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LEAN PRACTICES FOR WASTE PRIORITISING IN MACHINING BASED PRODUCT

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Original Article

ABSTRACT

Many organizations have dedicated to improve the efficiency of operations through waste removal and reduction as a philosophy in the lean manufacturing initiative. This paper aimed to examine the application of lean production techniques in machining based product production systems, particularly for block cross member automotive parts. The Lean tool as known as value stream mapping was deployed for preliminary analysis while the analytical hierarchy process was applied to analyse the multi criteria decision making model for a waste selection process in the production system. The results show that the lean practices' approach by the VSM screened eight waste on the production system, known as Kaizen burst that influence to company' profit which is high access inventory volume in between process, high rework and reject volume, delayed supplier and deliver product on time to customer, wrong forecast data, changeover time require long time, low machine performance/ inefficiency machine, travelled time in-between process and lack on 5S activities. By using another one of the lean approach, AHP prioritises the waste found into rank and defines the most influenced waste to resolve.

***KEYWORDS:** Lean Manufacturing, Value Stream Map & Analytic Hierarchy Process*

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1. INTRODUCTION

In general, a variety of tools and techniques are applied in the manufacturing industry to determine effective production performance. Although lean has received considerable attention over the years as a result of the literary work, up to now research has ignored the ongoing progress of the philosophy (Mourtzis, Papathanasiou and Fotia, 2016). To achieve perfection in the identification and elimination of the waste through the constant improvement in the product's attraction, it was necessary to create more benefit for customers with fewer resources (Omogbai and Salonitis, 2016).

However, there are several literatures which have dealt with industrial lean implementation failures (Scherrer-Rathje, Boyle and Deflorin, 2009; Esben Rahbek Gjerdrum Pedersen, 2011; Albliwi *et al.*, 2014). Ramadas and Satish (2018) reported that it was difficult to engage employees in an approach to problem solving. In contrast, Amin (2013) stated that the main reason for lean failure was to select the inappropriate way of taking decisions. In fact, Crute et al., (2003)point out the employees or lean practitioners did not find the best method in the Lean Practice because the lean deployment could not be prioritized. On the other hand, employees sometimes considered that all lean practices were the same without measuring the correlation between lean tools and lean deployment and how the two factors could simultaneously be integrated with performance improvement (Brown, Collins and McCombs, 2006). Thus, through the implementation of lean manufactured systems, employees or managers had spent more hours identifying important methods of improving efficiency.

This article is a case study that explains how lean manufacturing tools and techniques have been successfully implemented in the development and implementation of the block cross member production system in a case industry plant based on the metal part machining production. Block cross member manufacturing is a critical process and it involves nine operations starting from material cutting, material surface cleaning, cutting edge, first boring, second boring, third boring, threading, dimensioning/quality check, and packaging. The findings of the project include the development of lean manufacturing tools of the entire block cross-member production system. Therefore, this paper is organized as follows: the research literature review on lean manufacturing. The research method followed by the research activities' flow chart. Next, the result and discussion were shows three point of Kaizen burst including the pair wise comparison to get waste prioritise rank. Conclusions and recommendations for future research is at the end section of this paper.

2. LITERATURE REVIEW

Lean manufacturing (LM) is a drawn from the Toyota Production System (TPS) which can be termed as a management philosophy especially in manufacturing management (Holweg, 2007; Wilson, 2010). There are various similar terms and ideas before the term 'Lean' began to be used to describe this philosophy, such as world-class manufacturing, continuous flow manufacturing, zero inventory production, and just-in-time (King, 2009). However, the main thing and focus of all the terms including LM is to be communicated and aimed to eliminating waste (by eliminating non-value added activities) pursues the same goal which is to reduce the costs and increase the productivity (Yang, Hong and Modi, 2011; Hosseini Nasab, Aliheidari Bioki and Khademi Zare, 2012). In line with this situation we will be able to motivate and stimulate initiatives for manufacturers to persist competitive in the worldwide market environment.

