



Selecting the best alternative in pasting the outer side of the battery with the application of AHP

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General Note



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ABSTRACT

This paper presents the Analytical Hierarchy process (AHP) as a potential method for estimating the best alternative for pasting the battery outer layer in a battery manufacturing unit. A hierarchical structure is constructed for the parameters involved in the pasting alternatives, estimating the priority vectors for the alternatives involved in the pasting process, then estimating the global vector for the alternatives. The alternative which is having the highest global vector is taken as the best alternative.

Keywords: Analytical hierarchy process (AHP), pasting alternatives, priority vector, global vector.

1. INTRODUCTION

Selecting the best alternative considers the both methods involved in pasting the outer layer of the battery. The two pasting methods are

- Belt pasting
- Orifice pasting

Both the methods considers the criteria like production cost, scrap cost, process cost and type change cost which has the sub-criteria like cycle time, work in process, cost of poor quality, percentage of rejection, man power cost, machining cost, tooling and type change cost. By considering all these criteria and sub-criteria, we will be able to find the best method in the pasting alternatives. By noticing the criteria like production cost at regular intervals of time, we will get an idea about both the methods considering the output from the each alternative. But it takes more time as the production and manufacturing is a long process. In order to reduce the decision making time, the present method considers the preferences among the available criteria and sub-criteria to find out the best alternative in pasting that has more production rate within in a less period of time when compared to the other pasting method.

Six sigma is an integrated approach to reduce variability, waste, rework and defects. Six- Sigma is a statistical measurement of only 3.4 defects per million. Six sigma has become the financial improvement strategy for the organizations. This increases the customer satisfaction and produces high class products from the best process performances. Bill Smith who is vice president of Motorola Corporation is considered as father of six sigma. Fredrick Taylor, Walter Shewhart and Henry Ford played a great role in the evolution of six-sigma in the early twentieth century. Sigma traditionally used for measurement of variation with in a process. Six sigma level refers to 3-4 defects per million opportunities [18].The organization working daily with six sigma practices and concepts with notable improvements in customer satisfaction and process performance is considered to a six sigma organization [15].Many authors found benefits of six sigma methodology in reducing cycle time, cost reduction, defects elimination and customer satisfaction [18, 1]. Brue and Howes, (2005) [2] mentioned six sigma as a strategy for improvement and problem solving methodology that can eliminate root cause of effects. O" Nail and Duvall, (2003)[10] discussed applications of six sigma quality frameworks. They have used quality tools and post occupancy evaluation research method to create and manage optimal space for office workers. Some of six sigma program has been failed in manufacturing industry due to lack of knowledge of six sigma methodology.Kwak and Anbari, (2006)[7] discussed the obstacles and benefits of six sigma. They also identified future of six sigma approaches. Snee, (2004)[16] focused on process outputs that are of critical important to customer. Six sigma was described as business improvement approach that finds and eliminate defects or causes of mistake in processes. Mike Harry, (2000)[9] indicated that six sigma is a new paradigm of management innovation for companies survival in modern period, which is based on three things: Quality Culture, Management Strategy and statistical Measurement. Gijo and Rao, (2005)[4] suggested that selection of suitable belt projects plays an important role in six sigma implementation and six sigma projects should be selected on the bases of organization goal and objectives. Macmanus, (2007)[8] analyzed that there would be team work in every organization for process improvement. This kind of team approach is important for sustained progress toward process excellence to improve the sigma level.

