Bulletin of Business and Economics, 13(2), 1139-1145
https://bbejournal.com
https://doi.org/10.61506/01.00474

Implementation of Waste Assessment Matrix for Productivity Improvement in an Automotive Industry

Jahanzaib Jamil[1], Syeda Marya Zaidi[2]

Abstract
Lean system is a philosophy which targets in elimination of waste so as to enhance productivity and efficiency. The automotive firms aim to streamline production to enhance efficiency. The current research addresses a contemporary industry problem relevant to a practice-based case study along with coming up with appropriate rationale and creative problem-solving solutions to the problems being faced by an automotive industry in Pakistan. There were numerous issues occurring in the Assembly shop of the plant such as defects, longer lead times, and excess inventory etc. delaying the overall production. Based on these industry problems, this research is conducted by adopting the methodology of Waste Assessment Model (WAM). The waste assessment matrix, which is the foundation of this study, is used in this paper to detect various waste types in the assembly shop of an automotive plant to increase industrial production. This method helps in analyzing the relative significance of different kinds of wastes. Other lean tools, such as layout improvement are then utilized as creative solutions for improving the wastes. Results demonstrate that not only lead time, inventory, transportation and wastes are reduced but the accessibility and performance of the plant are likewise enhanced.
Keywords: Lean Manufacturing, Waste Assessment Model, Waste Minimization

1. Introduction

Lean manufacturing concepts have been known for the past 20 years, but implementing these concepts is an emerging trend. Knowing that every industry is under pressure to increase its competitive edge, industries today are using a lot of lean techniques to increase production (Rother and Shook, 2003). For the objective to address industry problems to improve productivity, a multinational automotive industry is selected as the case study in order to get rid of problems in its production process.

It has been observed that there have been certain problems in terms of wastes occurring in the assembly line of automotive industry during production of different Vehicle variants. These wastes can be big or small too. But these wastes overall hiders the smooth production which thus upsets the cycle. Alludes to the ideal supply management idea, this condition makes the organization less responsive and in danger of losing clients. Hence these wastes need to be identified in order to have smooth production so as the productivity can be improved. There are a few techniques which could be utilized for recognition of wastes, however this paper will utilize Waste assessment model (WAM) that would assist in analyzing the impact of seven kinds of wastes. This procedure characterizes the interrelationship between various types of waste in the assemble line to feature their relative importance (Fitriana and Gabriel, 2022). Thus, WAM is frequently incorporated with the Lean technique as an improvement strategy (Liker, 2021).

So, the current paper's main focus is to access the problems arising in the assembly line of an automotive industry by using a waste assessment model. The research scope is limited to the Assembly Shop due to the over whelming demand from customers and the Company also plans to increase Productivity by controlling wastes utilizing lean tools. Hence this paper focuses on addressing industry problems occurring on the assembly line.

1.1. Waste Assessment Model for identification of Problem

It is vital to figure out the significant problem that have the most noteworthy effect on production and in the event that if it is improved, entire cycle will move along. In such manner waste assessment model is utilized to figure out how high the impact of one waste puts on another waste in the assembly line. Then, at that point, waste relationship matrix WRM is utilized to gauge the degree of relationship of seven types of waste delaying the production. The waste having the strongest connection with any remaining wastes are then chosen as the conceivable non-value adding activity and will accordingly eliminated through lean approach for improving the process (Wilson, 2010). The following stage involves assessment questionnaire which will then be utilized for ranking the waste by consolidating the relationship matrix and the consequence of the assessment questionnaire (Amankwa, 2018). The answers of these questions are then summed up to generate the overall score. The matrix is utilized to assist in recognizing the top most occurring wastes in the line. The waste assessment model has been designed based on each kind of the seven wastes (below figure) (Ali et al., 2015).

