ANP IN PERFORMANCE MEASUREMENT AND ITS APPLICATION IN A MANUFACTURING SYSTEM

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ABSTRACT

As it is mentioned in the literature, performance measurement is a multi-perspective concept. For this reason, quantification of performance measurement can be modeled as a multi attribute decision problem. In this study, performance measurement is considered as an evaluation of the past activities with respect to the desired goals. With this definition, first a performance measurement system is proposed for a manufacturing system and an Analytical Network Process (ANP) technique is utilized in order to quantify the performance.

Keywords: performance measurement, analytical network process, manufacturing

1. Introduction

Performance is an efficiency measure with various measurement levels in itself while performance management is the development and improvement process based on the performance criteria defined on specifics of an institution or a firm. Performance measurement is defined as the process whereby an organization establishes the parameters within which programs, investments, and acquisitions are reaching the desired results (OCIO, 2007). It becomes more critical while improving performance through a better integration of operations across subsequent echelons and separate functions in the value chain became more important for the companies (Lohman, Fortuin , and Wouters, 2004).

According to Kaydos (1998), performance measures provide managers, front-line employees, and companies with a broad assortment of both cultural and technical benefits. These benefits go far beyond the bottom line, but they are not commonly recognized. While it is not a prerequisite to implementing performance measures, an understanding of these benefits will give managers insight into what makes a good measurement system and how performance measures should be used (Kaydos, 1998).

In performance measurement there exist lots of measurement models. The aim of this paper is to propose a performance measurement system by examining a manufacturing firm's performance using balanced score cards and analytical network process.

The rest of the paper is organized as follows. Literature reviews on performance measurement and analytical network process are given in Section 2. In Section 3, the methods used in the paper are

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represented. In Section 4, there is an application of the analytical network process on performance measurement of a manufacturing firm. In the last section we conclude the obtained results.

2. Literature Review

Ghalayini et al. (1997) represented an integrated dynamic performance measurement system developed in conjunction with a company. Mills at el. (2000) developed a framework for analyzing the implementation of a performance measurement system and used that framework to interpret three longitudinal case studies. Hudson et al (2001) described a research method to evaluate the appropriateness of strategic performance measurement system development processes for small- and medium-sized enterprises.

Chenhall (2005) identified a key dimension of strategic performance measurement systems, integrative information, as being instrumental in assisting managers deliver positive strategic outcomes. Parida and Kumar (2006) identified various issues and challenges associated with development and implementation of a maintenance performance measurement system. Henri (2006) tested the relationships between organizational culture and two attributes of performance measurement systems, namely the diversity of measurement and the nature of use.

Kim and Kim (2008) suggested a performance measurement framework called a customer relationship management scorecard to diagnose and assess a firm's customer relationship management practice. Chen (2009) modified the data envelopment analysis model to evaluate the performance of an enterprise, and showed that the available outputs of the modified model can be utilized to easily calculate the efficiencies of business units. Chin et al. (2009) presented a research using a K-user satisfaction based approach and evidential reasoning methodology to develop a user-satisfaction-based knowledge management performance measurement system for organizations to identify strengths and weaknesses, as well as enhance continuous learning.

3. Methodology

The method used in this study is Analytical Network Process. Saaty defines ANP as “The ANP is a theory of measurement generally applied to the dominance of influence among several stakeholders or alternatives with respect to an attribute or a criterion“(Saaty, 2001).

ANP has widespread usage in engineering applications. Saaty first found ANP in 1975 (Saaty, 2001). Gómez-Navarro et al. (2009) introduced a new approach to prioritize urban planning projects according to their environmental pressure in an efficient and reliable way, based on the combination of three procedures; the use of environmental pressure indicators, the aggregation of the indicators in an Environmental Pressure Index by means of the ANP and the interpretation of the information obtained from the experts during the decision-making process. Yazgan et al. (2009) developed an Artificial Neural Network model and trained it with using ANP results in order to calculate ERP software priority. Chang et al. (2009) developed a manufacturing quality yield model to forecast the 12 in silicon wafer slicing based on an ANP framework. Carlucci and Schiuma (2009) proposed a model, based on the ANP methodology, to disclose and assess how knowledge assets mutually interact and take part in company’s value creation dynamics.

The first stage of ANP is to determine the decision problem and structuring it into a network. After structuring the problem, pairwise comparison matrices of interdependent component levels should be developed. Than supermatrix which represents the tool by determining global priorities in a network system, should be formed. The last stage is prioritization and selection of the alternative with the highest overall priority (Carlucci and Schiuma, 2009).

4. Application

The goal is determined by experts as achieving corporate performance on a manufacturing company. The criteria of this goal are grouped into four perspectives which are customer, finance, learning & growth of the organization and process.

The indicators of customer perspective are market share, customer complaints and market share. The indicators of finance are determined as productivity, return on investment (ROI) and cost reduction rate. Labor training, time spent for continuous improvement and investment rate of improvement are the indicators of learning and growth perspective. Process criteria has five sub-criteria which are; flexibility, availability, delivery, speed and quality. Percentage of multipurpose equipment, load size and vendor lead time are defined as indicators for flexibility; percentage of machine uptime rate, usage of formalized preventive maintenance and ratio of maintenance cost repair are defined as indicators for delivery; set-up time, manufacturing lead time, cycle time and waiting time are defined as indicators for speed, and first pass yield, assembly line defects per hundred units and defects rate are defined as indicators for quality. The hierarchical structure is shown in Figure 1.

