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Lean Six Sigma Prioritization of Green Electro Chemical Machining using ANP

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***Abstract*— This paper presents a methodology for Lean Six Sigma (LSS) Prioritization of Green Electro Chemical Machining (GECM). Lean Six Sigma (LSS) provides collective profit of waste elimination as well as defects reduction from manufacturing sector. Priortization of GECM in the perspective of Lean Six Sigma is a typical Multi Criteria Decision Making(MCDM) problem. Analytical Netwrk Process (ANP) methodogoly comes under MCDM tools and used as solution methodology for this problem. In this contest simple scale is used for prioritizing Green ECM. In this paper five dimension and 15 criteria are used for priorizing GECM, based on computation using ANP, alternative (A1) is found to be the best solution. Efforts are being taken for deployment of the selected Green Electro Chemical LSS project. A case study conducted in an Indian auto component manufacturing organization is illustrated.**

***Keywords*: Six Sigma; Lean Six Sigma; Green Electro Chemical Machining; Prioritization of Green ECM; Multi Criteria Decision Making; Analytical Network Process.**

I. INTRODUCTION

Lean Six Sigma is one of the mainly essential business strategy that identifies the cause of defects and tries to eliminate them with in a specified time period. Six Sigma is generally known as a project driven methodology that delivers highest benefits and prioritizes crashs to the manufacturing organization. Lean Six Sigma (LSS) is made from two wrd Lean and Six Sigma is that combination of Lean and Six Sigma. Lean strategy introduced for the idea to eliminate waste from production sectors and Six Sigma reduces production defects form manufacturing sector. But the joint approach provides synergic benefits towards manufacturing organizations. LSS methodology work as a problem solving method that is more important for all manufacturing organizations. LSS is a systematic approach known for the process improvement as well as performance improvement. It is a commonly used business strategy which improve process performance and provide satisfaction to customer and improve foundation line result. It is also used as a guidance improvement tool. Priortization of GECM is a method for selecting the best alternative among all which gives maximum profit to the organization and should complete within a specified time period. Prioritizaton of alternatives is a typical Multi Criteria Decision Making (MCDM) problem. Analytical Network process (ANP) is a general from of Analytical Hierarchy Process (AHP) which enables interrelationship between decision levels and attributes in a more general form. ANP uses ratio scale measurement based on pair wise comparisons however, it does not impose a hierarchical structure as in AHP, and models the decision problem using a system. In this study, ANP is used to prirtize GECM for the best LSS aternatives.

II.LITERATURE REVIEW

In this paper the research studies in the perspective of Six Sigma and Lean Six Sigma alternatives priortization perspective have been Studied.

Adpolat and Xu (2002) addressed the selection of best Six Sigma project towards maximum profit. Design for Six Sigma (DFSS) is used in this context for selection and prioritizing right project in manufacturing organizations. DFSS assisted the priortization of Six Sigma project in existent living situation problem with highest revenue outcomes. Buyukozkan and Ozturkcan (2010) proposed merged technique for prioritizing and deciding right Six Sigma project for maximum outcomes. They exploited combined Analytical Network Process (ANP) and Decision Making Trial and Evaluation Laboratory (DEMATEL) methodology which helped in chooseing suitable Six Sigma project. This mixed techinique was used in a logistic company for Six Sigma project priortization which can produce maximum outcomes to organization; DEMATEL methodology is used for obtaining relationship