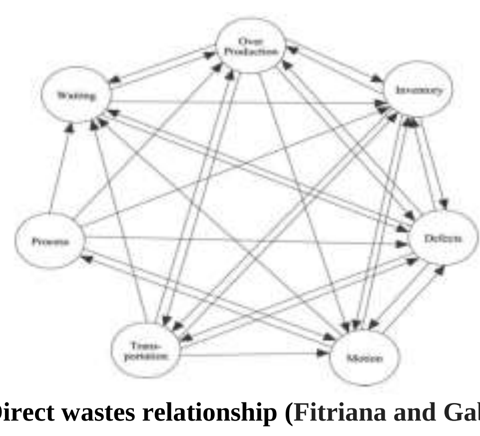

Figure 1: Direct wastes relationship (Fitriana and Gabriel, 2022).

[1] B.E in Industrial and Manufacturing from NED University of Engineering and Technology, Karachi, Master of Engineering Management (MEM) from NED University of Engineering and Technology, Karachi, jahanzaibjamil@live.com
[2] B.E in Industrial and Manufacturing from NED University of Engineering and Technology, Karachi, Master of Engineering Management (MEM) from NED University of Engineering and Technology, Karachi, syedamarya56@gmail.com

The current paper involves the usage of methodology of waste assessment model with the integration of lean system for identifying different wastes occurring in the shop. This will be followed by application of waste relationship matrix so as to find the utmost waste which needs to be given supreme importance for the purpose of improving productivity (Rahmanasari et al., 2021).
This methodology of WAM is carried out by taking field observations. Data is gathered by utilizing 4 approaches detailed out in the waste assessment matrix which includes taking survey from management related to problems of wastes occurring in the shop which is then followed by estimating the relationships of wastes with one another. The weightage will help in analyzing the top most waste which contributes the more in hindering smooth flow of production. Hence this WRM helps in identifying the highest waste that requires to be eliminated to improve the operations. Numerous brainstorming meetings among experts are conducted for exploring and answering to the below questions (Fitriana and Gabriel, 2022).

Table 1: Waste assessment questionnaire (WAQ) (Source: Self-Created)

	A- Answer	W- Weight
	Q 1. Does x produce y?	
a	Always	4
b	Sometimes	2
c	Rarely	0
	Q 2. What is the type of the relationship between x and y?	
a	As x increases y increases	2
b	As x increases y reaches a constant level	1
c	Random depends on conditions	0
	Q 3. The effect of y due to x:	
a	Appears directly and clearly	4
b	Needs time to appear	2
c	Not often appears	0
	Q 4. Eliminating the effect of x on y is achieved by:	
a	Engineering Methods	2
b	Simple and direct	1
c	Instructional solution	0
	Q 5. The effect of y due to x, mainly influences:	
a	Quality of products	1
b	Productivity of resources	1
c	Lead time	1
d	Quality and productivity	2
e	Productivity and lead time	2
f	Quality, productivity and lead time	4
g	Quality and lead time	2
	Q 6. In which degree does the effect of x on y increase manufacturing lead time?	
a	High degree	4
b	Medium degree	2
c	Low degree	0

Note: ‘x’ stands for any type of waste which has an effect on the other type of waste ‘y’

Table 2: The relationship between different types of waste (Source: Self-Created)