Among the issues and efforts that can assist manufacturers to stimulate the development of the best strategy in dealing with the impact of the current economic downturn is the competence in implementing and strengthening LM through consistent efforts. This can also successfully transforms the manufacturing operations to be more dynamic, but also in line with the development and increase the level of competitiveness (Magnier-Watanabe, 2011; Welo, Tonning and Rølvåg, 2013). This allows manufacturers to control and monitor the inventory level, optimise the utilisation of work space, and effectively monitor the total manufacturing costs efficiently (Sundin *et al.*, 2011; Nawawi *et al.*, 2018). Consequently, manufacturers can participate effectively in transforming the manufacturing operations, basically on expanding productivity, improving the performance of manufacturing operations as well as financial performance (Rahani and Al-Ashraf, 2012). Other than that, any production issue can be handled with more efficiency, especially in managing the variety of demands in a competitive market environment (Demeter and Matyusz, 2011; Aguado, Alvarez and Domingo, 2013). This is crucial, primarily for the manufacturer which produces the product that requires a high customisation level, in which a high response rate is mandatory (Houshmand and Jamshidnezhad, 2006).

Several researchers such as (Doolen and Hacker, 2005; Wilson, 2010; Rahani and Al-Ashraf, 2012) points out that these principles are useful as a guideline or recommendation to understand the implementation of the LM. Furthermore, through these principles, manufacturers also can effectively manage the manufacturing events and makes an improvement to the effects of processing time, demand, or unevenness in supply (Shah and Ward, 2007). Also, the LM implementation also proved valuable in establishing continuous improvement programs (Aguado, Alvarez and Domingo, 2013; Powell *et al.*, 2013). It has empowered workers to take an interest proactively in improving the performance and manufacturing processes (McKone, Schroeder and Cua, 1999). This subsequently increases worker motivation, strengthen the team work, and thus increase the ownership of the work (Linderman, Schroeder and Choo, 2006; Holweg, 2007; Holden, 2011).

Table 1: Five Fundamental Principles of Lean Manufacturing (Womack and Jones, 2003)

Lean Principle	Description
Specify value	Specify the value of the services or product from the end customer perspective standpoint
Map the value stream	Identify all of the product or services steps in the value stream to eliminate unnecessary steps where possible that do not create the value
Make the value flow	Ensuring the services in every process flow or value of the product to the customers without any detours, interruption, delay or waiting
Let the customer pull the (value) process	Product or service is produced according to what and when the customers want it
Pursue perfection.	Implement continuous improvement in to ensure that the value of products or services reaches the perfect stage at which value without waste is created

3. RESEARCH METHOD

In this session, there were divided into 4 stage which in the first stage is current VSM, second stage is the future VSM (Kaizen burst), the third stage is AHP structural model and the last stage is AHP rank performance measure. In preparing a future state value stream map from the actual state value stream map, the investigation work was conducted using the tools and techniques of the Lean Production System to determine the single piece flow through Kaizen. The analytical hierarchical process was then taken as an aid to justify the decision to improve the situation in the Kaizen and ultimately achieved the required targets. To reduce the waste, as the problem indicates in the existing system, several Kaizen burst was used to detect the waste which needed improvements. But this paper discusses only three important Kaizen burst. A summary for this method were shown in Figure 1.

