

Execution Quantification in a Process Industry Using Analytic Network Process (ANP)

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Abstract

In this work a general idea about decision making models and Analytical Network Process (ANP) are introduced. The Analytic Network Process (ANP) is a general theory of relative measurement used to derive priority ratio scales. Through its super matrix whose elements are themselves matrices of column priorities, the ANP captures the outcome of dependence within clusters of elements. The ANP is a new phase in decision making, neglected so far because of the linear structures used in traditional approaches and their inability to deal with feedback in order to choose alternatives. In this paper we will be using ANP to measure performance of cement production industry.

Keywords: *Analytic Network Process (ANP), Execution Quantification, Manufacturing sectors*

INTRODUCTION

Manufacturing sector has recently witnessed rather drastic changes. The manufacturing organizations today can no longer view itself as a closed system focused on efficiency. Rather, it must operate as an open system in order to cope with the dynamics imposed on it by a demanding global business environment.

The effectiveness of performance of such a system is dependent on whether the customer values the output or the extent to which such value provide advantage for the organization. Manufacturing performance management is becoming an elusive construct. In this context, manufacturing executives not only have to understand the different sides of manufacturing

performance, but they also must be able to design a manufacturing performance management system capable of measuring and improving these different facets. Decision making models are helping tools for the managers or decision makers to make future plans by using qualitative or quantitative data. It decision making model involves into two phases (i) Performance measurement and (ii) Performance improvement. Performance measurement is the fundamental for measuring company's objective. Since **Kaplan and Norton [1]** introduced the Balanced Scorecard in the early 1990s, it has become widely adopted by companies and divisions within companies. The Balance Score Card was considered as a way to achieve a company's vision and strategy. **Thomas L. Saaty [2]** explains the basic principles of Analytic Network Process in the fundamentals of Analytic Network Process with a simple example. The example deals with choosing the best shop which sells good hamburger from the four given shops. **McKenzie and Shilling [3]** talk about balanced scorecards in terms of performance measurement systems that are tied to incentive or compensation plans and all the problems this can create. **Ho and McKay [3]** compared two companies, one that abandoned use of Balance Score Card and one that is using it. It was found that

the company using Balance Score Card focuses on long term results and not short term results with a periodic feedback. **Ghodsypour and Brien [4]** in their journal adopted the AHP to determine the relative importance weightings of the suppliers with respect to three criteria - cost, quality, and service. **Kearns [5]** in his paper proposed the Analytic Hierarchy Process to evaluate the relative importance weight ages of alternative information systems. The evaluation was on the basis of five criteria - investment risk, revenue enhancing, operating efficiency, customer satisfaction, and market growth. **Gunasekaran et al. [6]** tell us about how a method has been developed to better understand the importance of Supply Chain Management - performance management and metrics. These measures play an important role in the success of an organisation. They affect strategic, tactical and operational planning & control.

Andy et al [7] in the journal "Performance measurement at system design: developing and testing a process-based approach" described the development and testing of a structured methodology for the design of performance measurement systems. Models, such as the balanced scorecard and the performance prism following a wide ranging review of

the performance measurement literature; a method identifying the desirable characteristics of a performance measurement system, a design process is developed. **Kaplan and Norton [1]** in their book “**The Balanced Scorecard Translating -Strategy Into Action- Kaplan & Norton**” were motivated by a belief that existing performance measurement approaches, primarily relying on financial accounting measures were becoming obsolete. The study participants believed that reliance on summary financial-performance measures were hindering organization’s abilities to create future economic value. **Punniyamoorthy and Dominica [9]** suggest a framework of performance measurement through a balanced scorecard and to provide an objective indicator for evaluating the achievement of the strategic goals of a corporate. This paper uses the concepts of balanced score card and adopts a decision model to measure an organization’s performance. **Taslicali and Ercan [10]** in their paper identify the critical benefits and factors of decision making models in a changing technological environment. Decision making models are helping tools for the managers or decision makers to make future plans by using qualitative or quantitative data. **Gencer and Didem[11]** in their paper help us understand on how

and what are the criterion that is needed for Performance Measurement in an Organisation. An example of supplier selection in an electronic firm is explained to us using the ANP. The criteria are selected depending on the objective and goal of the industry under consideration. **Yuksel and Dagdeviren [12]** in their journal “**Using the analytic network process (ANP) in a SWOT analysis – A case study for a textile firm**” we get an overview of the SWOT process, AHP and ANP. SWOT analysis provides a brief analysis of performance measurement. AHP in detail lets us asses the individual factors to know their performance and thereby removing the deficiency of the SWOT analysis. ANP has an advantage by being able to overcome the deficiency of both SWOT analysis and AHP.

