Implementation Study of Analytical Hierarchy Process Based Maintenance Quality Function Deployment in an Ice Cream Manufacturing Industry

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Abstract - In Total Quality Management (TQM), the customers' vague language can convert very effectively into technical languages by using a tool called Quality Function Deployment (QFD). Total Productive Maintenance (TPM) is a methodology for achieving high degree of quality in maintenance engineering and there is no tool available to find out the Voice of Customer (VOC). In this direction, by integrating QFD with TPM a new model named Maintenance Quality Function Deployment (MQFD) is derived to resolve this problem. The main highlights of MQFD implementation is the consideration of key factors like customers, technology, competitors, *etc*. One of the challenges of implementing MQFD is that it needs to fit into varied organisational cultures. For this purpose, the practicality of MQFD's components has to be studied. While implementing these components, numerous decision alternatives have to be considered. This will be a tedious task. In order to ease this task, the need for an appropriate tool is realised. In this context, the contribution of the Analytic Hierarchy Process (AHP) process is noticed with interest. AHP has been used as a tool to solve crucial decision-making problems. A maintenance-intensive Indian ice cream manufacturing industry was selected for this AHP implementation study. The details are illustrated in the consequent sections of the article.

Keywords – Quality Function Deployment; QFD; Total Productive Maintenance; TPM; Analytic Hierarchy Process; AHP; sensitivity analysis.

I. Introduction

The success of any customer-driven company is the ability to bring new products to market quickly. But today's highly competitive situation creates this mission more challenging than ever. Customers not only demand higher levels of quality in new products, but also insist the most recent innovations [1]. Nowadays, it is common practice that the companies focus on quality management as a mean to develop the competitive benefits of the organization by defining projects in the vicinity of total quality, management, customer service and quality management systems [2]. In this perspective, the voice of customer (VOC) gains vital significance. Quality function deployment (QFD) has been extensively used as a practice for performing the translation of customer necessities into design requirements [3]. In product development, QFD is considered as a powerful tool [4].

The food industry relies deeply on new products to invigorate and maintain its production. The quality function deployment (QFD) is a structured approach for integrating study of consumer requirement and descriptions of the competitive environment with technical realities into inimitable product specifications. QFD methodology evolves from the "House of Quality (HoQ)", a graphical depiction of the interrelationships between customer wants and associated product characteristics. QFD approach ensures that the product is developed according to the wants of the target consumer group, but it is appropriate for product improvements and not for truly innovative product.

The ice cream market in India is estimated to be around INR 2,000 crores, of which over 40% belongs to the organized sector growing at about 15% year over year. So, the quality-maintenance study in ice cream industry will certainly be a valuable one. From the literature it was found that, the QFD is implemented very little in various food industries and no work was carried out in the ice cream industry. So, the quality assessment in the ice cream industry is a necessity. The intend of this study is to investigate the prospective benefits to the customer by subjecting ice cream production to an integrated QFD and TPM study called MQFD.

One of the challenges of implementing MQFD is that it needs to fit into varied organisational cultures. For this purpose, the practicality of MQFD's components has to be studied. While implementing these components, numerous decision alternatives have to be considered. This will be a tedious task. In order to ease this task, the need for an appropriate tool is realised. In this context, the contribution of the Analytic Hierarchy Process (AHP) process is noticed with interest. AHP has been used as a tool to solve crucial decision-making problems. During the project work the method of making MQFD suitable for the ice cream industry using Analytic Hierarchy Process (AHP) has been examined.

II. PROPOSED MQFD MODEL

The proposed research model MQFD, integrates QFD and TPM. The MQFD model shown in Figure 1 starts with collecting the customer languages. The customer languages are then converted into the technical specifications after the development of House of Quality [5]. Then the decisions are made to find which parameters need to be passing through necessary technical requirements and action plans. The decisions which are made for actions requiring maintenance quality improvement will be subjected to TPM implementation [6] and [7]. The technical languages [8] are passed through the eight pillars of TPM. The output will reflect in the production environment. Then the maintenance quality is evaluated using Overall Equipment Efficiency (OEE), Mean Time between Failure (MTBF), Mean Time to Repair (MTTR), Performance Quality, Mean Down Time (MDT), and Availability. A properly run and monitored MQFD process is required to result in improved maintenance, increased profit [9], upgraded core competence, and enhanced goodwill. Some of the technical languages drawn out of the HOQ are not passing through TPM after the decision making process, will indicate the revised targets for the overall business performance improvement.