DMAIC is one of six sigma approach for process and quality improvement. This modal has five phases: Define Measurement, Analyze, Improve and Control. This DMAIC modal systematically helps organizations to solve problems and improve their processes. Chakravorty, (2009)[3] proposed a model for successful implementation of six sigma so that it can reduce the variation or waste from the operation. S. Soni et al., (2013) [17] discussed the quality and productivity improvement in a manufacturing enterprise. This study deals with an application of Six Sigma DMAIC (Define-Measure-Analyze-Improve-Control) methodology in an industry. H.C Hung and M.H. Sung, (2011) [6] explored how a food company in Taiwan can use a systematic and disciplined approach to move towards the goal of Six Sigma quality level. The DMAIC phases were utilized to decrease the defect rate of small custard buns by 70% from the baseline to its entitlement. The other important aspect of sig sigma methodology is training, involvement and rewards of employees. For implementation of six sigma program it is necessary to establishment of six sigma team. The main drawback with this six sigma is that it only considers the measurable aspects of criteria. But the criteria have both qualitative and quantitative characteristics. One more thing is that, this six sigma technique cannot be applicable in finding out the best pasting method (between methods: belt pasting and orifice pasting) in a battery manufacturing unit. Hence an algorithm that considers both the aspects is improved. Analytical hierarchy process is one such method. AHP is an easy and powerful technique, and is especially suited for problems involving both qualitative and quantitative criteria [19]. The methodology of AHP attempts to analyze the impacts of elements in the lowest levels on the overall objective or focus of a hierarchy. The strength of this approach is that it organizes tangible and intangible factors in a systematic way and provides a structured yet relatively simple solution to the problem [13].

2. THE ANALYTICAL HIERARCHY PROCESS (AHP)

In the early 1970's Satty developed AHP which is a problem solving framework based on the inherent human ability to make sound judgment for small problems. A hierarchy of the problem is structured to encompass the basic elements. The objective is to derive priorities on the elements in the last level that best reflect their relative impact on the focus of the hierarchy. To apply the principle of comparative judgments, a matrix is set up to carry out pair wise comparisons of relative importance of the elements in the second

level with respect to the overall focus of the first level. A number of criticisms have been launched at AHP over the years. Harker and Vargas [6] and Perez [7] discussed the major criticisms and proved that these are not valid with theoretical work and examples.

Applications of AHP

The hierarchy is developed from the general (upper levels) to the particular (bottom levels) or from the uncertain or uncontrollable (upper levels) to the more certain or controllable (bottom levels). A process which involves time and uncertainty is the forward-backward process of planning. For the convenience these applications have been classified into three groups, namely:

- (a) Applications based on a theme,
- (b) Specific applications, and
- (c) Applications combined

Themes in the first group are selecting a best alternative, evaluation, benefit–cost analysis, resource allocations, planning and development, priority and ranking, decision- making and resolving conflicts. Second group consists of the specific applications in forecasting, and medicine and related fields. AHP applied with Quality Function Deployment (QFD) is covered in the third group.

Satty [8,9] developed the following steps for AHP:

1. Define the problem and determine the objectives.
2. Structure the hierarchy from the top through the intermediate levels to the lowest levels which successfully contains the list of alternatives.
3. Construct a set of pair wise comparison matrices (size $n \times n$) for each of the lower levels. With one matrix for each element in the level immediately above by using the relative scale measurement shown in Table 1. The pair wise comparisons are done in terms of which an element dominates another. These judgments are then expressed as integers.
4. There are $n*(n-1)/2$ judgments required to develop the set of matrices in step 3. Reciprocals are automatically assigned in each pair-wise comparison.
5. Hierarchical synthesis is now used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.
6. Having made all the pair-wise comparisons and entered the data, the consistency is determined using the given value. W is solved. The consistency index, CI is calculated as follows: $CI = (\lambda_{max} - n) / (n - 1)$, where n is the matrix size. Judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in table 2. The CR is acceptable, if it does not exceed 0.10. If it is more, the judgment matrix is inconsistent. To obtain a consistent matrix, judgment should be reviewed and improved.
7. Step 3-6 are performed for all levels in the hierarchy.

3. APPLICATION OF AHP TO THE CONSIDERED CASE STUDY

Considering the criteria and sub-criteria involved in finding the best pasting method, the hierarchy has been drawn below. In the present work we consider both qualitative and quantitative criteria. AHP methodology has been applied to obtain priority vectors for each alternative which are subsequently employed to obtain global vectors.

