brown (84)	Red (68)	Blue (21)			
Glue Mixing	3,84	222,61	736,93	360,79	322,41	261,00	80,60	1.984,34	25.200	7,87
Glue Spraying	**48,70**	**2.824,66**	**9.350,60**	**4.577,90**	**4.090,89**	**3.311,67**	**1.022,72**	**25.178,45**	**25.200**	**99,91**
Sand Mixing	13,11	760,52	2.517,58	1.232,56	1.101,44	891,64	275,36	6.779,10	25.200	26,90
Sand Coating	**29,96**	**1.737,79**	**5.752,69**	**2.816,42**	**2.516,80**	**2.037,41**	**629,20**	**15.490,32**	**25.200**	**61,47**
Sand Coating Drying	**40,18**	**2.330,36**	**7.714,29**	**3.776,79**	**3.375,00**	**2.732,14**	**843,75**	**20.772,32**	**28.800**	**72,13**
Finishing Paint Mixing	1,76	102,18	338,24	165,60	147,98	119,79	37,00	910,78	25.200	3,61
Finishing Paint Spraying	24,08	1.396,85	4.624,05	2.263,86	2.023,02	1.637,68	505,76	12.451,21	25.200	49,41
Finishing Paint Drying	**40,18**	**2.330,36**	**7.714,29**	**3.776,79**	**3.375,00**	**2.732,14**	**843,75**	**20.772,32**	**28.800**	**72,13**

4.6. Alternatives Selection

The rest quantity of unachievable production target will be fulfilled by adding additional capacity with various alternatives. For sand coating drying and finishing paint drying, 10 additional drying racks are needed to increase the capacity according to the calculations that can be seen in Table 9. For glue spraying and sand coating, the calculation to get the amount of additional time needed can be seen in Table 10. The alternative chosen is to add 2 permanent workers compared to work overtime based on cost comparison which can be seen in Table 11.

Table 9. Calculation of Additional Drying Racks Needed

Production Process	Available Drying Rack	Drying Rack Capacity (Pcs)	Production Capacity (Pcs)	Demand (Pcs)	Deficiency (Pcs)	Additional Drying Racks Needed
Sand Coating Drying	14	32	716	858	142	5
Finishing Paint Drying	14		716	858	142	5
Total Additional Drying Racks						**10**

Table 10. Calculation of Addtional Time Needed

Production Process	Production Capacity (Pcs)	Standard Time (s)	Demand (Pcs)	Deficiency (Pcs)	Amount of Time Needed (s)	Amount of Time Needed (hour)
Glue Spraying	517	48,70	858	341	16.607,06	4,61
Sand Coating	841	29,96	858	17	509,35	0,14

Table 11. Cost Comparison

Daily Expenses	Total (Rupiah)	
	Work Day Overtime	Additional Workers
Raw Material	16.302.000,00	16.302.000,00
Electricity	36.660,79	36.660,79
Water	1.856,40	1.856,40
Salary	750.000,00	750.000,00
Additional Overtime Cost/ Salary	274.566,47	250.000,00
Additional Drying Rack Depreciation	14.650,00	14.650,00
Total Daily Expenses (Rp)	17.379.733,66	17.355.167,19
Total Daily Income (Rp)	22.397.700,00	22.397.700,00
Total Daily Profit (Rp)	5.017.966,34	5.042.532,81

5. Conclusion

Based on the forecasting results of each sand coated metal roof, the optimal quantity of safety stock for maroon, black, green, brown, red, and blue metal roofs are 6098, 2196, 1585, 1796, 1267, and 604 consecutively.

By using Theory of Constraint to minimize the occurring bottleneck on production line, the chosen best alternative is by recruiting 2 additional workers and 10 drying racks for production thus increasing company's profits and production capacity.

The suggestions for the company in future are to implement the forecasting method to get the optimal inventory level. For sub-processes in production that still need manpower, company is suggested to make Standard Operating Procedure so that the workers performance could be standardized thus achieve the production target.

Acknowledgements

Authors gratefully acknowledge all of the staff of XYZ Ltd. who have given an opporrtunity to perform a research at their company and to all Tarumanagara University lecturers of Industrial Engineering Department for giving suggestions to the writing.

References

Ballou, Ronald H., 2004, *Logistic/Supply Chain Management (Fifth Edition)*, Pearson Prentice Hall, New Jersey.

Barnes, Ralph M., 1980, *Motion and Time Study Design and Measurement of Work*, John Wiley & Sons, Singapore.

Goldratt, E.M., 1990, *What is this thing called Theory of Constraints and how should it be implemented?*, North River Press Great Barington Publishing Corporation, Massachusetts.

Gupta, Mahesh C., and Lynn H. Boyd, May 2008, *Theory of Constraint: A Theory for Operations Management*, International Journal of Operation & Production Management, Vol. 28. No. 10: 991-1012.

Herjanto, Eddy, 2008, *Manajemen Operasi, Edisi 3*, Grasindo, Jakarta.

Singh, Raghuraj, Raunak Gupta, P.L. Verma, and Lokesh Baipai, January 2018, *Theory of Constraints-Strategy for Continuous Improvement*, International Journal of Mechanical and Production Engineering, Vol. 6. No. 1: 66-69.

Taylor, Frederick Winslow, 1911, *The Principles of Scientific Management*, Harper & Brothers, New York and London.

Waters, C.D.J., 2003, *Inventory Control and Management (Second Edition)*, John Wiley & Sons, Ltd, England

Biographies

Jason Nathanael Chandra, was born in Indonesia in 1997. She is an undergraduated student of Tarumanagara University majoring in Industrial Engineering. She had been given two scholarships from Kemenrisekdikti and PKM–GT Winner in his college years. In 2018, she had an internship at PT. Inti Atap Suksesindo at steel, roof, and fiberglass production.

Lina Gozali is a lecturer of Industrial Engineering Department at Universitas Tarumangara since 2006 and be a free-lance lecturer at Universitas Trisakti since 1995. She got Bachelor degree at Trisakti University, Jakarta - Indonesia, then she graduated Master Degree at STIE IBII, Jakarta – Indonesia, and graduated her Ph.D at Universiti Teknologi Malaysia, Kuala Lumpur – Malaysia in year 2018. Her apprentice college experience was in paper at Kertas Bekasi Teguh, shoe at PT Jaya Harapan Barutama, automotive chain drive industry at Federal Superior Chain Manufacturing. She teaches Production System and Supply Chain Management Subjects and her Ph.D research about Indonesian Business Incubator. She actively writing for almost 40 publication since 2008 in Industrial Engineering research sector such as: Production Scheduling, Plant Lay Out, Maintenance, Line Balancing, Supply Chain Management, Production Planning and Inventory Control. She had been worked at PT. Astra Otoparts Tbk as International Business Development Department for 4 years, Citibank, N.A as customer service for 1 year , PT. Pandrol as assistant marketing manager for 1 year. PT. Texmaco as merchandiser for 3 years.

Lilyana Jap is a free lance lecturer of Industrial Engineering Department at Universitas Tarumangara since 2017 till present, graduated her master degree from University of Indonesia, majoring on Environmental science (industrial scope). She's interested with in-depth reasearch of modelling system with systems thinking methodes and system dynamics approachments. Her previous reasearch was using Power sim 10, with utmos analytical about modelling in system dynamics, from Causal loop until intervention schemes.