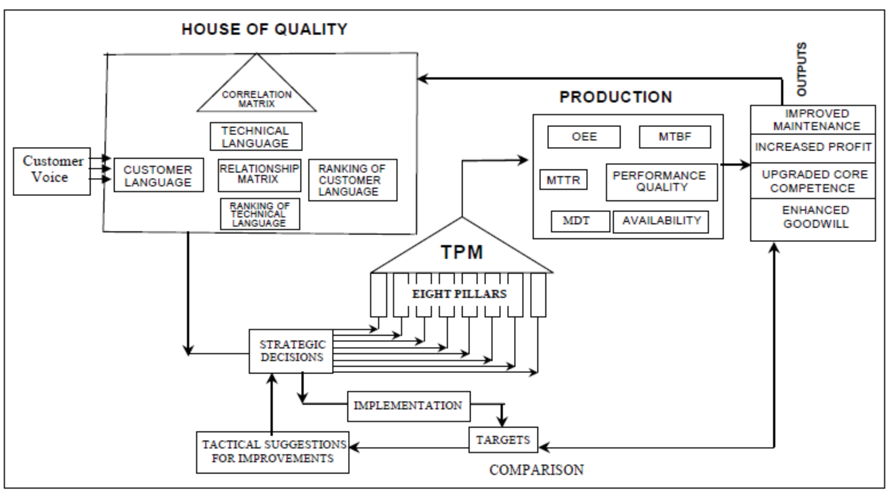

Figure 1. MQFD model

Source : V.R. Pramod, S.R. Devadasan , *'Synergising TPM and QFD: a case of electronic switch manufacturing'*, Int. J. Quality and Innovation, Vol. 1, No. 4, 2011

III. OVERVIEW ON AHP

The Analytic Hierarchy Process (AHP), introduced by Thomas Saaty (1980), is an effective tool for dealing with complex decision making, and may aid the decision maker to set priorities and make the best decision [10],[11], and [12]. By reducing complex decisions to a series of pair wise comparisons, and then synthesizing the results, the AHP helps to capture both subjective and objective aspects of a decision. In addition, the AHP incorporates a useful technique for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision making process.

The AHP is one of the most frequently addressed contemporary tools in literature. Table shows the various natures of AHP applications that are reported in the literature.

Table -1 Multifarious applications of AHP

Sl. No	Nature of application	Researchers
1	Measure for business excellence	Cheng and Li (2001)
2	Determination correlation of product issues to profit	Muller *et al.*(2001)
3	Prioritising customers and other Stakeholders	Jackson (2001)
4	Marketing	Davies (2001)
5	Safety management	Chan *et al*. (2004)
6	Evaluation of success factors for implementing ISO14001-based EMS	Chin *et al.* (1999)
7	Tourism	Ramos *et al*. (2000)
8	Higher education	Badri *et al*. (2004)
9	Supplier selection	Kahraman *et al.* (2003)
10	Study of TQM benefits	Lewis *et al*. (2005)
11	Environmental quality	Bender *et al.* (2000)
12	Aircraft maintenance	Cheung *et al.* (2005)
13	Determining an appropriate equity risk premium	Palliam (2005)
14	Assessment of the ISO14001environmental management system	Pun and Hui (2001)
15	Selecting optimal order	Choi *et al*. (2004)
16	Evaluation of airline service quality	Tsaur *et al.* (2002)

IV. SAMPLE APPLICATION STUDY

In order to examine the practicality of the AHP in MQFD, a sample case study was conducted in an ice cream production industry named SNOCAP. The industry is located in Thrissur district, Kerala state, India. SNOCAP is one of the leading ice cream producers in Kerala and the main products include Vanilla ice cream, strawberry ice cream, choco bar, mango bar, etc. From 4 liter packs to small cup ice creams are been dispatched through various distributors to different bakeries.

A. Survey

To instigate the AHP, first the hierarchy components of MQFD were developed [13]. House of Quality, decision system, TPM, maintenance parameters, and quality parameters are the five decomposed components of MQFD. Further, the factors critical factors to their implementation were identified. These factors have also been divided into sub factor. This is represented below in Figure 2.