Table 1 Pair-wise comparison scale for AHP preferences [8, 9]

Numerical Rating	Verbal judgments of preferences
9	Extremely preferred
8	Very strongly to extremely
7	Very strongly preferred
6	Strongly to very strongly
5	Strongly preferred
4	Moderately to strongly
3	Moderately preferred
2	Equally to moderate
1	Equally preferred

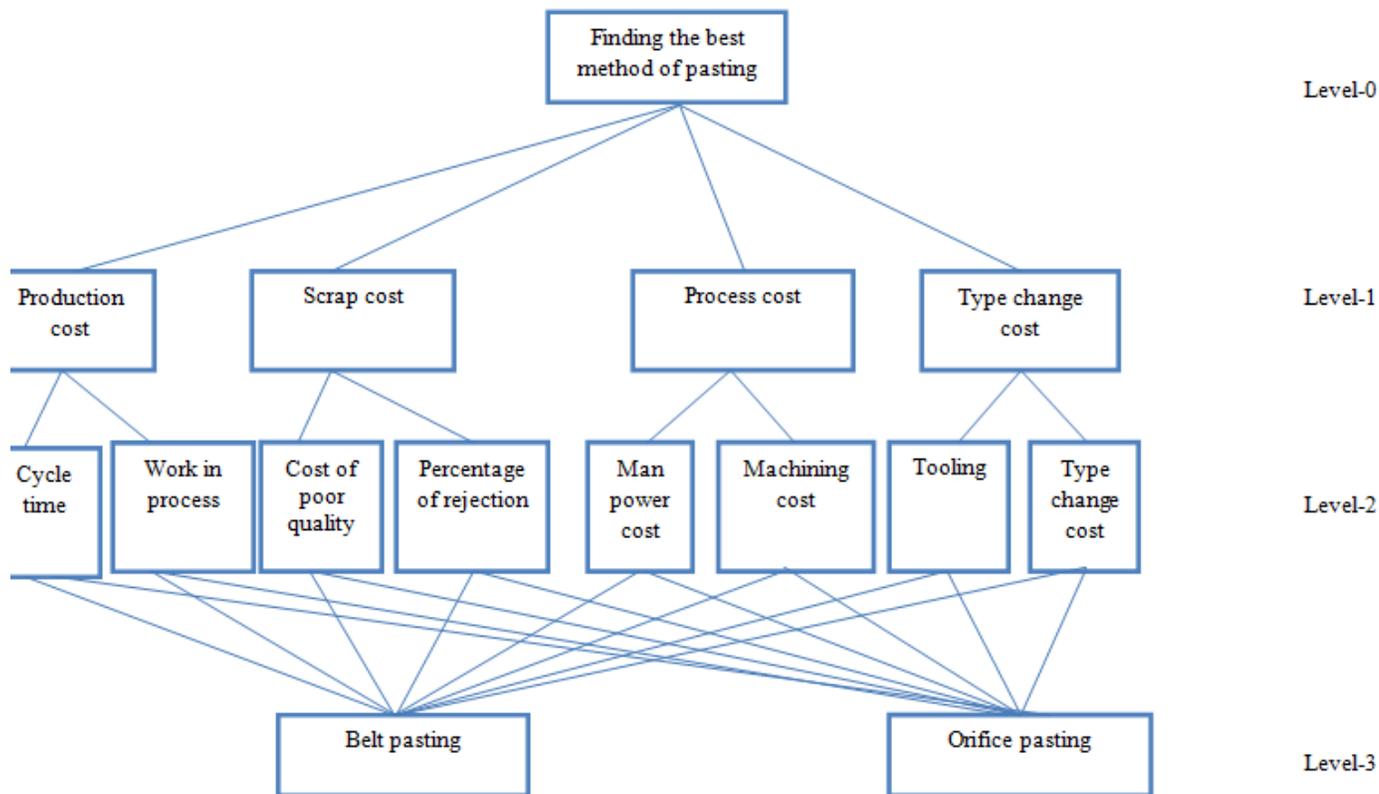


Figure 1 Hierarchy of the considered case study

4. CASE STUDY

A case study has been conducted in the battery manufacturing unit of IBD, Amara Raja Batteries Limited near Karakambadi, Tirupathi. Amara Raja Batteries Limited was established in the year 1985 as private limited and then converted into public limited in the year 1990. The company is currently poised on a healthy growth curve and ended the financial year 2007 – 08 with a turnover of Rs.745 cores with a profit of 47 cores. Amara Raja Batteries has a strategic tie up with Johnson Control Inc. of the USA who owns 26% stake in this company. Johnson Controls is a Fortune 500 company and also the largest manufacturer of lead acid batteries in North America and a leading global supplier to major automobile manufacturers and industrial customers. Amara Raja has demonstrated its commitment to offer optimum system solutions of the highest quality. And it has become the largest supplier of standby power systems to core Indian utilities such as the Indian Railways, Department of Telecommunications, Electricity Boards and major power generation companies. Extensive plans have been charted out for the future, wherein the company undertakes to become the most preferred supplier for power back-up systems. Amara Raja has always offered time tested world-class technology and processes developed on international standards – be it high integrity VRLA systems like Power Stack or the high performance UPS battery – Quanta. The Aaron hi-life automotive batteries are the products of the collaborative efforts of engineers at Johnson Controls Inc. and at Amara Raja Batteries Limited. Now it also started to compete with 'The only left-out segment' in lead-acid battery market - Two Wheeler batteries. With its commitment to transform the spheres of influence, ARBL has recently launched the two wheeler battery – Aaron bike rider. It will take no time to capture the market because of Aaron's extensive Business network. Amara Raja Batteries Limited comprises of three major divisions viz., Industrial Battery Division [IBD] and Automotive Battery Division [ABD] and the recently established Small Battery Division [SBD].