In this project the performance of a Cement Industry is analysed. Three methodologies have been used. Balance Score Card, which is used to find the difference between actual and target performance of the industry and also the weightage of the criteria. The output of Balance Score Card is given as input to Analytic Network Process. In this method we find the global priorities of the criteria i.e., to identify the top ten criteria whose small change will bring drastic change in the functioning of

the industry. Thus a periodic check of these parameters will help the industry to function in par with the target of the industry.

BALANCE SCORE CARD

The **Balanced Score Card (BSC)** is an effective tool used by many Fortune 500 companies to evaluate and analyse factors impacting organizational stability and progress with an integrated approach. These factors are compared pair wise and 0 or 1 is assigned based on the importance of one perspective over another.

PERSPECTIVES OF BALANCE SCORE CARD

Customer's Perspective:

A customer always aligns towards a product that promises to fulfil his needs to

the maximum outcome at a minimum cost and maintenance investment. Therefore, satisfying a customer begins at the product planning stage and doesn't end till it reaches the market as a finished product. Therefore, understanding the customer's expectations of a product is key to successfully designing, manufacturing and marketing it. Those who hold transaction with a firm expect it to be the best one in the competition and choose it for the same reason. It is the responsibility of the firm to uphold this position by constantly updating and upgrading its practices to match current market trends. Every company may not be expected to handle all facets of production, distribution and marketing with its own manpower and resources.

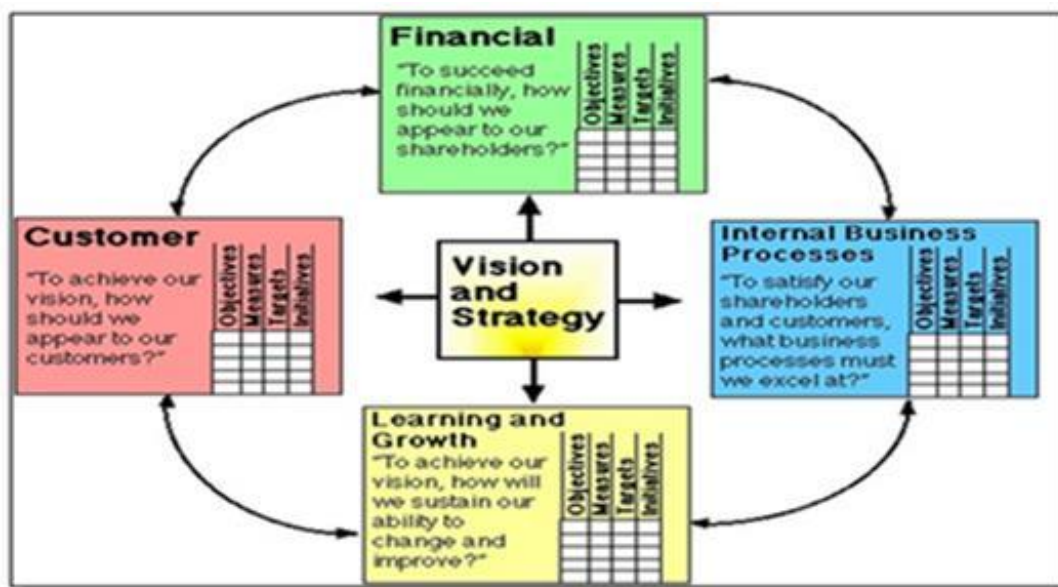


Fig 1: Blueprint of Balance Score Card

Therefore, outsourcing becomes an important part of activities aiming towards maintaining market and industry relevance. Specialized services that are not economical for the company to develop by itself can be outsourced to vendors. However, from the customer's point of view, this outsourcing should not affect their privacy through unsolicited advertising and contact which in turn will adversely affect the parent firm, leading to a loss of market.