Question	1		2		3		4		5		6		Score	Relationship
Relation of wastes	A	W	A	W	A	W	A	W	A	W	A	W		
T-O	c	‘0’	C	‘0’	b	‘2’	B	‘1’	c	‘1’	c	‘0’	4	U
T-I	c	‘0’	C	‘0’	b	‘2’	B	‘1’	f	‘4’	c	‘0’	7	O
T-D	b	‘2’	A	‘2’	a	‘4’	B	‘1’	f	‘4’	b	‘2’	15	E
T-M	c	‘0’	C	‘0’	b	‘2’	B	‘1’	g	‘2’	b	‘2’	7	O
T-W	b	‘2’	A	‘2’	b	‘2’	A	‘2’	c	‘1’	c	‘0’	9	I
I-O	b	‘2’	A	‘2’	a	‘4’	A	‘2’	e	‘2’	b	‘2’	14	E
I-D	a	‘4’	A	‘2’	a	‘4’	A	‘2’	g	‘2’	b	‘2’	16	E
I-M	c	‘0’	C	‘0’	b	‘2’	A	‘2’	c	‘1’	b	‘2’	7	O
I-T	a	‘4’	A	‘2’	a	‘4’	A	‘2’	c	‘1’	b	‘2’	15	E
M-I	c	‘0’	C	‘0’	c	‘0’	C	‘0’	c	‘1’	c	‘0’	1	U
M-D	a	‘4’	A	‘2’	a	‘4’	B	‘1’	g	‘2’	b	‘2’	15	E
M-W	a	‘4’	A	‘2’	a	‘4’	A	‘2’	e	‘2’	a	‘4’	18	A
M-P	c	‘0’	C	‘0’	c	‘0’	C	‘0’	b	‘1’	c	‘0’	1	U
W-O	c	‘0’	C	‘0’	c	‘0’	C	‘0’	b	‘1’	c	‘0’	1	U
W-I	c	‘0’	C	‘0’	c	‘0’	C	‘0’	b	‘1’	c	‘0’	1	U
W-D	b	‘2’	C	‘0’	b	‘2’	B	‘1’	g	‘2’	b	‘2’	9	I
O-I	a	‘4’	A	‘2’	a	‘4’	A	‘2’	a	‘1’	c	‘0’	13	E
O-D	c	‘0’	A	‘2’	b	‘2’	A	‘2’	f	‘4’	c	‘0’	10	I
O-M	c	‘0’	C	‘0’	c	‘0’	C	‘0’	b	‘1’	c	‘0’	1	U
O-T	b	‘2’	A	‘2’	a	‘4’	A	‘2’	a	‘1’	c	‘0’	11	I
O-W	c	‘0’	C	‘0’	c	‘0’	C	‘0’	c	‘1’	c	‘0’	1	U
P-O	c	‘0’	C	‘0’	c	‘0’	C	‘0’	a	‘1’	c	‘0’	1	U
P-I	c	‘0’	C	‘0’	c	‘0’	C	‘0’	c	‘1’	c	‘0’	1	U
P-D	c	‘0’	C	‘0’	c	‘0’	C	‘0’	a	‘1’	C	‘0’	1	U
P-M	c	‘0’	C	‘0’	c	‘0’	C	‘0’	b	‘1’	c	‘0’	1	U
P-W	a	‘4’	A	‘2’	a	‘4’	A	‘2’	e	‘1’	c	‘0’	13	E
D-O	b	‘2’	C	‘0’	c	‘0’	B	‘1’	c	‘1’	c	‘0’	4	U
D-I	c	‘0’	C	‘0’	c	‘0’	C	‘0’	c	‘1’	c	‘0’	1	U
D-M	c	‘0’	C	‘0’	c	‘0’	C	‘0’	b	‘1’	c	‘0’	1	U
D-T	b	‘2’	C	‘0’	c	‘0’	B	‘0’	e	‘1’	c	‘0’	3	U
D-W	c	‘0’	C	‘0’	c	‘0’	C	‘0’	c	‘0’	c	‘0’	0	U

1.2. Using the Model for Analysis of Problem

For addressing the waste assessment model in the assembly shop of an automotive firm, originally the questionnaire has been distributed to discover the scores of wastes occurring in the assembly shop. After assessing the questionnaire results, ranking has been provided utilizing WAM. This method comprises of major 2 phases which are (Henny and Budiman, 2018):

- Utilizing Waste Relationship Matrix (WRM) for determining the degree of relations among different wastes in the firm.
- Utilizing Waste Assessment Questionnaire (WAQ) for assessing every kind of waste and determining the weightage of every waste.