Solution Procedure

Step1: Developing the pair-wise comparison matrix for the resources required for the activities.

Step2: Developing the normalized comparison matrix for the pair-wise comparison matrix by dividing the each element in the column by the sum of that particular column.

Step3: Establishing priority vector

Step4: Comparison of alternatives

Step5: Calculating priority vector for alternatives

Step6: Obtaining the global vector

Step7: Selecting the best alternative in consideration of global vector

Table 2 Development of priority vector for the criteria

Pair-wise comparison matrix						
	Production cost	Scrap cost	Process cost	Type change cost		
Production cost	1	1/3	1/3	1/7		
Scrap cost	3	1	1/5	1/7		
Process cost	3	5	1	1/3		
Type change cost	7	7	3	1		
Sum	14	13.33	4.53	1.619		
Normalized matrix						
	Production cost	Scrap cost	Process cost	Type change cost	sum	Principal vector
Production cost	0.071	0.025	0.073	0.088	0.257	0.0604
Scrap cost	0.214	0.075	0.044	0.088	0.421	0.0921
Process cost	0.214	0.375	0.22	0.205	1.014	0.2546
Type change cost	0.5	0.525	0.662	0.617	2.304	0.5928

Table 3 Production cost sub-criteria analysis

Pair-wise comparison matrix			
	Cycle time	Work in process	Principal vector
Cycle time	1	1/5	0.17
Work in process	5	1	0.83
Sum	6	1.2	C.I = 0.00
			C.R = 0.00

Table 4 Scrap cost sub-criteria analysis

Pair-wise comparison matrix			
	Cost of poor quality	Percentage of rejection	Principal vector
Cost of poor quality	1	1/3	0.25
Percentage of rejection	3	1	0.75
Sum	4	1.33	C.I = 0.00
			C.R = 0.00

Table 5 Process cost sub-criteria analysis

Pair-wise comparison matrix			
	Man power cost	Machining cost	Principal vector
Man power cost	1	1/5	0.17
Machining cost	5	1	0.83
Sum	6	1.2	C.I = 0.00
			C.R = 0.00

Table 6 Type change cost sub-criteria analysis

Pair-wise comparison matrix			
	Tooling cost	Type change cost	Principal vector
Tooling cost	1	1/3	0.25
Type change cost	3	1	0.75
Sum	4	1.33	C.I = 0.00
			C.R = 0.00