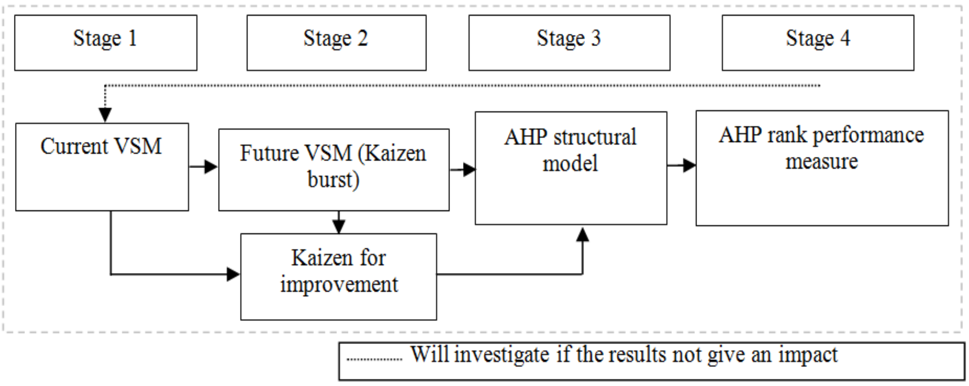
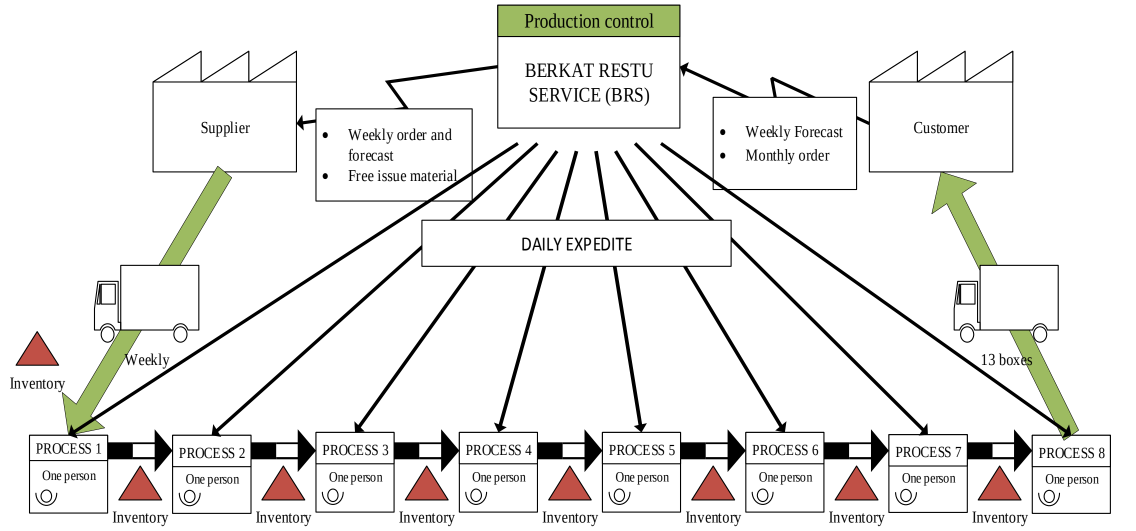


Figure 1: Research Activities' Flow Chart

4. RESULT AND DISCUSSION

4.1. Value Stream Mapping

The quantity of orders for the metal bar cross member sent from customers monthly through email (electronic information). Then order the materials from metal bar suppliers for the product to manufacture. The production plan is set according to an order from the customer. It proceeds to the production phase. The item is then produced in batch for 24 pieces times 5 boxes per day with the manpower one man one machine. The items then are sent to the customer if the required amount of box about 13 boxes are being fulfilled in a given time. The usual lead time for production to produce 13 boxes of items is about three days (based on order). The last part is shipping to the customer. The current state and future state value stream mapping for the production were shown in the Figures. Future State Value Stream Map is an interim stage between the current state map and the ideal state that targets to improve the critical that was defined in the production to achieving company waste elimination goals. By using the current value map before to identify the areas of concern that need to be improved over the coming months and targets for company changes.