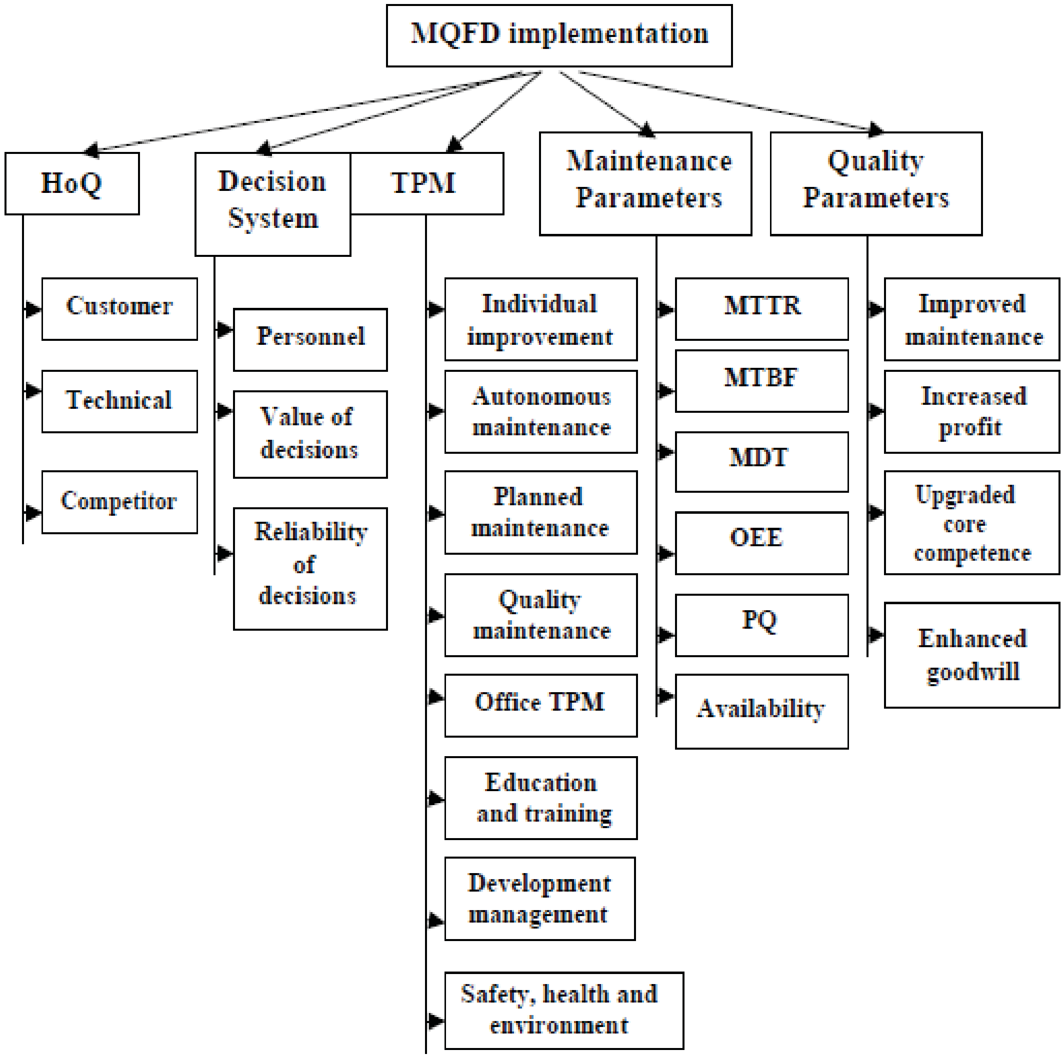

Figure 2. Discretisation hierarchy of MQFD

Then the pair wise evaluations of these factors need to be done to identify the important parameters that should be considered initially for the resource allocations. This comparison is done initially after developing a questionnaire with a suitable scale. Figure 3 depicts a part of the AHP questionnaire.

QUESTIONNAIRE

KINDLY ANSWER THE FOLLOWING QUESTIONS. YOUR RESPONSE WILL BE A VALUABLE CONTRIBUTION FOR MY PROJECT WORK

Mark your opinion about the relative importance of the factors given on the two sides of the scales (refer the scoring pattern). Please put tick marks on the number of your choice on each scale.

Scoring pattern

LHS				MIDDLE	RHS			
A is					B is			
9	7	5	3	1	3	5	7	9
Absolutely Important	V.Strongly Important	Strongly Important	Slightly Important	Equally Important	Slightly Important	Strongly Important	V.Strongly Important	Absolutely Important
		Than	B			Than	A	

If 'A' is more important, use left hand side (LHS) of the scale.
If 'A' and 'B' are equally important, put tick mark on center portion (MIDDLE) of the scale.
If 'B' is more important, use right hand side (RHS) of the scale.
The numbers 2,4,6,8 in between.

PRIORITIZATION OF CRITICAL FACTORS OF HOUSE OF QUALITY

a) As per your judgment which one is more important for your firm (A) **Customer's voice** or (B) **Technology parameters?**

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

b) Which factor among these, (A) **Customer's voice** or (B) **Competitors** has more priority?

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Figure 3. AHP questionnaire

AHP questionnaire in Saatys 1-9 scale was distributed to the production engineer and supervisors and collected the details from the industry. The judgment and their explanation of Saatys scale is denoted in the table 2.

Table -2 Saaty's 1–9 scale for multicriteria decision making

Judgment	*Explanation*	*Score*
Equally	Two attributes contribute equally to the upper-level criteria	1
Moderately	Judgment slightly favors one over another	3
Strongly	Judgment strongly favors one attribute to another	5
Very strongly	An attribute is very strongly favored and its dominance demonstrated in practice	7
Extremely	The evidence of extremely favoring one attribute over another is of highest possible order of affirmation	9
Intermediate values for finer resolution		2, 4, 6, 8

After collecting the filled-in questionnaires, the average value of the prioritization of critical factors and sub factor were computed. Based on these values, comparison matrices were made.

