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**Research Article**

# Lean Manufacturing System Optimization with Simulation Models and Response Surface Methodology

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**Abstract: The design of lean manufacturing system to solve the problem of inefficiency or waste in the process of ship production in Madura shipyard, with consideration because in a manufacturing system can always be found things that actually do not provide added value or things that are too excessive in doing so. This is commonly called waste workshop. Lean's approach aims to eliminate waste elimination and non value added activity, facilitate the flow of material, product and information, and continuous improvement of quality. With lean approach, it is expected that the shipyard of kapa madura will be more efficient and productive**

**In this research, a simulation model for lean manufacturing in SME Madura shipyard was developed. Development of simulation model is done with ARENA software. To measure the lean manufacturing system performance that was designed, experiments and optimization were carried out using the Response Surface Methodology. The measurement of multi performance criteria with the Analytical Hierarchy Process (AHP) method with work in process criteria, waiting time, and flow time is carried out to determine the optimal lean manufacturing system. From the completion of the AHP method, it can be seen that the weight for the waiting time criterion is 0.7; flow time 0.2, and Work in Process 0.1. The weight of each criterion generated from the AHP method multiplied by the response of each criterion will be A weighted performance measure (WPM).**

**Based on the optimization graph in the Response Surface Methodology method, Global Solution or the optimal solution is obtained using Minitab 16 software as follows : A (Set Up Time) = 2 (80 minutes), B (Lot Size) = -1.51515 (8 tons), C (Loading interval) = -1.23232 (208 minutes), D (Demand Stability) = -2 (90%), With the value of the goal for the minimum WPM, the lowest value is 0, the target value is 0 and the upper value is 11000**

**Keywords*: Lean Manufacturing, Shipyard, Simulation Mode, Response Surface Methodology, A nalytical Hierarchy Process (AHP*)**

## 1. Introduction

Based on the theory and study of lean methods conducted by Taiichi Ohno (1988), Shingo (1989), Womack et al. 1996, 1998, 2000, 2005and 2009), this study developed a lean manufacturing simulation model for the Madura shipyard, and determined its optimal conditions with Response Surface Methodologhy. Kolic, D., Fafandjel, Zamarin (2013) states that the implementation of the lean method in shipyards requires an analysis of the layout of shipyard facilities in the present conditions. Damir Kolich,Richard L. Storch, and Niksa Fafandjel (2017) States that Improvement on panel assembly using the lean method will reduce working hours at shipyards**.** Lean thinking can also be defined as a method to define value, construct value added activity in the best order, make it flow without hindrance, and maximize more and more effective performance (Womack and Jones, 1996). The results of this study can provide an alternative lean ship production system, so that it will be able to help Madura shipyards achieve maximum system efficiency. With the existence of a lean production system, the benefits that can be obtained by the Madura shipyard areas follows :The work process becomes simpler and more efficient because waste in the production process can be minimized, Work-in-process (WIP) inventory decreases , product defect decreases, over production can be minimized, unnecessary operational and work movements can be minimized, Excessive transportation can be minimized. Manufacturing lead time is shorter, and higher yield satisfaction.

The objectives of this study are:

1. Development of a lean manufacturing system simulation model at the Madura shipyard.
2. Experiments and optimization lean manufacturing systems with Response Surface Methodologhy
3. Determine the optimal setting for lean manufacturing configurations in Madura Shipyard

## 2. Development of Simulation Model

Taho Yang, Yiyo Kuo, Chao-Ton Su, Chia-Lin Hou (2015) adopting lean principles that are applied toa fishing net manufacturing and doing optimization with simulation models. Oleghe Omogbai Konstantinos Salonitis (2016) create a simulation model for the lean improvement scenario so that the optimal scenario can be determined. Serdar Baysan, Ozgur Kabadurmus, Emre Cevikcan, Sule Itir Satoglu, Mehmet Bulent Durmusoglu (2019) using energy value stream mapping, experimental design and simulation models to analyze the effect of lean tools on energy efficiency in the power distribution industry. The selection of software to be used in the simulation will have a major impact on the success of the researcher. This will affect the model's accuracy, model validity, execution time, and overall research completion time. Lean manufacturing simulation model for Madura shipyard as shown below in Figure 1.