Financial Perspective

Monetary capital and returns are essential to set up a company and keep it going. Therefore, all of the company's operations have to be moulded to function within an optimally flexible financial framework. Financial resources available for investment should be disbursed to respective sectors of the firm after careful consideration, evaluation and prioritization of needs. Tasks can be divided into those that are to be performed within the firm and those that can be outsourced so that the latter can be completed without much expenditure of the firm's own manpower while cutting costs. Capital hence freed can be channelled into other departments which are wanting in resources so that all-round development of the firm is achieved. Outsourcing also aids in lowering costs

incurred in supervising the in-house work done as this will no longer be applicable. Also, energies directed towards establishing larger market share will result in a better financial performance and position which will in turn facilitate more developmental activities.

Internal Operations Perspective

Those functions that have to be carried out strictly within the firm can be identified and those that can be done elsewhere should be outsourced so that the focus of the company's management can be trained on these essential tasks. This approach ensures maximum benefit as innovations can be made within the company with maximum concentration while outsourcing to vendors who are experts in the respective fields' guarantees up gradation to cutting-edge technology all round.

ANALYTIC NETWORK PROCESS

It is generalisation of Analytic Hierarchy Process used to solve problems with multi criteria. Even this method uses pair wise comparison to calculate the weights and rank the alternatives. The only main difference between both the methods is that Analytic Network Process allows interdependence among criteria. It is a general approach for any kind of problem. Forces precise definition of nodes and inter

connections. Ideal tool to get a deeper understanding of a problem and its relation to related factors. Explanation of concept and process to management is extremely challenging. Requires specific software to calculate results. Verification of results due to feedback loss and interrelations are impossible.

Outline of the Steps to Be Followed In Analytic Network Process Suggested By Saaty

1. The criteria and sub-criteria for the systems to be compared are determined based on benefits, cost and risks.
2. The cluster to which each sub criteria or nodes belong is then determined.
3. The sub-criteria for each cluster now is organized in a better format by placing them below each cluster and giving them appropriate numbers.
4. Now the relationship between the various sub criteria of each cluster with respect to one another is stated. This is one of the most important areas as they will determine the result directly. It is the root of this method.
5. Once the entry has been done, now cluster comparison with each other is

carried out. The derived weights are later used in the columns of the super matrix based on the influence. A zero is added in the non-related columns.

6. Now pairwise comparison is done for each sub criteria with respected to its related sub-criteria of other clusters based on the influence entered at the start. The pair-wise comparison is another critical area as this is the input for all the data.
7. To form the super matrix, a table with nodes on the vertical left hand side and horizontal upper side is laid out. Now, the appropriate cluster values are entered in the respective column and zeros are entered in the non-related columns.
8. Compute the limiting priorities of each super matrix according to whether it is irreducible or it is reducible, with one being a simple or a multiple root and whether the system is cyclic or not.
9. Synthesize the limiting priorities by weighting each limiting super matrix by the weight of its control criterion and adding the resulting super matrices.
10. This synthesis is repeated for each of

the clusters. This will thereby give us a complete weighted super matrix.

11. The limit matrix is obtained by multiplying the benefits with opportunities and dividing by the costs multiplied with risks. Now the derived values are then ranked based on descending order of the values.