The responses to the questionnaires range from 0 to 4 and are shown in beneath table:

WAM was the initial step which was carried out to inspect and confirm the waste that needs to be focused deeply for the purpose of starting the execution procedure of productivity improvement with the help of lean tools. The distribution of ranges are provided in beneath table:

Table 3: Range divisions of strength of direct relationship (Source: Self-Created)

Range	Type	Relation Symbol
17 to 20	Absolutely necessary	A
13 to 16	Especially important	E
9 to 12	Important	I
5 to 8	Ordinary closeness	O
1 to 4	Unimportant	U

This procedure is followed by listing the scores in terms of a matrix known as Waste assessment matrix. This WRM is then utilized for recognizing that waste having the utmost impact on all other wastes. Eliminating this waste identified will help in maintain the smooth production flow. Hence when the matrix has been allotted with the numbers as determined in the range distribution table, *waste relationship matrix* is figured out as depicted in beneath table (Ali et al., 2015).

Table 4: Waste relationship matrix (WRM) (Source: Self-Created)

F/T	T=Transportation	I=Inventory	M=Motion	W=Waiting	O=Over Production	P=Processing	D=Defect	N=Non used Talent
T=Transportation	A	O	O	I	U	X	E	X
I=Inventory	E	A	O	X	E	X	E	X
M=Motion	X	U	A	A	X	U	E	X
W=Waiting	X	U	X	A	U	X	I	X
O=Over production	I	E	U	U	A	X	I	X
P=Processing	X	U	U	E	U	A	U	X
D=Defect	U	U	U	U	U	X	A	X
N=Non-Used Talent	X	X	X	X	X	X	X	A

Table 5: Waste matrix values (Source: Self-Created)

F/T	T	I	M	W	O	P	D	N	Score	Percentage
T	10	4	4	6	2	0	8	0	34	16%
I	8	10	4	0	8	0	8	0	38	18%
M	0	2	10	10	0	2	8	0	32	15%
W	0	2	0	10	2	0	6	0	20	9%
O	6	8	2	2	10	0	6	0	34	16%
P	0	2	2	8	2	10	2	0	26	12%
D	2	2	2	2	2	0	10	0	20	9%
N	0	0	0	0	0	0	0	10	10	5%
Score	26	30	24	38	26	12	48	10	214	100%
Percentage	12%	14%	11%	18%	12%	7%	22%	5%	100%	
Based On A: 10; E: 8; I: 6; O: 4; U: 2; X: 0										

Above table shows the waste relationship matrix developed so as to identify different kinds of waste. This matrix has been utilized for analyzing the impact of wastes with one another. There are total seven kinds of wastes occurring in the shop each having different percentage.

2. Solution

2.1. Strategic transitions

Founded on the methodology of WAM, it has been found that the waste of inventory contributes the highest percentage which is 18%. This waste is the biggest waste affecting the overall assembling operations. Excess inventory, i.e. inventory-waste, prompts to upsurge lead-time, averts quick recognition of issues and asks for space requirements. After using the waste assessment model, it has been recognized that problem of buffer stock is a foremost issue which needs to be solved. Similarly, next in the sequence are the wastes of transportation and overproduction each of 17%. Consequently, lean tools are needed to implement for reducing these wastes to enhance the smooth flow of production (Feld, 2000).

For the reason of conducting smooth production flow, it is particularly essential to eradicate waste of inventory as it consumes greater lead time and greater space utilization (Shinde and Shende, 2014). Hence layout modification is suggested to implement to optimize the space utilization and remove inventory.

2.2. Existing Condition of Manufacturing Plant

- In an Auto Industry general pattern of Product flow starts from Press Shop where large sheets of metal are cut into desired shapes via Press Machine.
- From Press Shop parts go into Weld Shop where different types of Welding operations are performed to get the desired shape of Vehicle.
- Shell Body then moves into Paint Shop and from Paint Shop vehicle moves to Assembly Shop where Finished product is made ready by assembling different components like Suspension System, Braking System, Engine and Transmission, Electronics and ECUs and finally Garnishing parts and after Final Quality checks it is ready for Customer.

In overall product flow from Press to Paint, Lot is maintained (1 Lot = 10 Vehicles). However, as vehicles move from Paint Shop to Assembly during this Lot gets break due to different Quality Issues. Non-defective units move to Assembly while defective units are hold for repairing. As vehicle moves to Assembly Shop, Logistics operations supply entire Lot parts at designated stations and due to Lot break-up inventory gets built-up at Assembly stations due to hold defective vehicles. Over the period of time as break-up lots increased more and more inventory gets piled up on racks which ultimately results in excessive handling of parts and internal failure costs.