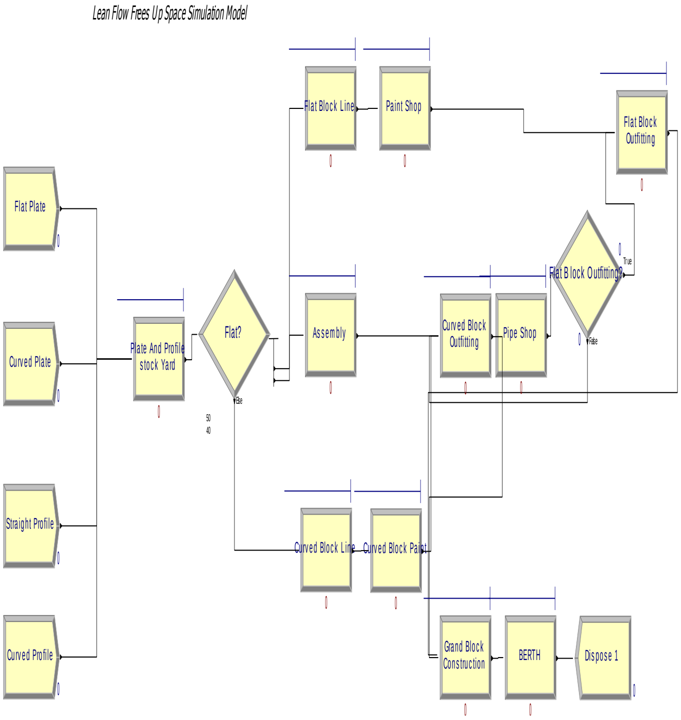


**Figure 1. Lean manufacturing simulation model for Madura shipyard**

**Optimization with Response Surface Methodology (RSM)**

Response surface methodology is a collection of statistical and mathematical techniques that are useful for analyzing problems about several independent variables that affect non-independnt variables or responses, and aim to optimize that response (Montgomery 1997). Thus the response surface method can be used by researchers to:

• Looking for a suitable approach function to predict future responses.

• Determine the values of independent variables that optimize the response learned. Design of experiments with Response Surface Methodology (RSM).

in this study as follows:

a. Set up time factor (A) with factor level:

1. Set up time for 80 minutes (code X1 = 2)
2. Set up time for 70 minutes (code X1 = 1)
3. Set up time for 60 minutes (code X1 = 0)
4. Set up time for 50 minutes (code X1 = -1)

b. Lot size factor (B) with a factor level:

1. Lot size of 22 tons (code X2 = 2)
2. Lot size of 18 tons (code X2 = 1)
3. Lot size of 14 tons (code X2 = 0)
4. Lot size of 10 tons (code X2 = -1)
5. Lot size of 6 tons (code X2 = -2)

c. Loading interval factor with factor level:

1. 400 minute loading interval (code X3 = 2)
2. 340 minute loading interval (code X3 = 1)
3. Loading interval for 280 minutes (code X3 = 0)
4. Loading interval for 220 minutes (code X3 = -1)
5. Loading interval for 160 minutes (code X3 = -2)

d. Demand stability factor with factor level:

1. demand stability is 100% (code X4 = 2)
2. demand stability is 97.5% (code X4 = 1)
3. demand stability is 95% (code X4 = 0)
4. demand stability is 92.5% (code X4 = -1)
5. demand stability is 90% (code X4 = -2)

Furthermore, experiments with simulations can be carried out in accordance with the central composite design or at the level of factors corresponding to the values of X1, X2, X3, X4. Based on the central composite design it was known that repetitions were carried out 8 times at the center so that the suitability test of the model could be carried out.