EXERIMENTAL PROCEDURE

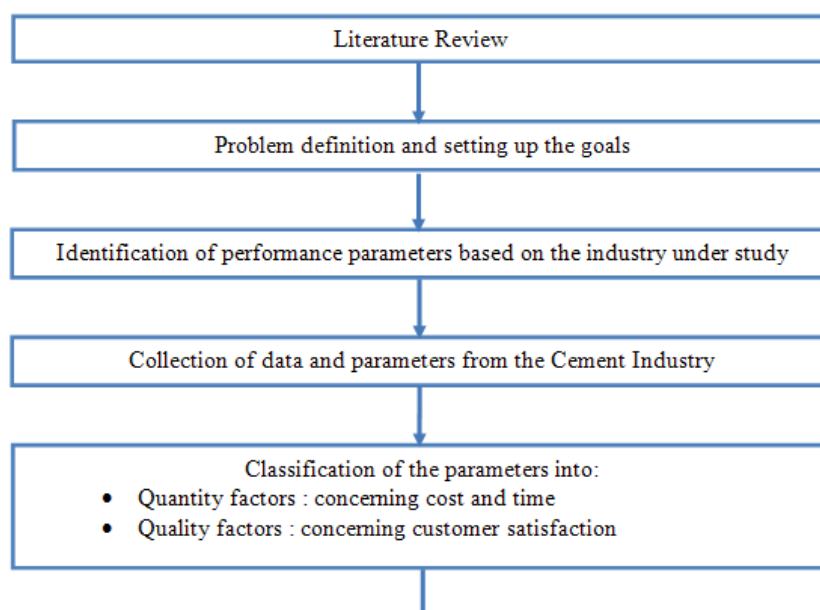
OBJECTIVE

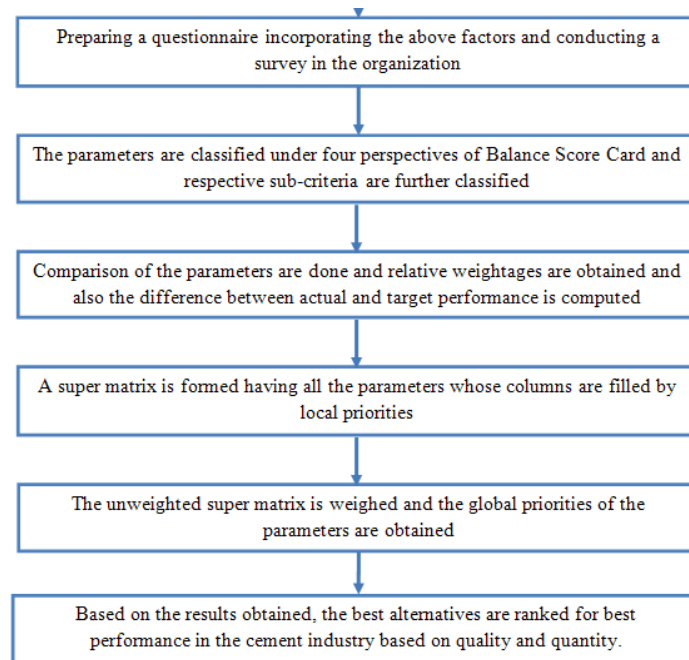
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Process. We also find the global priorities of the criteria i.e., to identify the top ten criteria whose changes will have significant improvement on the process. Thus a periodic check of these parameters will help the industry to function in par with the target of the industry.

W1, W2, W3 and W4 are the weightages obtained from tables 7. X1, X2, X3 and X4 are the values, obtained by adding the products of the corresponding target and weightage multiplied with weightage of the perspectives of Balance Score Card. Y1, Y2, Y3 and Y4 are the values, obtained by adding the products of the corresponding actual value and weightage multiplied with the weightage of the perspectives of Balance Score Card.

METHODOLOGY FLOW CHART





DATA COLLECTED

Table 1: Data sheet containing data collected from industry

	ACTUAL	TARGET
MAINTANANCE COST	1500c	1550C
MARKET SHARE	1480c	1460C
PROFIT PERCENT	42%	30%
COST SAVINGS	150/1700	100/1700
INITIAL SETUP COST	855C	860C
EMPLOYEE SALARY	28c	25C
MACHINE WORKING HOUR	18 HOURS	18 HOURS
CUSTOMER COMPLAINTS	5%	10%
SERVICE RESPONSE	98%	98%
PRICE STABILITY	+/-1%	+/-1%
PRODUCT AVAILABILITY	100%	98%
PERCENT OF RETURNED GOODS	0.001%	0.0002%
ONTIME DELIVERY RATE	2 DAYS	2 DAYS
BRAND IMAGE	100%	100%
EMPLOYEE COMPETANCY	98%	96%
EMPLOYEE SATISFACTION	98%	98%
MANAGEMENT CAPABILITY	98%	96%
R&D INNOVATION	55%	45%
SALES PERCENTAGE	17%	15%
IPP	45%	42%
FIRM'S RESPONSIVENESS	98 %	96%
PATENT & LISCENCES	98%	98%
PACT	98%	98%
QUALITATIVE BENCH MARKETING	16 DAYS	14 DAYS
TOTAL CYCLE TIME	4 HOURS	4 HOURS
REJECTION RATIO	0.001%	0.002%

CALCULATIONS AND TABLES

Balance Score Card

Table 2 Balance Score Card – Financial Perspective.