C/T= 59 sec	C/T= 237 sec	C/T= 123 sec	C/T= 93 sec	C/T= 86 sec	C/T= 136 sec	C/T= 39 sec	C/T= 75 sec
C/O= 361 sec	C/O= 180 sec	C/O= 168 sec	C/O= 86 sec	C/O= 79 sec	C/O= 107 sec	C/O= 87 sec	C/O= 23 sec
Travel Time= 17 sec	Travel Time= 10 sec	Travel Time= 4 sec	Travel Time= 7 sec	Travel Time= 4 sec	Travel Time= 5 sec	Travel Time= 11 sec	Travel Time= 5 sec
5S Time= 562 sec	5S Time= 611 sec	5S Time= 626 sec	5S Time= 648 sec	5S Time= 680 sec	5S Time= 690 sec	5S Time= 450 sec	5S Time= 512 sec
Rework Time= 7 sec	Rework Time= 127 sec	Rework Time= 133 sec	Rework Time= - sec	Rework Time= - sec	Rework Time= - sec	Rework Time= 13 sec	Rework Time= - sec
Norm. Break T= 315 sec	Norm. Break T= 132 sec	Norm. Break T= 143 sec	Norm. Break T= 58 sec	Norm. Break T= 56 sec	Norm. Break T= 87 sec	Norm. Break T= 62 sec	Norm. Break T= - sec

Figure 2: Current State Value Stream Mapping.

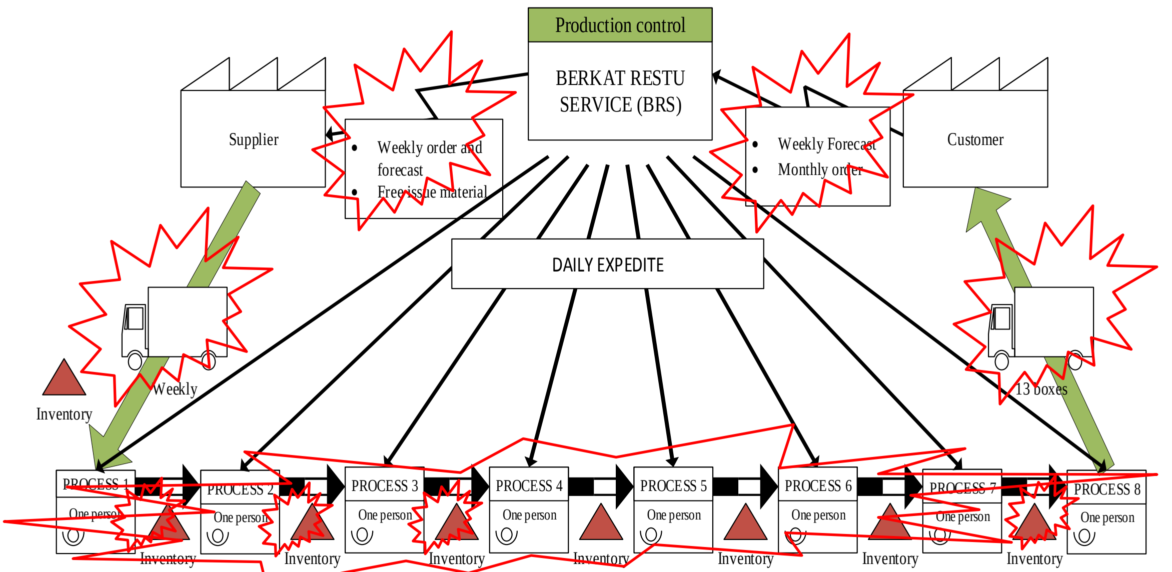


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Figure 3: Future State Value Stream Mapping.

The block cross member is fabricated from a combination of four categories, namely material cutting, milling, turning, and tapping. Then, from the four categories separated into eight processes which is material cutting, material surface cleaning, cutting edge, first boring, second boring, third boring, threading, dimensioning/quality check and packaging. For material cutting, the material is cut using a horizontal band sawing machine. After being cut, the second sub-process is the milling process which is the metal bar will go through the cleaning process, cutting-edge, and boring process. Furthermore, two boring processes were done in the third sub-process known as the turning process. Similar to the boring process, the fourth sub-process is the tapping process for making a thread. All these fabricated conducted by human and machine approach. Finally, the quality check is to make sure the final product followed the specification and functions as well before packaging for delivery. The complete structure of all sub-process becomes a final product that is known as block cross member. The following wastages were identified in the current system based on VSM of block cross member production process; high access inventory volume in between process, high rework and reject volume, delayed supplier and deliver product on time to customer, wrong forecast data, changeover time require long time, low machine performance/ inefficiency machine, travelled time in between process and lack on 5S activities.