To complete the multi criteria response in response surface methodology in this study used analytical hierarchy process (AHP). The AHP method in this study was used to weight the performance criteria of each type of layout based on his opinion, which in this study was taken by technical experts who truly mastered the ship production system in Madura Shipyard. The scale value between 1 (indeferent) to 9 (extremely preferred) is used to express the expert's preference. Based on the expert judgment of Madura Shipyard, it can be seen that waiting time is four times more important than flow time and six times more important than Work in Process, while flow time is four times more important than Work in Process, as in table 1. Based on the weights generated from the AHP method, A weighted performance measure (WPM) is calculated on the central composite design on Response Surface experiments. So the AHP method in this study is used to evaluate the combination of many responses into a single response as seen in table 5.23

**Table 1 Judgment Expert for each performance type layout criteria**

| | Flow Time | Waiting Time | WIP |
|---|---|---|---|
| Flow Time | 1 | 0.25 | 4 |
| Waiting Time | | 1 | 6 |
| WIP | | | 1 |

From the completion of the AHP method, it can be seen that the weight for the waiting time criterion is 0.7; flow time 0.2 , and Work in Process 0.1 . The weight of each criterion generated from the AHP method multiplied by the response of each criterion will be A weighted performance measure (WPM). For more details see the experimental design with a central composite design (Central Composite Design) (CCD)

**Table 2 Central Composite Design ( CCD )**

| A | B | C | D | WPM |
|---|---|---|---|---|
| -2 | 0 | 0 | 0 | 722 |
| -1 | -1 | 1 | -1 | 679 |
| 0 | 2 | 0 | 0 | 14168 |
| 0 | 0 | 0 | 0 | 1361 |
| 0 | 0 | 0 | 0 | 1361 |
| 0 | 0 | 0 | -2 | 566 |
| 1 | 1 | 1 | -1 | 10722 |
| -1 | 1 | -1 | -1 | 627 |
| 0 | 0 | 0 | 0 | 1361 |
| -1 | -1 | -1 | -1 | 654 |
| 1 | -1 | 1 | 1 | 5507 |
| 1 | 1 | -1 | -1 | 1190 |
| 0 | 0 | 0 | 0 | 1361 |
| 0 | 0 | 0 | 2 | 7193 |
| 1 | -1 | 1 | -1 | 1796 |
| 1 | -1 | -1 | 1 | 1739 |
| -1 | 1 | 1 | 1 | 1547 |
| -1 | 1 | 1 | -1 | 948 |
| 0 | -2 | 0 | 0 | 512 |
| -1 | -1 | 1 | 1 | 892 |
| 2 | 0 | 0 | 0 | 3383 |
| 1 | 1 | 1 | 1 | 12156 |
| 0 | 0 | 0 | 0 | 1361 |
| 0 | 0 | -2 | 0 | 479 |
| 0 | 0 | 0 | 0 | 1361 |
| -1 | -1 | -1 | 1 | 720 |
| 0 | 0 | 0 | 0 | 1361 |
| 1 | -1 | -1 | -1 | 788 |
| 0 | 0 | 0 | 0 | 1361 |
| 0 | 0 | 2 | 0 | 16313 |
| -1 | 1 | -1 | 1 | 101 |
| 1 | 1 | -1 | 1 | 4292 |

The results of the analysis of Response Surface Regression WPM versus X1, X2, X3, X4 obtained the regression coefficient and ANOVA table as follows:

**Table 3 RSM Regression Coefficient**

| Term | Coef | SE Coef | T | P |
|---|---|---|---|---|
| Constant | 1361.00 | 946.2 | 1.438 | 0.168 |
| A | 1556.00 | 546.3 | 2.848 | 0.011 |
| B | 1921.67 | 546.3 | 3.518 | 0.003 |
| C | 2325.17 | 546.3 | 4.256 | 0.001 |
| D | 950.17 | 546.3 | 1.739 | 0.100 |
| A*A | -267.90 | 492.4 | -0.544 | 0.593 |
| B*B | 1053.98 | 492.4 | 2.140 | 0.047 |
| C*C | 1317.98 | 492.4 | 2.677 | 0.016 |
| D*D | 188.85 | 492.4 | 0.384 | 0.706 |
| A*B | 1140.75 | 669.1 | 1.705 | 0.106 |
| A*C | 1263.00 | 669.1 | 1.888 | 0.076 |
| A*D | 552.88 | 669.1 | 0.826 | 0.420 |
| B*C | 886.87 | 669.1 | 1.326 | 0.203 |
| B*D | -20.75 | 669.1 | -0.031 | 0.976 |
| C*D | 147.75 | 669.1 | 0.221 | 0.828 |

While the Analysis of Variance from the RSM is:

**Table 4 Analysis of Variance from WPM**

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| Regression | 14 | 446388138 | 446388138 | 31884867 | 4.45 | 0.002 |
| Linear | 4 | 298155732 | 298155732 | 74538933 | 10.41 | 0.000 |
| A | 1 | 58107264 | 58107264 | 58107264 | 8.11 | 0.011 |
| B | 1 | 88627267 | 88627267 | 88627267 | 12.37 | 0.003 |
| C | 1 | 129753601 | 129753601 | 129753601 | 18.12 | 0.001 |
| D | 1 | 21667601 | 21667601 | 21667601 | 3.03 | 0.100 |
| Square | 4 | 84057074 | 84057074 | 21014269 | 2.93 | 0.052 |
| A*A | 1 | 5771537 | 2119922 | 2119922 | 0.30 | 0.593 |
| B*B | 1 | 26747838 | 32813452 | 32813452 | 4.58 | 0.047 |
| C*C | 1 | 50484183 | 51310348 | 51310348 | 7.16 | 0.016 |
| D*D | 1 | 1053516 | 1053516 | 1053516 | 0.15 | 0.706 |
| Interaction | 6 | 64175332 | 64175332 | 10695889 | 1.49 | 0.239 |
| A*B | 1 | 20820969 | 20820969 | 20820969 | 2.91 | 0.106 |
| A*C | 1 | 25522704 | 25522704 | 25522704 | 3.56 | 0.076 |
| A*D | 1 | 4890732 | 4890732 | 4890732 | 0.68 | 0.420 |
| B*C | 1 | 12584756 | 12584756 | 12584756 | 1.76 | 0.203 |
| B*D | 1 | 6889 | 6889 | 6889 | 0.00 | 0.976 |
| C*D | 1 | 349281 | 349281 | 349281 | 0.05 | 0.828 |
| Residual Error | 17 | 121756229 | 121756229 | 7162131 | | |
| Lack-of-Fit | 10 | 121756229 | 121756229 | 12175623 | * | * |
| Pure Error | 7 | 0 | 0 | 0 | | |
| Total | 31 | 568144367 | | | | |

Based on the response surface methodology method also known the correlation coefficient value R-Sq = 78.57% and RR-Sq (adj) = 60.92%