The scores in Saaty's scale were afterward substituted in pairwise comparison matrices. An example of these matrices is shown in Table 3. subsequent to that, normalisation of critical factors has been conceded. During this practice, the normalised values and local sensitivity were evaluated. Normalised values indicates the fraction of pairwise contribution of critical factors against each other. Local sensitivity refers to the average of normalised values of each critical factor. Normalised values of critical factors of the MQFD component 'House of Quality' are shown in Table 4

Table-3 Pair wise degree comparison matrix of critical factors of the component 'House of Quality'

House of Quality (HOQ)	Customer	Technology	Competitor
Customer	1	4	5
Technology	1/4	1	3
Competitor	1/5	1/3	1
Sum	1.45	5.33	9
Consistency Parameters	$\lambda_{\max}$ = 3.0858 CI=0.0429 RI= 0.58 CR = 0.0739 CR < 0.1		

The sum of these values in the table below the customer column is 1.45.All values in this column are divided by this sum. That is, in the Customer row and column in Table, the value 1 is divided by the sum 1.45. This value is 0.69, which is posted in normalised Table. Similarly, in the 'Technology' row and 'Customer' column, the value 1/4 is divided by 1.45. The value 0.172 is posted in Table. In the Competitor row and the Customer column in Table, the score 1/5 is divided by 1.45. The resultant value 0.138 is posted in the representing cell in Table. In some cases, normalised values were slightly modified so that the sums under each column are equal to 1.

Local sensitivity of a critical factor refers to the influence of that factor on its parent component. On consideration with that value, the importance of that factor on the organizational goals can be identified and thereby making proper resource allocation. Global sensitivity of sub factor refers to its influence over the system with respect to the corresponding critical factor as well as the component. After that, normalisation of critical factors has been carried out. Through this process, the normalised values and local sensitivity were calculated. Normalised values represent the fraction of pair wise contribution of critical factors against each other. Local sensitivity refers to the average of normalised values of each critical factor. Global sensitivity of a sub factor is obtained by multiplying the local sensitivity. The global sensitivity of sub factors computed during this simple application study is presented in Table 9.

Local sensitivity is the average of normalized values of the corresponding row of critical factor. Global sensitivity of sub factor is obtained by multiplying its local sensitivity with the local sensitivity of the corresponding critical factor. For example, the calculation of the global sensitivity of the sub factor 'frequency of complaints' for the parent critical factor 'customer' is illustrated here. As shown in Table 9, its local sensitivity is 0.036. As shown in Table 4, the local sensitivity of its related critical factor 'Customer' is 0.665.Then the Global sensitivity of 'Frequency of complaints' = 'Customer' local sensitivity × local sensitivity of 'Frequency of complaints'. This value 0.024 is illustrated in Table 9. This indicates that any changes in the functioning of this sub factor will influence the working of MQFD to the extent of 2.4% (0.024 × 100). Subsequent to the calculation of global sensitivities, their proper representation of reality had to be confirmed by computing the Consistency Index (CI).

B. Computation of consistency ratio and sensitivities

The CI for each pair wise comparison matrix was calculated by using the following equation:

$$CI = \frac{(\lambda_{max} - n)}{n-1}$$

Where λ_{max} stands for the principal Eigen value of the matrix and was evaluated using the software 'MATLAB', and n is the size of the matrix. The parameter random index (RI) depends on the size of the matrix and has to be found out from Saatys's table given in table 5.

For HoQ, the

$$CI = \frac{(3.0858 - 3)}{3-1} = 0.0429$$

Consistency Ratio CR,

$$CR = \frac{CI}{RI}$$

For HoQ,

$$CR = \frac{0.0429}{0.58} = 0.0739$$

As a thumb rule, this value is to be less than 0.1 or 10%, this is taken as the criterion of consistency of the results. Rarely are CRs greater than 0.1. Here, factor 'Autonomous Maintenance' has CR>10%. So, the decision makers need to readjust the decision about its consistency. If they are satisfy with the consistency of that factor then no need for another decision making. The consistency parameters of critical factors and its sub factors are illustrated in table 6 & 8. Pair wise degree comparison matrix of sub factors of the critical factor 'Customer' also posted in table 7. Here, the sub factor component 'Autonomous Maintenance' having the CR value is 0.1023, which is more than the accepted value of 0.1. As stated above, if the investigator of the system is fulfilled with the consistency, then the consistency level can be accepted. In this case, it was concluded that the results were consistent, since the analysis was carried out systematically.