4.1.1. Kaizen Burst 1: High Access Inventory Volume in between Process

Understanding the inventory control system in between processes can help lower costs, increasing performance and prevent fraud in the company. It also assesses company current assets, accounts balance, and provides reporting for financial. Materials inventory management differs from the management of other manufacturing-related inventories, including raw materials inventories between process (Puurunen, Majava and Kess, 2014). The function of the materials inventory derives from the needs of the maintenance, and the size of the inventory depends significantly on the production policy. In the current situation in the company selected for a case study, there were problems with high inventory volume in between process because the rate part completed per minutes in every process is not the same and sometimes overload and pending for the next process, its caused delay on progress to finish. Thus highlighting the obvious bottleneck situation in between process as shown in Figure 2.

This current situation during 5 days of data collection for access inventory in between the process. This process does not include the rest time for one hour which has been set. The rate of quantity access inventory in between process per half an hour is different for all process, especially greatly different in between Process 1 and Process 2 in which Process 1 attains a higher number of producing inventory in between per half an hour compare to the other process from day 1 until day 5. These also show that the lowers are from access inventor in between Process 4 and Process 5.

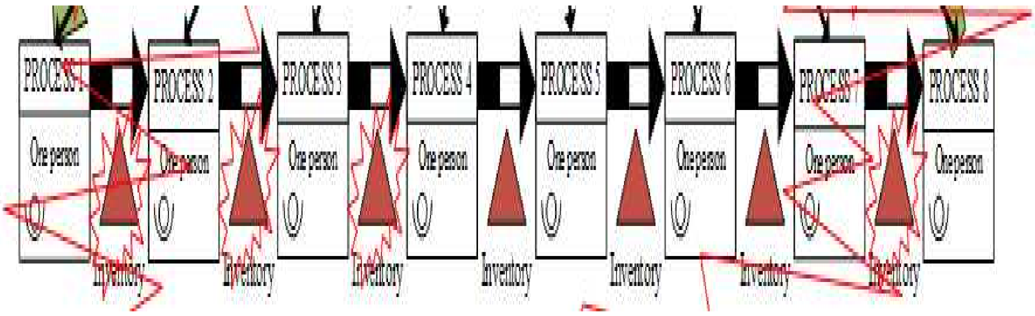

Figure 4: High Inventory Volume in between Process 2, 3, 4 and 8.

Table 2: Average of Access Inventory in between Process during 5 days

Process	Day					Average (pieces)
	1	2	3	4	5	
Process 1–Process 2	38	38	37	37	37	**37**
Process 2–Process 3	27	27	27	27	27	**27**
Process 3–Process 4	22	22	22	22	22	**22**
Process 4–Process 5	21	22	22	22	22	**22**
Process 5–Process 6	23	23	22	22	22	**22**
Process 6–Process 7	22	22	23	23	22	**22**
Process 7–Process 8	26	26	27	26	26	**26**

The higher average rate with 37 pieces, Process 1 taking roughly about 4 minutes to complete one process cycle of a cutting process using the horizontal band saw machine while for the Process 2 takes about 9 minutes per process cycle for face cutting (4 sides of the face) using a vertical milling machine. Thus highlighting the obvious bottleneck situation over the process for the access inventory in between the process. The rate of part complete per hour is greatly different for both processes, in which Process 1 attains a higher rate number part of complete every half an hour as a part for the next process compared to the Process 2. Process 2 to Process 3 and Process 7 to Process 8 shows that there are almost same of the value of the total average of the access inventory in between process within 5 days with 27 pieces and 26 pieces respectively. The other process shows that the same total average with the amount of 22 pieces and also the process of the part complete almost the same for every process. Figure 5 shows the total average for the access inventory in between process within 5 days data collection as in Pareto Chart with the sequence of priority. Overall, 80 % of the access inventory in between process need to improve and the other 20 % is the least. The problem based on high access inventory volume in between process existed in every cycle of the process especially in Process 1 to Process 2.