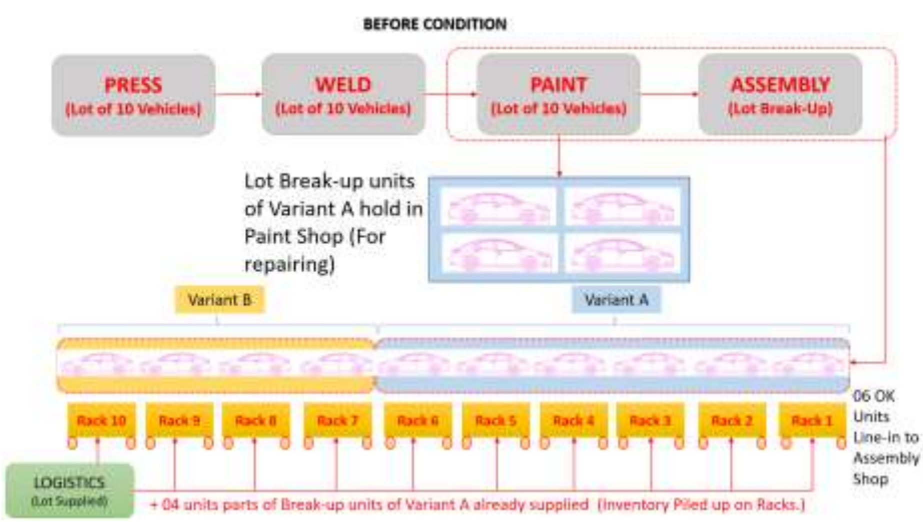

Figure 2: Existing Layout (Source: Self-Created)

2.3. Layout Modification for MUDA Elimination- proposed solution

Two options are found to be available for the solution of this particular problem of Inventory (Nallusamy and Adil Ahamed, 2017).

- Lot Size Reduction from 10 to 05 units.
- Layout Improvement (Paint → Assembly)

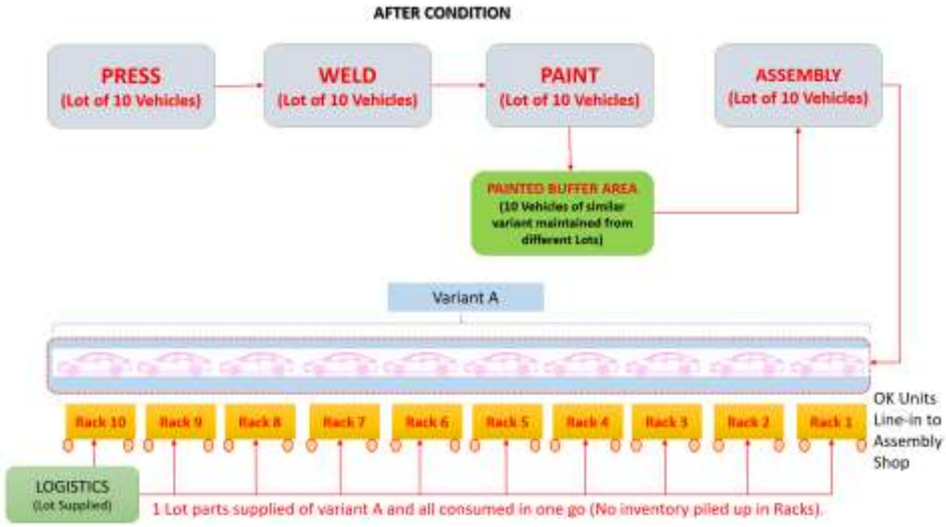

Figure 3: Layout Modification (Source: Self-Created)

In adopting proposal number 1 there rises a constraint that parts supplied to industry are from multi source and those sources are providing to other OEMs as well with common Lot size. In case of special packaging of 05 Vehicles Lot, the overall Cost would increase and this cost is recurring cost in each Lot. Hence due to this cost the overall cost will go up resulting in withdrawal from this proposal.