between criteria to criteria and ANP method is used for obtaining criteria weight towards solving problem. Padhy and Sahu (2011) obtained two stage solution methodology for Six Sigma project priortization. This two stage techniques of prioritization project combined Real Option Analysis and Zero – one Integer Linear Programming for right Six Sigma project priortization based on manufacturing industry objectives and goals. This combined strategy was used to select profitable project which gives maximum outcomes to organization and gives customer satisfaction. The Real Option theory approach was used for assessment of valuable project and conveys supple amends in top level management and Zero Integer Linear Programming method was used for creationing right schedule of Six Sigma project selection. This approach recognized a new way of evaluating Six Sigma project considering all types of hazard. Bahari et al. (2011) defined the effectiveness of criteria for evaluatting Six Sigma project for organization. In this paper used Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach for evaluating Six Sigma project. Analytical Hirarchy Process was used for pairwise comparison of criteria and TOPSIS was used for ranking of alternatives. They evaluated how MCDM tools assisted to select best Six Sigma project. This study was conducted in poly acryl. Corporation towards maximum profit, Six criteria was used for Six Sigma project selection and after selection of best project in concusion they found A5 was the best project with 0/665 score. Kindi (2011) establishd notation of expected utility and implemented Six Sigma project selection in an organization. This study talk about key factors that are really helpful for selecting best profitable project which gives maximum profit. They also talk about the use of proper Six Sigma tools during project selection. Normative approach was used for Six Sigma project selection. Ray and Das (2010) recommend Top Down approach model for evealuating Six Sigma project with different problem situation which is occurring day to day in manufacturing industries. The developed approach explained problem occurring in different situations and helped the selection of suitable and profitable project with customer satisfaction. In this study, they proposed the use of selection tools and techniques for better priortization of well defined project. They suggested in this paper, Six Sigma DMAIC approach provides better result and elucidated three approch for project selection with their advantages and disadvantages. Kumar et al. (2009) spotlighted Six Sigma project selection process and highlighted its importance for industry. They used combined approach of AHP and desirable matrix for Six Sigma Project priortization. This techniques identified and focused on critical factors for selection of suitable and profitable project. The technique was applied in a small manufacturing enterprizes. This study evaluated the results with other project prioritizing methods for project selection such as project prioritized matrix and Failure Mode Effect Analysis and found better result. Banuelas et al. (2006) proposeed key ingredients for selection of Six Sigma project. They used this key of ingredients for implementation and prioritization of suitable and profitable project towards provding maximum profit for organization. This study identified how criteria influence the priortization of right projects. In this study, tools and techni9ques used such as cost benefit analysis, cause and effect matrix, pareto analysis are used for prioritization right projects. Shanmugaraja et al. (2012) developed a new approach for Six Sigma project evaluation. They used Quality Function Deployment (QFD) methodology for selection of right Six Sigma project. The main aim of this study was to select project using combined QFD and Six Sigma approach in organization. The case study was conducted in small and medium size enterprise. Wang and Chen (2014) developed a model for Six Sigma project selection and evaluation of project. This study aimed at selection and performance evaluation of right and effective Six Sigma project. They used DEA method for calculating efficiency of Six Sigma project and truncated regression model was used for calculating variable of interest. Soft System Method (SSM) was used for calculation of inputs and outputs for proposed evaluation model. The inference from the study is that Six Sigma project selection and evaluation model result was not related to process of business and type of organization. Kumar et al. (2009) focused on Six Sigma project selection process and emphasized its importance for organization. They used combined AHP and desirable matrix for Six Sigma Project selection. This methodology identified and focused on critical factors for selection of right and profitable project. The methodology was applied in a SME. This study compared the results with other methods for project selection such as project prioritized matrix and Failure Mode Effect Analysis. Banuelas et al. (2006) suggested key ingredients for prioritization of Six Sigma project. They used this key of ingredients for implementation and prioritization of right and profitable project. This study identified how criteria influence the evaluation of projects. Tools such as cost benefit analysis, cause and effect matrix, pareto analysis are used for prioritization of Six Sigma projects. Wang and Chen

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(2014) developed a model for Six Sigma project selection and evaluation of project. They used DEA method for calculating efficiency of Six Sigma project and truncated regression model was used for calculating variable of interest.