FINANCIAL PERSPECTIVE																								
Sr.No	CRITERIA	1&2	1&3	1&4	1&5	1&6	1&7	2&3	2&4	2&5	2&6	2&7	3&4	3&5	3&6	3&7	4&5	4&6	4&7	5&6	5&7	6&7	TOTAL	WEIGHTAGE
1	MAINTAINANCE COST	1	0	0	1	0	0																2	0.083333333
2	IMPROVED MARKET SHARE	0						1	0	1	1	1											4	0.166666667
3	PROFIT PERCENT		1					1					1	1	1	1							6	0.25
4	COST SAVINGS			1					1				0				1	1	0				4	0.166666667
5	INITIAL SETUP COST				0					0				0			1			1	0		2	0.083333333
6	EMPLOYEE SALARY					1					0				0			0		1		1	3	0.125
7	TRANSPORTATION COST						1					0				0			1		1	0	3	0.125
SUB TOTAL																							24	

Table 3 Balance Score Card – Customer Perspective

CUSTOMER PERSPECTIVE																								
Sr.No	CRITERIA	1&2	1&3	1&4	1&5	1&6	1&7	2&3	2&4	2&5	2&6	2&7	3&4	3&5	3&6	3&7	4&5	4&6	4&7	5&6	5&7	6&7	TOTAL	WEIGHTAGE
1	CUSTOMER COMPLAINTS	0	0	1	1	0	0																2	0.076923077
2	SERVICE RESPONSE	1						0	1	1	1	0											4	0.153846154
3	PRICE STABILITY		1					1					0	1	0	0							3	0.115384615
4	PRODUCT AVAILABILITY			1					1				1				1	1	0				5	0.192307692
5	PERCENT OF RETURNED GOODS				0					0				0			1			1	0		2	0.076923077
6	ON-TIME DELIVERY RATE					1					1				1			0		1		0	4	0.153846154
7	BRAND IMAGE						1					1				1			1		1	1	6	0.230769231
SUB TOTAL																							26	

Table 4 Balance Score Card – Company Learning and Growth

COMPANY LEARNING AND GROWTH													
Sr.No	CRITERIA	1&2	1&3	1&4	1&5	2&3	2&4	2&5	3&4	3&5	4&5	TOTAL	WEIGHTAGE
1	EMPLOYEE COMPETANCY	1	1	0	1							3	0.214285714
2	EMPLOYEE SATISFACTION	1				1	0	0				2	0.142857143
3	MANAGEMENT CAPABILITY		1			0			1	1		3	0.214285714
4	R&D INNOVATION			1			1		1		1	4	0.285714286
5	SALES PERCENTAGE				1			1		0	0	2	0.142857143
SUB TOTAL												14	

Table 5 Balance Score Card – Internal Operations

INTERNAL OPERATIONS																		
Sr.No	CRITERIA	1&2	1&3	1&4	1&5	1&6	2&3	2&4	2&5	2&6	3&4	3&5	3&6	4&5	4&6	5&6	TOTAL	WEIGHTAGE
1	FIRM'S RESPONSIVENESS	1	0	1	1	1											4	0.210526316
2	PATENT & LICENSE	1					0	1	1	1							4	0.210526316
3	% OF ACHIEVING COMPANY'S TR**		1				1				1	1		1			5	0.263157895
4	QUALITATIVE BENCH MARKETING			1				0			0				1	1	3	0.157894737
5	TOTAL CYCLE TIME				0				1			0		0		1	2	0.105263158
6	REJECTION RATIO					1				0			0		0	0	1	0.052631579
**TARGET RATE														SUB TOTAL			19	

**TARGET RATE

Table 6 Balance Score Card – External Operations

OVERALL OPERATIONS									
Sr.No	CRITERIA	1&2	1&3	1&4	2&3	2&4	3&4	TOTAL	WEIGHTAGE
1	FINANCIAL PERSPECTIVE	1	1	1				3	0.333333333
2	CUSTOMER PERSPECTIVE	0			1	1		2	0.222222222
3	COMPANY LEARNING AND GROWTH		1		0	0	1	2	0.222222222
4	INTERNAL OPERATIONS			1			1	2	0.222222222
					SUB TOTAL			9	