4.1.2. Kaizen Burst 2: High Rework and Reject Volume

On the quality check section, through a decision process where the work piece is examined using a jig to ensure the work piece accordance with the specifications. The decision will result in yes and no based on the quality check observation. The meaning of yes is that the work piece will continue through the next process which is the packaging process and then continue for the end process to be sent to the customer. On the other hand, no will be divided into two, reject and rework after the decision is made, yes for rework and no for reject. Rework process is a workable material that defect can be repaired like a rough thread and the size of the finished work piece is too large. The work piece will be shipped according to identified and marked damage and will undergo a re-machining process. Unlike the rejection which meant that the problem identified could not be resolved (defect cannot be repaired) as the work piece was too small in size and the threads were damaged, the work piece would be disposed of. From the problems above, it is often a rework process and rejected because of the defect of the work piece. Therefore, the percentages for rework and rejected product problems that indicate the largest population to be avoided is process rework by 86% compared with reject only 14%. From this problem, Table 4.12 below shows the reason for this rework process.

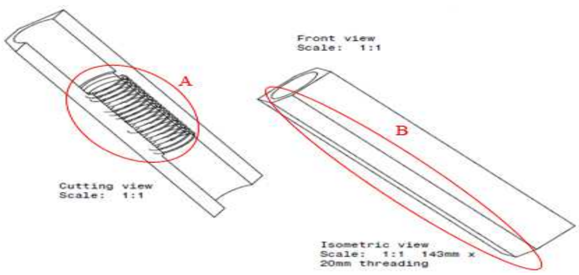

Figure 5: Rework and Reject Point.

Table 3: Causes of the Rework Process

Point	Description	Cause
A	Female thread is too abusive and cannot be inserted by the male jig screw	The cutting tool blade is not sharp The point of the tip (angled) or the work piece is tilted and not straight
B	The cut corners are too little and rough that cannot get into the jig	The tool points are broken or blunt Do not cut according to the specified size

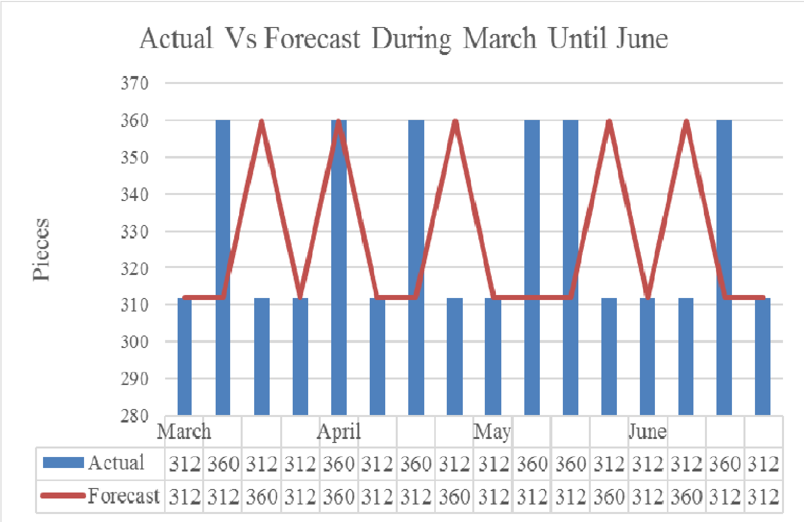

Figure 6: Actual Versus Forecast Graph.

From the observation data obtained, the rework process was conducted to fixing errors and corrections to the product and to find out some of the causes that led to these problems. For point A, when inserting a jig screw on the product, there was a difficulty for the screw to function properly through the female thread that has been made. This is due to the cutting edge of the tool to make the thread not sharp and cause the resulting thread to be rough. Also, the position of the eye of the cutting tool or the work piece is tilted also causes this to happen and produce a slender female thread. While point B, the problem is that the vertices cut too little (not according to the size of the cut) and the surface is rough so that it cannot enter the jig. This happens because the tool points are broken or blunt during the cutting process. The rework process and rejected should not have taken place in the process if the problems identified did not happen and solve. The Rework process is also needed to be avoided and it will give more time to increase the quantity and quality of product production. As an addition, the male jig needs to change and use the proper male jig screw. The existing jig used is not suitable because it only uses conventional screws as jigs.