III. METHODOLOGY

Analytical Network Process (ANP) is a multi criteria decision making tool first introduced by Yoon and Hwang in 1981 which is used for decision making. It is a simple mathematical model used for ranking of alternatives with multiple criteria. The analytic network process (ANP) is known as a general form of the analytic hierarchy process (AHP) used in multi-criteria decision making process for selecting best alternative amoung predefined group of alternative. The goal of Analytical Hirarchy Process (AHP) is a convering decision problem into a hierarchy with a profitable goal, decision criteria, and alternatives, while the ANP structures it as a network. In ANP techniques, ranking of alternatives is based on final normalized matrix.

IV. CASE STUDY

The case study was performed in an automotive component manufacturing organization situated in tamilnadu, india. There existed a necessitate to prioritize best alternatives among all which gives maximum profit to organization and should complete within specified time period. The detailed evaluation model for ranking Lean Six Sigma Prioritization of Green Electro Chemical Machining (GECM) alternatives is shown in figure 1. In this study, we considered 5 Diamension and criteria and 15 criteria which are shown in Table 1.

1.Computational Steps for LSS Proritizaton of Green ECM

Table 1: Dimensions and criteria used for LSS Proritizaton of Green ECM

Dimensons	Criteria
Process Characterstics (D_1)	Material Removal Rate (C_1)
	Accuracy (C_2)
	Surface Finish (C_3)
Operating Parameter ($D_{2\backslash}$)	Feed Rate (C_4)
	Current and Voltage (C_5)
	Overcut (C_6)
Machining Parameter ($D_{\backslash 3}$)	Servo System (C_7)
	Electrolyte (C_8)
	Tool Design (C_9)
Environmental Aspects (D_4)	Process Energy (C_{10})
	Exposure to Aerosol (C_{11})
	Electrolyte Consumpton (C_{12})
Growth & Financial Status (D_5)	Project Budget (C_{13})
	Traininig & Education (C_{14})
	Customer Satisfaction (C_{15})

Step 1: Problem analysis and construction of model.

The first step of ANP technique is the analysis of problem and model construction for Priortizaton of best solution amoung givem critera with respect to dimensions. The main aim is to Prioritize best LSS of Green ECM among alternatives, which

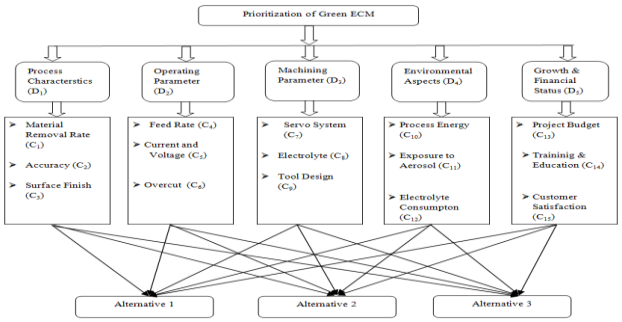

Figure 1 Detailed evaluation model for Priortze Green ECM

Step 2: Determine pair-wise comparison of component or dimension.

In the next step, is to perform pair-wise comparison between components. First we have to determine the relation between criteria and dimension using experts opinion then the pair-wise comparison will be done using ANP methodology. In this paper simple scale is required for pair-wise comparison, here 1-9 scale is used, and shown in table 2. Calculate Eigen value and Eigen vector for all matrix and then normalize each matrix. Pairwise comparison of dimention is shown in table 3.

Table 3: Pair-wise comparison matrix of dimension

	D_1	D_2	D_3	D_4	D_5	Eigen Vector
D_1	1	4	5	6	8	0.5725
D_2	0.25	1	3	5	8	0.3479
D_3	0.2	0.333	1	3	6	0.2401
D_4	0.166	0.2	0.333	1	3	0.1692
D_5	0.125	0.125	0.166	0.333	1	0.1285

Step 3: Determine pair-wise comparison between criteria and dimension.

The third step in ANP is to determine pair-wise comparison between dimension and criteria for priortiztion of GECM. In this step, the pair-wise

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comparison of dimension of each step will be done according to its own relative criteria. In this paper we have taken five dimensions for LSS prioritization of GECM, then total five pair-wise comparison matrices are being created and then the Eigen value and Eigen vector is to be calculated for the all five matrices. This Eigen vector serves as a weight used for prioritizing GECM. Example of one such pair-wise comparison matrix for process characterstics (D1) dimension shown in table 4.