Normalised values of the component House of Quality (HOQ)	*Customer*	*Technology*	*Competitor*	*Local sensitivity*
Customer	0.69	0.75	0.556	0.665
Technology	0.172	0.188	0.333	0.231
Competitor	0.138	0.062	0.111	0.104

Table-4 Normalised values of 'House of Quality'

Table-5 Saaty's Table for Random Index vs. Size of the Matrix

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49
n = size of the matrix R.I – Average Random Index										

Table-6 Consistency parameters of critical factors

Critical factors	λ_{max}	CI	RI	CR	Inference
House Of Quality	3.0858	0.0429	0.58	0.0739	CR < 0.1
Decision Making	3.0037	0.00185	0.58	0.0032	CR < 0.1
TPM	8.81544	0.11645	1.41	0.0826	CR < 0.1
Maintenance Parameters	6.3355	0.0671	1.24	0.0541	CR < 0.1
Quality Parameters	4.2421	0.0807	0.9	0.0896	CR < 0.1

Table-9 Global sensitivity and local sensitivities of critical factors and subfactors of MQFD

Critical factors	***Local sensitivity***	***Sub factors***	***Local sensitivity***	***Global sensitivity***
Customer	0.665	Frequency of Complaints	0.036	0.024
		Cultural background	0.024	0.016
		Complaint redressal	0.144	0.096
		Responsiveness	0.202	0.134
		Quality of products	0.528	0.351
		Price of the product	0.064	0.043
Technology	0.231	Infrastructure	0.341	0.079
		Skill of the personnel	0.045	0.01
		Employer–employee relationship	0.273	0.063
		Organisational climate	0.251	0.058
		Modern Maintenance methods	0.089	0.021
Competitors	0.104	Financial power	0.084	0.009
		Performance of competitors	0.044	0.005
		Customer relationship	0.159	0.017
		Strategies of competitors schemes	0.036	0.004
		Quality parameters	0.568	0.059
		New technology	0.109	0.011
Personnel Factor	0.083	Authority	0.083	0.007
		Responsibility	0.462	0.038
		Initiatives	0.349	0.029
		Motivation	0.105	0.009
Value of decision	0.445			
Reliability of decision	0.472			
Autonomous maintenance	0.034	Attitude of workers	0.3	0.01
		Attitude of management	0.38	0.013
		Motivation schemes	0.058	0.002
		Incentive schemes	0.077	0.003
		Financial benefits	0.08	0.003
		Lubrication management	0.054	0.002
		Daily maintenance	0.05	0.002
Individual improvement	0.116	Reputation of individual	0.261	0.03
		Kaizen principles	0.059	0.007
		Employee suggestion Scheme	0.102	0.012
		Employee Involvement Scheme	0.202	0.023
		Daily Maintenance	0.043	0.005
		Inter personnel relations	0.265	0.031
		Employee Wish	0.078	0.009

Table-9 Global sensitivity and local sensitivities of critical factors and sub factors of MQFD (continued)

Critical factors	***Local sensitivity***	***Sub factors***	***Local sensitivity***	***Global sensitivity***
Planned maintenance	0.026	Schedule of maintenance	0.611	0.016
		Frequency	0.118	0.003
		Idleness of machine	0.27	0.007
Quality maintenance	0.368	TQM tools	0.685	0.252
		Sampling	0.222	0.082
		Data management	0.093	0.034
Education and training	0.178	Feasibility for higher studies	0.244	0.043
		Training Facility	0.244	0.043
		Employee’s interest	0.057	0.01
		Motivation for training	0.222	0.039
		Reward for better performance	0.233	0.041
Development management	0.065	Target setting	0.346	0.022
		Job scheduling	0.262	0.017
		Production planning	0.312	0.02
		Maintenance schedule	0.08	0.005
Office TPM	0.061	New technology	0.69	0.042
		Training	0.161	0.009
		Motivation Scheme	0.149	0.009
Safety, health and environment	0.151	Safety	0.474	0.072
		Health	0.474	0.072
		Pollution	0.052	0.008
OEE	0.294			
MTBF	0.028			
MTTR	0.062			
PE	0.294			
MDT	0.028			
Availability	0.294			
Improved maintenance	0.051			
Increased profit	0.708			
Upgraded core competence	0.078			
Enhanced goodwill	0.162			

Table-7 Pairwise degree comparison matrix of sub factors of the critical factor ‘Customer’

Customer	Frequency of complaints	Cultural background	Complaint redressal	Responsiveness	Quality of products	Price of the product
Frequency of complaints	1	2	¼	1/5	1/9	1/3
Cultural background	½	1	1/7	1/7	1/9	1/3
Complaint redressal	4	7	1	1	1/9	4
Responsivenes s	5	7	1	1	1	3
Quality of products	9	9	9	9	1	9
Price of the product	3	3	¼	1/3	1/9	1
Sum	22.5	29	11.64	11.676	2.44	17.67
Consistency Parameters	λ_{max} = 6.6146 CI = 0.12292 RI= 1.24 CR = 0.0991 CR < 0.1					