EFFECTIVE SCORE

Table 7 Effective Score – Financial Perspective and Customer Perspective

FINANCIAL PERSPECTIVE								
Sr.No	CRITERIA	W1		TARGET	W1*TGT		ACTUAL	W1*ACT
1	MAINTAINANCE COST	0.163333333	T1	1550	253.1666667	A1	1500	245
2	IMPROVED MARKET SHARE	0.166666667	T2	1460	243.3333333	A2	1480	246.6666667
3	PROFIT PERCENT	0.25	T3	0.3	0.075	A3	0.42	0.105
4	COST SAVINGS	0.166666667	T4	0.0588	0.0098	A4	0.088	0.014666667
5	INITIAL SETUP COST	0.123333333	T5	860	106.0666667	A5	855	105.45
6	EMPLOYEE SALARY	0.125	T6	25	3.125	A6	25	3.125
7	TRANSPORTATION COST	0.125	T7	18	2.25	A7	18	2.25
				x1	608.0264667		y1	602.6113333
CUSTOMER PERSPECTIVE								
Sr.No	CRITERIA	W2		TARGET	W2*TGT		ACTUAL	W2*ACT
1	CUSTOMER COMPLAINTS	0.176923077	T8	0.1	0.017692308	A8	0.05	0.008846154
2	SERVICE RESPONSE	0.153846154	T9	0.98	0.150769231	A9	0.98	0.150769231
3	PRICE STABILITY	0.115384615	T10	0.01	0.001153846	A10	0.01	0.001153846
4	PRODUCT AVAILABILITY	0.192307692	T11	0.98	0.188461538	A11	1	0.192307692
5	PERCENT OF RETURNED GOODS	0.076923077	T12	0.003	0.000230769	A12	0.001	7.69231E-05
6	ON-TIME DELIVERY RATE	0.153846154	T13	2	0.307692308	A13	2	0.307692308
7	BRAND IMAGE	0.230769231	T14	1	0.230769231	A14	1	0.230769231
				x2	0.896769231		y2	0.891615385

Table 8 Effective Score – Company Learning and Growth.and Internal Operations.

COMPANY LEARNING AND GROWTH								
Sr.No	CRITERIA	W3		TARGET	W3*TGT		ACTUAL	W3*ACT
1	EMPLOYEE COMPETANCY	0.214285714	T15	0.96	0.205714286	A15	0.98	0.21
2	EMPLOYEE SATISFACTION	0.142857143	T16	0.98	0.14	A16	0.98	0.14
3	MANAGEMENT CAPABILITY	0.214285714	T17	0.96	0.205714286	A17	0.98	0.21
4	R&D INNOVATION	0.285714286	T18	0.45	0.128571429	A18	0.55	0.157142857
5	SALES PERCENTAGE	0.142857143	T19	0.15	0.021428571	A19	0.17	0.024285714
				x3	0.701428571		y3	0.741428571

INTERNAL OPERATIONS								
Sr.No	CRITERIA	W4		TARGET	W4*TGT		ACTUAL	W4*ACT
1	FIRM'S RESPONSIVENESS	0.210526316	T20	0.96	0.202105263	A20	0.98	0.206315789
2	PATENT & LICENSE	0.210526316	T21	0.98	0.206315789	A21	0.98	0.206315789
3	% OF ACHIEVING COMPANY'S TR**	0.263157895	T22	0.98	0.257894737	A22	0.98	0.257894737
4	QUALITATIVE BENCH MARKETING	0.157894737	T23	14	2.210526316	A23	16	2.526315789
5	TOTAL CYCLE TIME	0.105263158	T24	0.125	0.013157895	A24	0.125	0.013157895
6	REJECTION RATIO	0.052631579	T25	0.002	0.000105263	A25	0.001	5.26316E-05
				x4	2.890105263		y4	3.210052632

**TARGET RATE

Table 9 Effective Score – Ext ernal Operations.

OVERALL OPERATIONS									
Sr.No	CRITERIA	WEIGHTAGE			WGT*X			WGT*Y	DIFFERENCE
1	FINANCIAL PERSPECTIVE	0.333333333	X1	608.026467	202.6754889	Y1	602.611333	200.8704444	1.805044444
2	CUSTOMER PERSPECTIVE	0.222222222	X2	0.89676923	0.199282051	Y2	0.89161538	0.198136752	0.001145299
3	COMPANY LEARNING AND GROWTH	0.222222222	X3	0.70142857	0.155873016	Y3	0.74142857	0.164761905	-0.008888889
4	INTERNAL OPERATIONS	0.222222222	X4	2.89010526	0.642245614	Y4	3.21005263	0.713345029	-0.07109942
				P	203.6728896		Q	201.9466881	

$$P-Q= 1.726201439$$

CALCULATIONS

To find whether the industry is working as per the scheduled manner we have to find the difference between actual and target performance. To do so we have to find the difference of the summation of all values obtained by adding the products of the corresponding target and weightage multiplied with weightage of the Similarly P2, P3 and P4 values are obtained by multiplying with corresponding

perspectives of Balance Score Card with the values obtained by adding the products of the corresponding actual value and weightage multiplied with the weightage of the perspectives of Balance Score Card.