Table 4: Pair-wise comparison matrix for process characterstics

	C_1	C_2	C_3	Eigen Vector
C_1	1	3	6	0.5879
C_2	0.333	1	3	0.2520
C_3	0.166	0.333	1	0.1087

Step 4: Determine pair-wise comparison for criteria.

In this step, pair-wise comparison will be done between criteria. In this paper, we have taken 15 criteria for LSS prioritization of GECM. So 15 pair-wise matrix will be created, but in our problem, first dimension has three criteria are and other dimensions have also three criteria. In this situation, five pair-wise comparison (3□3) matrices will be created. Example of one of the pair-wise comparison matrix for Process characterstics (D1) dimension with Material Removal Rate (C1) as control criteria over other remaining criteria is shown in Table 5.

Table 5: Pair-wise comparison matrix for Material Removal Rate criteria under process characterstics dimension

C_1	C_2	C_3	Eigen Vector
C_2	1	3	0.7491
C_3	0.333	1	0.3791

Step 5: Establish evaluation for alternatives.

In 5th step of ANP Process, after completion of pair-wise comparison of criteria, we have to make evaluation of alternatives. In this paper, we have taken three alternatives i.e. A1, A2, and A3, which is shown detailed model of LSS Priortization of GECM in figure 1. The pair-wise comparison of alternatives is performed for each criteria, which influence the dimension. In this step, total 15 pair-wise comparison matrices are being formed. Example of one of the pair-wise comparison matrix of alternatives under Material Removal Rate (C1) criteria is shown in table 6.

Table 6: Pair-wise comparison matrix of alternatives under Material Removal Rate

C_1	A_1	A_2	A_3	Eigen Vector
A_1	1	4	8	0.6985
A_2	0.25	1	5	0.2370
A_3	0.125	0.2	1	0.0644

The calculated Eigen Vector of all 15 pair-wise comparison matrices for alternatives under 15 criteria is used in final supermatrix for project selection, as shown in Table 8.

Step 6: Design a supermatrix

In this step, after calculation of all previous matrices a supermatrix is designed for combining the all value of matrics for calculation of weight. The supermatrix is composed of all solved sub-matrices calculated in previous steps. The supermatrix for LSS prortization of GECM before convergence is shown in Table 7. Each sub-matrix weight in supermatrix is calculated using MATLAB software.

Table 7: Supermatrix of LSS prioritization of GECM before convergence

		D_1			D_2			D_3			D_4			D_5		
		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
D_1	C_1	0	0.807	0.805												
	C_2	0.749	0	0.311												
	C_3	0.379	0.323	0												
D_2	C_4	0.172	0.170	0.184	0	1										
	C_5				1	0										
	C_6						0	1								
D_3	C_7						1	0								
	C_8								0	1						
	C_9								1	0						
D_4	C_{10}										0	1				
	C_{11}										1	0				
	C_{12}												0	1		
D_5	C_{13}												1	0		
	C_{14}														0	1
	C_{15}														1	0

The weight convergence matrix is shown in Table 8 and after convergence, sum up of each column value should be 1.

Table 8: Supermatrix of LSS prortization of GECM after convergence

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		D1			D2			D3			D4			D5		
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
D1	C1	0.4015	0.4015	0.4015												
	C2	0.2105	0.2105	0.2105												
	C3	0.2210	0.2210	0.2210												
D2	C4	0.1670	0.1670	0.1670	0.5	0.5										
	C5				0.5	0.5										
	C6						0.5	0.5								
D3	C7						0.5	0.5								
	C8								0.5	0.5						
	C9								0.5	0.5						
D4	C10										0.5	0.5				
	C11										0.5	0.5				
	C12												0.5	0.5		
D5	C13												0.5	0.5		
	C14														0.5	0.5
	C15														0.5	0.5

Step 7: Ranking of Alternatves.