Table-8 Consistency parameters of sub factors

Sub factors	λ_{max}	CI	RI	CR	Inference
Customer	6.6146	0.12292	1.24	0.0991	CR < 0.1
Technology	5.2529	0.0632	1.12	0.0564	CR < 0.1
Competitors	6.54	0.108	1.24	0.087	CR < 0.1
Personnel Factor	4.1617	0.0539	0.9	0.0598	CR < 0.1
Autonomous Maintenance	7.8106	0.1351	1.32	0.1023	CR > 0.1
Individual Improvement	7.6772	0.1128	1.32	0.0855	CR < 0.1
Planned Maintenance	3.026	0.0063	0.58	0.0108	CR < 0.1
Quality Maintenance	3.0536	0.0268	0.58	0.0462	CR < 0.1
Office TPM	3.0055	0.00275	0.58	0.00474	CR < 0.1
Education and Training	5.0283	0.007075	1.12	0.00631	CR < 0.1
Development Management	4.1617	0.0539	0.9	0.0598	CR < 0.1
Safety, Health, and environment	3	0	0.58	0	CR = 0

V. RESULTS AND DISCUSSIONS

Enumeration of local sensitivities of critical factors and global sensitivities of sub factors were the final outcomes of AHP in MQFD in the company under study. The values of these sensitivities were used to determining the priorities among the critical factors and sub factors. The company must take interest and care regarding these factors while implementing MQFD. The analysis of the computed sensitivities during AHP starts by preparing the tables of both local and global sensitivities. This is shown in Table 9. Further, the local sensitivities of critical factors in the descending order was prepared, which is shown in Table 10. Similarly, the global sensitivities of all sub factors have also been shown in Table 11 in the descending order. A bar chart was prepared for Local sensitivities of critical factors is depicted in Figure 4. Following are the observations which describe the situation existing in the company under study for implementing MQFD:

- As shown in Table 10 and Figure 4, the critical factor 'Increased Profit' has the highest value of local sensitivity. This point outs that, the company has to give more attention to in this critical factor for the successful application of MQFD.

- As shown in Table 10 and Figure 4, the local sensitivity of the critical factor 'Planned Maintenance' is the least among all. Therefore, the company has to spend minimum time and money on 'Planned Maintenance' while implementing MQFD.

- As shown in Table 11, the 'Quality of products' has the highest global sensitivity. Hence, the company has to focus maximum attention and commitment towards this sub factor while implementing MQFD.

- As shown in Table 11, the subfactors 'Motivation schemes, Lubrication management and Daily maintenance' possess the least global sensitivity. Thus, the company wants to spend only very little resource and concern on it.

- The studies point outs that no critical factors and sub factors have more than 75% local and global sensitivities. This indicates that these factors are intrinsically in progress in the company and do not want critical care and plentiful resource allocation for their deployment. In other terms, these judgments specify that the continuation of the culture in the industry is favorable for MQFD implementation.

- The 'Increased Profit' and 'customer' are the critical factors, whose global sensitivities are between 50% and 75%. This indicates that extreme care has to be taken by the company towards customer-associated strategy and Increased Profit while implementing MQFD.

- 22 critical factors and 56 sub factors have sensitivities less than 50%. This specifies that the company has to concern to the minimum extent regarding these activities. This judgment indicates that MQFD execution require much less investment and care on the part of the company.

Table-10 Local sensitivity and critical factors in descending order

Critical factors	***Local sensitivities***
Increased Profit	0.708
Customer	0.665
Reliability of Decisions	0.472
Value of Decisions	0.445
Quality Maintenance	0.368
Overall Equipment Effectiveness (OEE)	0.294
Availability	0.294
Performance Efficiencies	0.294

Technology	0.231
Education & Training	0.178
Enhanced Goodwill	0.162
Safety, Health, Environment	0.151
Individual Improvement	0.116
Competitor	0.104
Personnel Factor	0.083
Upgraded Core Competence	0.078
Development Management	0.065
Mean Time To Repair (MTTR)	0.062
Office TPM	0.061
Improved Maintenance	0.051
Autonomous Maintenance	0.034
Mean Time Between Failure (MTBF)	0.028
Mean Down Time (MDT)	0.028
Planned Maintenance	0.026

Table-11 Global sensitivity and sub factors in descending order

Sub factors	***Global sensitivity***
Quality of products	0.351
TQM tools	0.252
Responsiveness	0.134
Complaint redressal	0.096
Sampling	0.082
Infrastructure	0.079
Safety	0.072
Health	0.072
Employer–employee relationship	0.063
Quality parameters	0.059
Organisational climate	0.058
Price of the product	0.043
Feasibility for higher studies	0.043
Training Facility	0.043
New technology	0.042
Reward for better performance	0.041
Motivation for training	0.039
Responsibility	0.038
Data management	0.034