In adopting proposal number 2, the solution requires internal layout improvement and capital expense and not any repeated expense. After detailed study of current available resources and area it is proposed to develop a temporary buffer area between Paint Line-off and Assembly Line-in. After extensive study of working Lot break-up units, a buffer area needs to be developed comprising of storage area of around 60 units.

In after condition, 10 vehicles of same variant but different lot will be maintained and then once all the vehicles from same variant reaches quantity of 10 then those vehicles will be Lined-in. Simultaneously, Logistics will be supplying 1 Lot part which will be timely consumed and hence no pilling-up of inventory which ultimately will result in minimal internal failure cost and reduced part/material handling unlike previous condition. In this way, waste of inventory will be eliminated.

3. Creative problem-solving by using 5S

5S is another creative solution which is recommended to be implemented in the assembly shop so as to eliminate industry problems of waste occurring especially the waste of inventory and transportation and the other TIMWOOD also (Ohno, 1988). It is truly an innovative management strategy that encourages employees to think lean, opening the way for the adoption of Lean concepts in the business, despite the fact that it is usually perceived as a housekeeping technique (Gupta, 2022).

Seiri (Sort), Seiton (set in order), Seiso (Shine), Seiketsu (Standardize), and Shitsuke are the 5 Japanese terms that make up the acronym 5S. (Sustain) (Ab Rahman et al., 2010). These five Ss emphasize an efficient workplace and work process, and their appropriate implementation enables all employees to apply continual improvement.

3.1. 5S Solution

Sort: 5S has been suggested to implement in the assembly line. This is done by separating useful from extraneous objects is a prerequisite for sorting. The standard procedure to follow during sort is to red-tag the things that are unneeded. Results acquired shows significantly decrease TIMWOOD to a much greater extent. The execution of 1st step will depict the following results in the image below:

5S Sheet-1s			
LMS		Product shorting	
Before 5s		After 5s	
			
Before 5s		After 5s	
Problem	idea	Result	Benefits
Difficult to find	Different products placed in different racks	Easy to find	Product easily find in the place.

Figure 4: Example of Sort implementation (Source: Self-Created)

Set in order: All of the equipment used in the assembly shop are organized according to its function and requirements. The following steps are taken to implement this section (Kumar et al., 2022):

- Arrange the objects in the workspace according to how frequently they are used.
- Keep commonly used goods close to where they will be utilized.
- Make storage space greater than the object so that it is simple to put back.
- Put frequently used things away from the site of use.

The execution of 2nd step depict the following results in the image below

5S Sheet-2s			
LMS		Tools are difficult to find	
Before 5s		After 5s	
			
Before 5s		After 5s	
Problem	idea	Result	Benefits
Tools difficult to find	Specify each tool position	All Tools clearly visible &	Easy to find.

Figure 5: Example of Set-in-order implementation (Source: Self-Created)

Shine: The entire place is then cleaned and refurbished. Better aesthetics are produced and the floor is also marked (Xu, 2013). Picture following displays an illustration of shine activity as follows:

5S Sheet-3s			
LMS		Cleaning the machine	
Before 5s		After 5s	
			
Before 5s		After 5s	
Problem	idea	Result	Benefits
Difficult to Work on it	Cleaning & oiling the machine	Smoothly working	Easy to work & time Reducing to complete a work

Figure 6: Example of Shine implementation (Source: Self-Created)

Standardize: Everything is then organized into areas for proper placement, by placing all of the equipment in their standard locations. It is clear from Figure below that floor marking will become a standard for related case.

Figure 7: Standardization Activity (Source: Self-Created)

Sustain: In the last step, a performance chart is added to the visual board, and a weekly discussion is scheduled, in order to maintain the 5S activities effectively.

To summarize the above solution, the 5S method is a fantastic place to start for any improvement initiatives that attempt to reduce problems in terms of waste in the manufacturing process and, eventually, boost a company's bottom line by raising the quality of its goods and services while cutting costs. Productivity will surely increase as a result of the 5S methodology's successful use.