This is the last step in LSS prioritization of GECM. In this step the final supermatrix is created. The final supermatrix is made up of 11 columns, first column shows five dimensions and second column shows 15 criteria with respect to each dimension, third column 'W1', it shows weight one and taken from pair-wise comparison matrix of dimension (Table 3). Fourth column 'W2', shows weight two, and this column taken from pair-wise comparison matrix for dimension/criteria, (example given in Table 4). Fifth column weight 'W3' is calculated form initial matrix. Columns 6, 7, 8, values are taken from calculated 14 pair-wise comparison matrices of alternatives (one such example is given in Table 6). Columns weights 9, 10, 11 are calculated using Eq. (1). The final supermatrix of LSS prioritization of GECM is shown in Table 9.

$$Pi=W\_1\times W\_2\times W\_3\times A\_i \quad (1).$$

Pi = Project, W1 = weight 1, W2 = weight 2, W3 = weight 3, and Ai = relative impact for project performance.

Table 9: Final supermatrix of LSS Prioritizaton of Green ECM

		W1	W2	W3	A1	A2	A3	Alternative 1	Alternative 2	Alternative 3
D1	C1	0.5725	0.5879	0.0686	0.6985	0.2370	0.0644	0.0161	0.0055	0.0015
	C2	0.5725	0.2520	0.0544	0.5588	0.3627	0.0885	0.0044	0.0028	0.0007
	C3	0.5725	0.1087	0.0322	0.7959	0.3290	0.0851	0.0016	0.0007	0.0002
D2	C4	0.3479	0.0414	0.0114	0.4959	0.2290	0.0851	0.0001	0.0000	0.0000
	C5	0.3479	0.8565	0.0833	0.8491	0.4791	0.0817	0.0211	0.0119	0.0020
	C6	0.3479	0.1865	0.0833	0.7267	0.3798	0.0835	0.0039	0.0021	0.0005
D3	C7	0.2401	0.8535	0.0833	0.5491	0.3791	0.0817	0.0094	0.0065	0.0014
	C8	0.2401	0.1965	0.0833	0.7588	0.3627	0.0885	0.0030	0.0014	0.0003
	C9	0.2401	0.7497	0.0833	0.8910	0.2177	0.0813	0.0134	0.0033	0.0012
D4	C10	0.1692	0.2803	0.0833	0.9444	0.3704	0.0952	0.0037	0.0015	0.0004
	C11	0.1692	0.8535	0.0833	0.5985	0.1370	0.0744	0.0072	0.0016	0.0009
	C12	0.1692	0.1865	0.0833	0.8766	0.2526	0.0807	0.0023	0.0007	0.0002
D5	C13	0.1285	0.7902	0.0833	0.7867	0.2864	0.2269	0.0067	0.0024	0.0019
	C14	0.1285	0.2698	0.0833	0.9312	0.1983	0.0905	0.0027	0.0006	0.0003
	C15	0.1285	0.2898	0.0833	0.8312	0.1993	0.0905	0.0026	0.0006	0.0003
$\sum A_i$								0.0981	0.0415	0.0118
Normalized value								0.5619	0.3468	0.1478

Place each value in the final supermatrix as mentioned earlier, then ranking of the project is done The calculated values are Alternative 1 = 0.5619, Alternative 2 = 0.3468, and Alternative 3 = 0.1478.

V. CONCLUSIONS

- LSS prioritization of Green Electro Chemical Machining is formulated as MCDM problem.
- ANP is used as a solution methodology.
- Five dimensions and 15 criteria are used for LSS prioritization of GECM.
- Computations are performed using ANP.
- Alternative 1 is found to be the prioritized GECM Appropriate lean and six sigma tools are being incorporated in DMAIC phases and deployment is under progress.
- Efforts are being initiated for further deployment of prioritized LSS Green ECM alternative.

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