Table 7 Cycle time alternatives analysis

Pair-wise comparison matrix			
	Belt pasting	Orifice pasting	Principal vector
Belt pasting	1	1/3	0.25
Orifice pasting	3	1	0.75
Sum	4	1.33	C.I = 0.00
			C.R = 0.00

Table 8 Work in process alternatives analysis

Pair-wise comparison matrix			
	Belt pasting	Orifice pasting	Principal vector
Belt pasting	1	1/5	0.17
Orifice pasting	5	1	0.83
Sum	6	1.2	C.I = 0.00
			C.R = 0.00

Table 9 Cost of poor quality alternatives analysis

Pair-wise comparison matrix			
	Belt pasting	Orifice pasting	Principal vector
Belt pasting	1	1/3	0.25
Orifice pasting	3	1	0.75
Sum	4	1.33	C.I = 0.00
			C.R = 0.00

Table 10 Percentage of rejection alternatives analysis

Pair-wise comparison matrix			
	Belt pasting	Orifice pasting	Principal vector
Belt pasting	1	1/3	0.25
Orifice pasting	3	1	0.75
Sum	4	1.33	C.I = 0.00
			C.R = 0.00

Table 11 Man power cost alternatives analysis

Pair-wise comparison matrix			
	Belt pasting	Orifice pasting	Principal vector
Belt pasting	1	1/3	0.25
Orifice pasting	3	1	0.75
Sum	4	1.33	C.I = 0.00
			C.R = 0.00

Table 12 Machining cost alternatives analysis

Pair-wise comparison matrix			
	Belt pasting	Orifice pasting	Principal vector
Belt pasting	1	1/7	0.12
Orifice pasting	7	1	0.87
Sum	8	1.14	C.I = 0.00
			C.R = 0.00

Table 13 Tooling cost alternatives analysis

Pair-wise comparison matrix			
	Belt pasting	Orifice pasting	Principal vector
Belt pasting	1	1/7	0.12
Orifice pasting	7	1	0.87
Sum	8	1.14	C.I = 0.00
			C.R = 0.00

Table 14 Type change cost alternatives analysis

Pair-wise comparison matrix			
	Belt pasting	Orifice pasting	Principal vector
Belt pasting	1	1/7	0.12
Orifice pasting	7	1	0.87
Sum	8	1.14	C.I = 0.00
			C.R = 0.00

As the CR value is less than 0.1, the judgments are acceptable.

Table 15 Global vector of alternatives

S.No.	Sub-criteria description	Weight of sub-criteria(A)	Criteria weight(B)	Belt pasting(X)	Orifice pasting(Y)	A.B (C)	C.X	C.Y
1	Cycle time	0.17	0.0604	0.25	0.75	0.01	0.002	0.0075
2	Work in process	0.83	0.0604	0.17	0.83	0.05	0.008	0.0416
3	Cost of poor quality	0.25	0.0921	0.25	0.75	0.023	0.0057	0.0172
4	Percentage of rejection	0.75	0.0921	0.25	0.75	0.069	0.0172	0.0517
5	Man power cost	0.17	0.2546	0.25	0.75	0.042	0.0105	0.0315
6	Machining cost	0.83	0.2546	0.12	0.87	0.21	0.0265	0.1855
7	Tooling cost	0.25	0.5928	0.12	0.87	0.148	0.0185	0.1295
8	Type change cost	0.75	0.5928	0.12	0.87	0.445	0.0556	0.389
	Decision Index =					Sum	0.144	0.853

From the above table, Orifice pasting has the highest global vector. So it is considered as the best pasting method in pasting the outer layer of a battery.

5. CONCLUSION

A case study has been taken from the battery manufacturing unit of an organization. To find out the best pasting method, all the criteria and sub-criteria are considered. Using Analytical Hierarchy Process (AHP), the priority vectors for alternatives and their corresponding global vector is calculated. The alternative having the highest global vector is taken as the best alternative. So from the above analysis, we can conclude that Orifice pasting is the best pasting method.

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