Inter personnel relations	0.031
Reputation of individual	0.03
Initiatives	0.029
Frequency of Complaints	0.024
Employee Involvement Scheme	0.023
Target setting	0.022
Modern Maintenance methods	0.021
Production planning	0.02
Customer relationship	0.017
Job scheduling	0.017
Cultural background	0.016
Schedule of maintenance	0.016
Attitude of management	0.013
Employee suggestion Scheme	0.012
New technology	0.011

Table-11 Global sensitivity and sub factors in descending order (continued)

Sub factors	***Global sensitivity***
Attitude of workers	0.01
Employee's interest	0.01
Financial power	0.009
Motivation	0.009
Employee Wish	0.009
Training	0.009
Motivation Scheme	0.009
Pollution	0.008
Authority	0.007
Kaizen principles	0.007
Idleness of machine	0.007
Performance of competitors	0.005
Daily individual Maintenance	0.005
Maintenance schedule	0.005
Strategies of competitors schemes	0.004
Incentive schemes	0.003
Financial benefits	0.003
Frequency	0.003
Motivation schemes	0.002
Lubrication management	0.002
Daily maintenance	0.002

In general, the company may not face any complexity for executing MQFD, since the local and global sensitivities of its critical factors and sub factors are below 50%. Since it is a common practice to admit auspiciously the implementation of every system, which is not caused by any critical factors and sub factors to any level more than 50%, it can be concluded that the company under study is susceptible to the successful application of the MQFD practice.

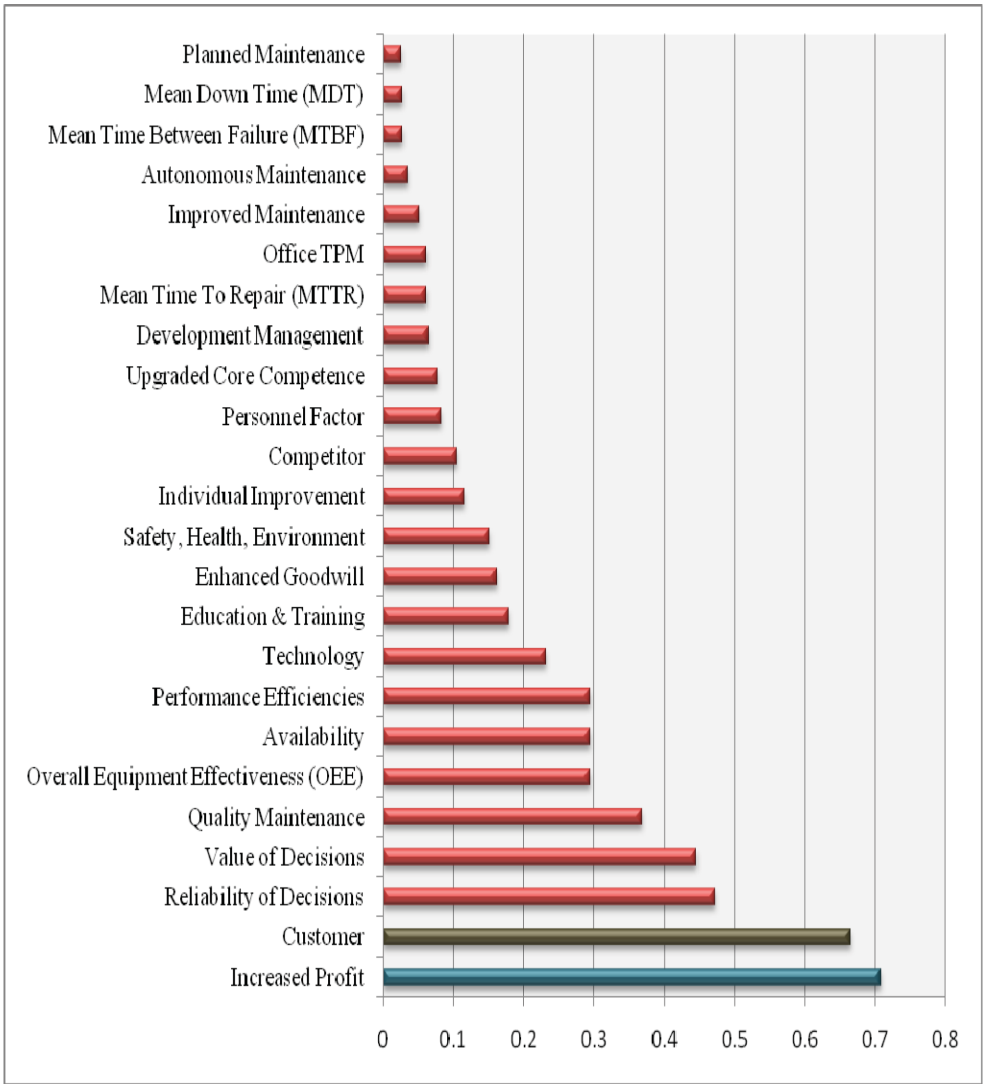

Figure 4. Level of sensitivities of critical factors

VI. CONCLUSION

AHP on MQFD study carried out in the company disclosed the viability of MQFD without any intricacy and extraordinary care and investment. Though, the exercise of AHP on MQFD is not inadequate to review the viability of applying MQFD in the company. Somewhat, its actual use lies in the multicriteria decision making, which is a feature of strategic decision of the MQFD model.