4.1.3. Kaizen Burst 3: Wrong Forecast Data

Given active asset management, the study and information on the business cycles for the future are important for the company to achieve its goal. The forecasting production planning is a decision for the next few months or one year to minimize total costs for the determination of production quantity, inventory level, level of employment and other decisions. However, the technique with a small forecast error is usually accepted as good and it is calculated based on the difference between actual and forecast values (Ha, Seok and Ok, 2018).

The expected number of times is 312 pieces and also 360 pieces. Had the number of requests increased from 312 pieces to 360 pieces would cause the company to make purchases against material also increased from 21 pieces to 24 pieces. Expectations for inventory on packaging and machinery tools are the same throughout the year. The situation that has occurred in March until June last was different between the forecast and the sales during those months. This can be seen through Figure 5 above which is in March there were differences in the second and third week of 312 pieces from expectations to 360 pieces in actual and also 360 pieces from expectations to 312 pieces in actual. In April the pattern of change to the sum was the same for the previous month but it was in the third and fourth week. Subsequently, in May the difference occurred three consecutive weeks from the second week until the fourth week. In June the difference for this forecast and actually occurred in the second and third week as in March last but the sum is the mirror for that month. Implications that occur as an error in this forecast will result in the delay as noted above. The Product delivered to the customer will be delayed due to lack of material and will also cause high rework volume. This will only make a sick situation to the company from the point of waste of time, labour and others.

4.2. Analytic Hierarchy Process

AHP analysis is been used to make a decision-marking for prioritizing alternatives for considered the critical criteria to the most critical criteria for the solution idea. Therefore the objective of this analysis is to investigate the current practice of lean deployment in metal part machining production and then define the weight of each criterion for identifying and prioritising for each criterion. Starting with a detailed manufacturing process description, the VSM graphical approach enables activities to be identified, and the AHP technique leads to a structural classification of components based on FVSM evaluation criteria in the previous map. There are 8 criteria assessment found from FVSM as stated at the problem in the existing system and shown at Table 2 with the AHP code representation that need to be model structure and rank performance measure.

The analysis was begun by defining the importance of key based objective relates to the case study to meeting the goals. The next step is focused on the structural elements to measure that related to the problems that want to achieve before making a pair wise comparison of element in each group. Then, the criteria were states and found will calculate on the weighting and consistency ratio. Finally, the results of the analysis are synthesized to meeting the goals and then get the rank to smaller the main problem found. The summary of the analysis of AHP process has been shown in Figure 8 below.

In the AHP analysis, the pair wise comparison is used to define the weighting of each the element. The main purpose of the AHP pair wise comparison method is to classify n factors or alternatives. A scale {1/9, 1/8..., 1, 2..., 8, 9} is often used to compare the factors. The criteria and dimension with the highest priority value will be seen as the most important to influence the strategic objectives and vice versa.

Table 4: The AHP Criteria from the Previous FVSM

No	Factor	AHP Code
1	High Access Inventory Volume in Between Process	F1
2	High Rework and Reject Volume	F2
3	Delayed Supplier and Deliver Product on Time to Customer	F3
4	Wrong Forecast Data	F4
5	Changeover Time Require Long Time	F5
6	Low Machine Performance/ Inefficiency Machine	F6
7	Travelled Time In between Process	F7
8	Lack on 5S Activities	F8