**Plot of Surface Response**

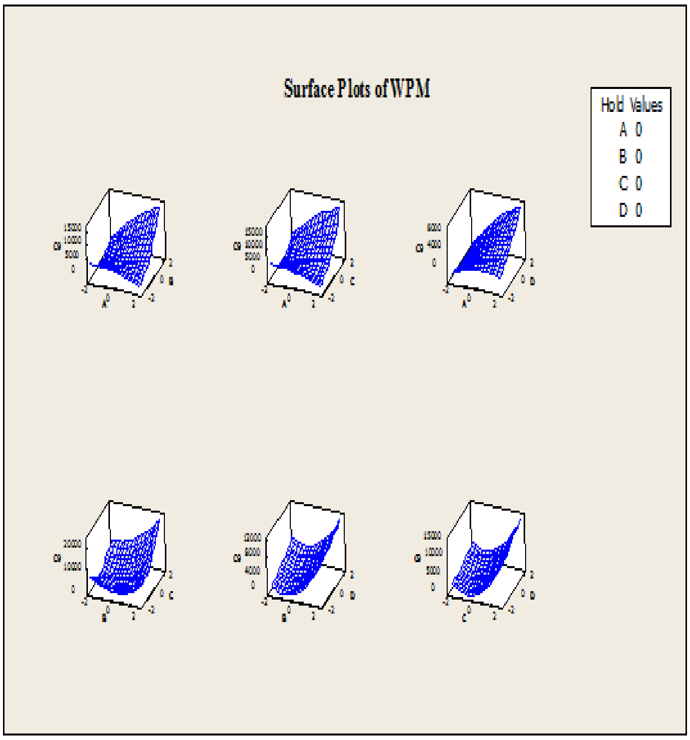


**Figure 2 Plot of Surface Response**

The optimal value for factors A, B, C, D is as follows:

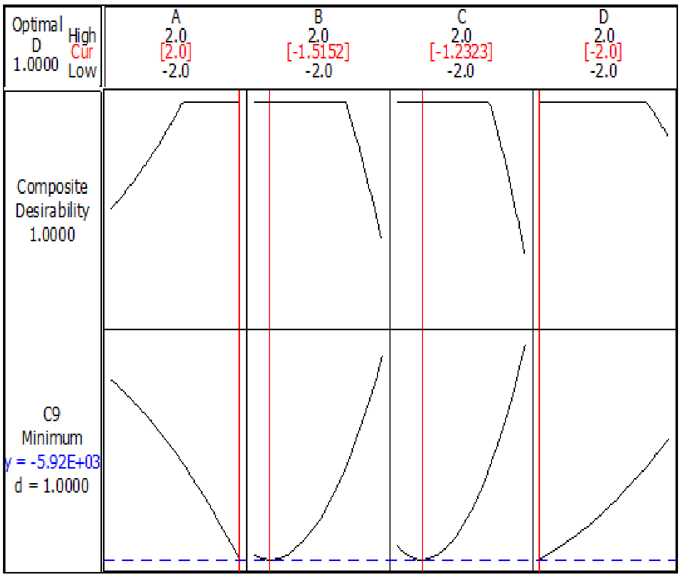


**Figure 3 The optimal value for factors A, B, C, D**

Based on the optimization graph in the Response Surface Methodology method, Global Solution or the optimal solution is obtained using Minitab 16 software as follows
A (Set Up Time) = 2 (80 minutes)
B (Lot Size) = -1.51515 (8 tons)
C (Loading interval) = -1.23232 (208 minutes)
D (Demand Stability) = -2 (90%)

With the value of the goal for the minimum WPM, the lowest value is 0, the target value is 0 and the upper value is 11000.

### Conclusion

1. Created three alternative ARENA simulation models to determine the optimal lean manufacturing configuration for Madura shipyards.
2. The lean manufacturing simulation model is used to determine the optimal settings of the lean manufacturing configuration, set up time, lot size, loading interval, and demand stability
3. From the completion of the AHP method, it can be seen that the weight for the waiting time criterion is 0.67; flow time 0.24, and Work in Process 0.09. The weight of each criterion produced from the AHP method multiplied by the response of each criterion will be an A weighted performance.
4. Based on the optimization graph in the Response Surface Methodology method, Global Solution or the optimal solution is obtained using Minitab 16 software as follows
   A (Set Up Time) = 2 (80 minutes)
   B (Lot Size) = -1.51515 (8 tons)
   C (Loading interval) = -1.23232 (208 minutes)
   D (Demand Stability) = -2 (90%

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