The company has to implement a maintenance quality strategy by using AHP by which the MQFD phase has to be encouraged. In this case, the company may retain the following maintenance quality strategies.

- Critical factors having sensitivities above 20% may pass through the eight pillars of TPM. Remaining critical factors may be focused to direct implementation.
- The sub factors with global sensitivities above 10% may pass towards the eight pillars of TPM. Other sub factors may be subjected to direct implementation.

According to the first strategy, the critical factors MDT, OEE, PQ, Technology, enhanced goodwill, improved maintenance, personnel and customers have to be given utmost attention while implementing the eight pillars. Other critical factors may be subjected to execution by spending least amount of resources. For example, the supervisors may verbally educate the subordinates regarding those critical factors. In these cases, the proper conduct of training programmes spending significant resources is not essential.

According to the second strategy, the company has to forward the sub factors, namely, responsibility, motivation, initiatives, quality of spare parts and emergencies/necessity through eight pillars of TPM. Other sub factors may be subjected to implementation by spending minimum resources on them.

Thus, the AHP on MQFD is helpful for identifying the critical factors and sub factors, which will sensitise the MQFD plan. Subsequently, it tilts MQFD execution towards these critical factors and sub factors by taking extreme care that significant resources are invested on them.

REFERENCES

[1] Paulo A and Cauchick M, "Innovative new product Development: a study of selected QFD case studies", *The TQM Magazine* ,Vol. 19 No. 6, pp. 617-625, 2007.

[2] Henny and Jan, "Choosing a quality improvement project using the analytic hierarchy process", *International Journal of Quality & Reliability Management,* Vol. 23 No. 4, pp. 409-425, 2006.

[3] Chan, L-K. and Wu, M-L. "Quality function deployment: a literature review", *European Journal of Operational Research*, Vol. 143, pp.463–497, 2002

[4] Akao, Y. and Mazur, G.H. "The leading edge in QFD: past, present and future", *International Journal of Quality and Reliability Management*, Vol. 20, No. 1, pp.20–35.2003.

[5] Chein, T.K. and Su, C.T. "Using the QFD concept to resolve customer satisfaction strategy decisions", *International Journal of Quality and Reliability Management*, Vol. 20, No. 3, pp.345–359.2003.

[6] Pramod, V.R., Devadasan, S.R. and Jagathy Raj, V.P. "Customer voice adoption for maintenance quality improvement through MQFD and its receptivity analysis", *Int. J.Management Practice*, Vol. 2, No. 2, pp.83–108.2006.

[7] Pramod, V.R., Devadasan, S.R., Muthu, S. and Jagathy Raj,V.P."MQFD: a model for synergising TPM and QFD", *Int.J.Process Management and Benchmarking*, Vol. 1, No. 2, pp.176–200, 2006.

[8] Rahim, A.R.A. and Baksh, M.S.N. "Application of Quality Function Deployment (QFD) method for pultrusion machine design planning", *Industrial Management & Data Systems*, Vol. 103, No. 6, pp.373–387, 2003.

[9] Kwon, O. and Lee, H. "Calculation methodology for contributive managerial effect by OEE as a result of TPM activities", *Journal of Quality in Maintenance Engineering*, Vol. 10, No. 4, pp.263–272, 2004.

[10] Chin, K-S., Pun, K-F., Xu, Y. and Chan, J.S.F. "An AHP-based study of critical factors for TQM implementation in Shanghai manufacturing industries", *Technovation*, Vol. 22,pp.707–715, 2002.

[11] Taha, H.A. "*Operations Research: An Introduction"*, 7th ed., Prentice-Hall of India Pvt. Ltd, 2003.

[12] Haj Shirmohammadi, A. and Wedley, W.C. "Maintenance management – an AHP application for centralization/decentralization", *Journal of Quality in Maintenance Engineering*, Vol. 10, No. 1, pp.16–25, 2004.

[13] V.R. Pramod, K. Sampath, S.R. Devadasan, V.P. Jagathy Raj, G. Dakshina moorthy "Multi criteria decision making in Maintenance Quality Function Deployment through the Analytical Hierarchy Process" *Int. J. Industrial and Systems Engineering*, Vol. 2, No. 4, 2007.