→P1= weightage of financial perspective*[(W1a*T1) + (W1b*T2) + (W1c*T3) + (W1d*T4) + (W1e*T5) + (W1f*T6) + (W1g*T7)] weightage of the perspective.

→Q1= weightage of financial perspective*[(W1a*A1) +(W1b*A2) + (W1c*A3) + (W1d*A4) + (W1e*A5) + (W1f*A6) + (W1g*A7)]

Similarly Q2, Q3 and Q4 values are obtained by multiplying with corresponding weightage of the perspective.

Therefore difference between target and actual performance

$$= [(P1+P2+P3+P4)-(Q1+Q2+Q3+Q4)]$$

$$= (202.675+0.199+0.155+0.642) - (200.870+0.198+0.164+0.713)$$

$$=203.672-201.946$$

$$=1.72620$$

The above difference shows that the industry is performing 1.727 less than the target.

RESULTS AND CONCLUSION

Here an integrated closed model to enhance performance management model has been proposed. It also provides a means to identify the current performance of an organization and a methodology to improve further. An important contribution of this model is that it combines both qualitative and quantitative dimensions of manufacturing performance measurement. The proposed model provides an

opportunity to operationalize the relationship among cost, time and service quality dimensions. Both objective factors and manufacturing quality factors have been converted into consistent dimensionless indices to measure System Performance Measure.

The Balanced Scorecard enabled organizations to eliminate all the drawbacks and strategies were developed taking into account the concerns of all involved and the organization came out with one united strategy for all its activities which was made clear to all. This enabled the widespread and successful implementation of the balanced scorecard across the industry, cutting across regional, departmental, nature of business and other barriers. It has been successfully adopted by many companies across the world today.

From the Balance Score Card it is seen that the actual performance is 1.726less than the target performance. This tells that the industry's performance is not sufficient enough to achieve the target. From the financial perspective, the company's actual performance score 1.805 is less than the target score. Learning and growth perspective also shows that the actual performance 0.001145299 is less than the

target performance. Internal perspective shows the actual performance 0.00889 to be more than the target performance. Regarding the customer perspective the actual performance 0.071 is greater than the target performance.

As the result of pair wise comparison within the cluster it is seen that in financial perspective profit percent has high priority and employee salary has the least priority, in customer perspective price stability is of more importance and customer complaints is of less importance comparatively, in company learning and growth management capability and R&D innovation are having higher priority whereas employee satisfaction is of east importance. In internal operation percent of achieving company's target is of more importance and total cycle time is having less priority. The end result of Analytic Network Process is ranking the top ten criteria among the total 26 criteria. They are as follow:

TOP TEN CRITERIA

Cost Savings (1)
Price Stability (2)
Profit Percent (3)
Customer Complaints (4)
Employee Competency (5)
Improved Market Share (6)
Maintenance Cost (7)

Product Stability (7)
Percentage of Achieving Company's Target rate (9)
Employee Salary (10)

By monitoring these above criteria periodically one can check the performance of the industry. Instead waiting till the end of the year to check the performance one can monitor the functioning of the industry periodically

LIST OF SYMBOLS AND ABBREVIATIONS

ANP – Analytic Network Process
AHP – Analytic Hierarchy Process
BSC – Balance Score Card
PACT – Percent of Achieving Company's Target Rate
IPP – Increase in Percent of Products Protected By Plant
Cr - Crore
W1, W2, W3, W4 – Weightages
TGT – Target
TGT*W – Target * Weightage
X1, X2, X3 and X4 – Values, obtained by adding the products of the corresponding target and weightage multiplied with weightage of the perspective of BSC
Y1, Y2, Y3 and Y4 – Values obtained by adding the products of the corresponding actual value and weightage multiplied with

the weightage of the perspectives of
Balance Score Card

ACT – Actual Values

SCM – Supply Chain Management

SWOT – Strengths Weakness
Opportunities & Threats

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