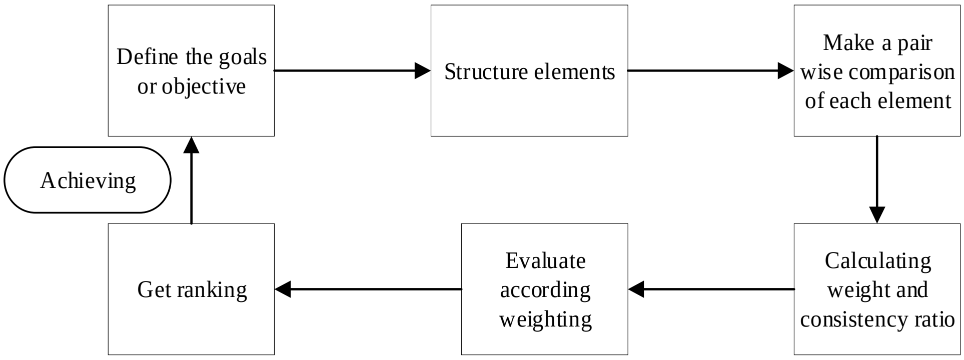

Figure 7: AHP Process Analysis.

4.2.1. Pair Wise Comparisons Matrix

Single piece flow for block cross member manufacturing system based on metal part machining was established in the company selected for the case study. The non-value adding activity of having high access inventory volume in between process were discussed focussing to eliminate the waste. In the high rework and reject volume was discussed about the point fount that always repeated and also detected the problem causes from the problems. Quick response to the wrong forecast data material supply frequently in small lots of waste elimination to minimise total costs for the determination of production quantity, inventory level, level of employment and other decisions. Then, from the criteria found in the FVSM were define the weight of each criterion for identified the prioritising for waste selection identification. The complete process of block cross member manufacturing cell was established to meet the customer quality, cost and delivery requirements. The results for waste selection identification from AHP rank performance measure are shown in Table 5.

Based on the Table 5, F2 which is high rework and reject volume got the highest weightage on the analysis, 28.9% with the rank number is 1 from the overall 28 numbers of comparisons with the principal eigen value is 8.62. The consistency ratio is 6% and it is acceptable based on Saaty suggest lined the consistency ratio should be less than 10% and if not consistent enough (>10%) need to do again and revise the comparisons. This is due to the fact that the two parts that often for the rework process. The section has been figured in Figure 6 labelled as A and B, which is from threading process and cutting edge process, which means once this sector is faulty or the measurement is off the limit, the other next processes might be also on the risk of being rejected. The tools required might be critical in ensuring that the process is able to be carried out in repeating motions during mass production. Now the jigs and fixtures involved for the selected process can be analyzed for any requirements for tool redesign.

Table 5: Summarise of AHP Priorities

Process	Consistency Measure	Consistency Index (CI)	Random Index (RI)	Consistency Ratio (CR)	Priority	Rank
F1	8.74	$CI = \frac{8.62 - 8}{7}$	(Saaty suggest)	$CR = \frac{0.09}{1.41}$ Should be less than 0.10 @ 10%	**9.3%**	**5**
F2	8.70				**28.9%**	**1**
F3	8.39				**6%**	**6**
F4	8.23				**5.2%**	**7**
F5	8.83				**14.1%**	**3**
F6	8.87				**22.1%**	**2**
F7	8.85				**11.2%**	**4**
F8	8.35				**3.1%**	**8**
	λ_{max} = **8.62**	**0.09**	**1.41**	**0.06 @ 6%**		

5. CONCLUSIONS

Lean manufacturing system implemented in this paper is done in the manufacturing of block cross member based on metal part machining production to eliminate waste found. There are 8 non-value adding wastes found from the future state which is high access inventory volume in between process, high rework and reject volume, delayed supplier and deliver product on time to customer, wrong forecast data, changeover time require long time, low machine performance/ inefficiency machine, travelled time in between process, and lack on 5s activities. However, in this paper, only three waste were discussed in term of Kaizen burst to detect the waste problem. The limitations in this research is that this manufacturing cell can produce only block cross member and there is no flexibility of producing other products based on the machining based product. For this reason, the effects of integrating the lean practices to develop a more robust research model can be compared with comparative studies involving a number of manufacturing companies in future work.

6. ACKNOWLEDGEMENTS

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