4. Conclusion

This research paper looks into the contemporary industry problem occurring in the automotive industry by using a new model for carrying out a valuation of diverse kinds of waste {problems) in an assembly shop. The waste assessment matrix is utilized as a methodology for identification of Muda (wastes) for improving productivity in the manufacturing plant. This research paper concludes that the model is expected to contribute a noteworthy part in recognizing waste. The results displayed that inventory waste has found to be greatly affected by all others; whereas defects-waste is the least influenced by others (Ali et al., 2015). There are other wastes also like problems of transportation etc. The results of the model are used to apply layout changes and 5S, two examples of lean manufacturing solutions. These tools significantly reduce recognized problems of transportation, inventory, motion, and defect wastes, improving production volume and reducing lead time as a consequence (Ab Rahman et al., 2010). This methodology has not only focused on a particular waste but has also provided a route for continuous improvement, meaning that after two or three large waste have been removed, it is time to move to the next category of waste and its eradication. There are yet, a few things need to be carried out in future among which the study of waste assessment in service sector is the major one (Gupta, 2022). Nevertheless, the results in this research paper proposes in equal relevance in a high volume manufacturing plant.

References

Ab Rahman, M. N., Khamis, N. K., Zain, R. M., Deros, B. M., & Mahmood, W. H. W. (2010). Implementation of 5S practices in the manufacturing companies: A case study. *American Journal of Applied Sciences*, *7*(8), 1182-1189.

Ali, B., Jaweed, S., & Fahad, M. (2015). Implementation of waste assessment matrix and line balancing for productivity improvement in a high variety/high volume manufacturing plant. *Proceedings of ESMD, Karachi*, 65-75.

Amankwa, E. (2018). *Factors Influencing Sustainable Operations Management Development in the Dairy Manufacturing Sector in Johannesburg*. University of Johannesburg (South Africa).

Feld, W. M. (2000). *Lean manufacturing: tools, techniques, and how to use them*. CRC press.

Fitriana, R., & Gabriel, D. S. (2022, May). The Identification of Waste in Mineral Water Company Using Waste Assessment Management Method and Lean Manufacturing Approach. In *2022 7th International Conference on Business and Industrial Research (ICBIR)* (pp. 689-693). IEEE.

Gupta, K. (2022). A review on implementation of 5S for workplace management. *Journal of applied research on industrial engineering*, *9*(3), 323-330.

Henny, H., & Budiman, H. R. (2018, August). Implementation lean manufacturing using Waste Assessment Model (WAM) in shoes company. In *IOP Conference Series: Materials Science and Engineering* (Vol. 407, No. 1, p. 012077). IOP Publishing.

Kumar, K. S., Akila, K., Arun, K. K., Prabhu, S., & Selvakumar, C. (2022). Implementation of 5S practices in a small scale manufacturing industries. *Materials Today: Proceedings*, *62*, 1913-1916.

Liker, J. K. (2004). The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer McGraw-Hill Education.

Nallusamy, S., & Adil Ahamed, M. A. (2017). Implementation of lean tools in an automotive industry for productivity enhancement-A case study. *International journal of engineering research in Africa*, *29*, 175-185.

Ohno, T. (2019). *Toyota production system: beyond large-scale production*. Productivity press.

Rahmanasari, D., Sutopo, W., & Rohani, J. M. (2021, March). Implementation of lean manufacturing process to reduce waste: a case study. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1096, No. 1, p. 012006). IOP Publishing.

Rother, M., & Shook, J. (2003). *Learning to see: value stream mapping to add value and eliminate muda*. Lean enterprise institute.

Shinde, D. B., & Shende, P. N. (2014). Improvement of Plant Layout by using 5S technique-An industrial case study. *International Journal of Modern Engineering Research*, *4*(2), 141-146.

Wilson, L. (2010). How to implement lean manufacturing. *(No Title)*.

Xu, C. J. (2013). Research on implementation plan of 5S management. *Applied Mechanics and Materials*, *380*, 4440-4443.