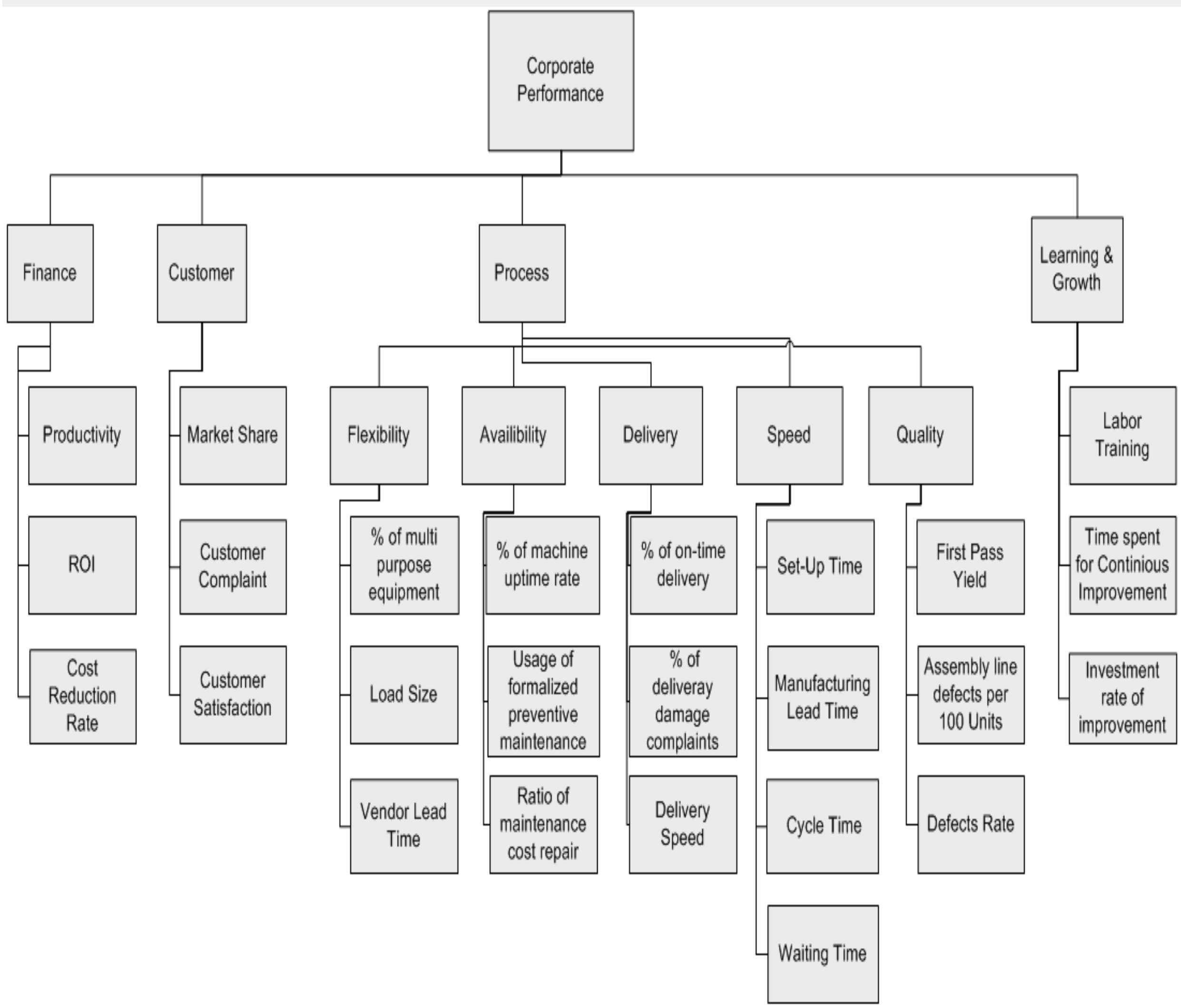

Figure 1. Hierarchical Structure

After defining criteria and sub-criteria, the relations should be determined to learn whether the structure is a hierarchy or a network. Perspectives have an effect on each other as shown in Figure 2, so in this problem there is a network structure which can be solved by ANP methodology.

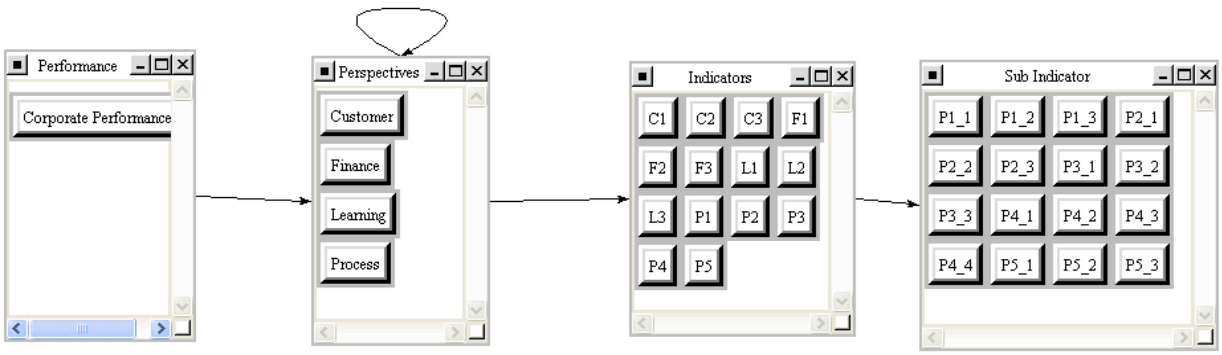

Figure 2. Relations on the structure

After building the structure, weights are calculated within the clusters. We used Super Decisions Software to calculate them. At the first step of weight calculations, perspectives are weighted by experts as shown in Table 1.

Table 1. Weights of the perspectives

Perspectives	**Weights**
Customer	0,20781
Finance	0,29338
Learning	0,18885
Process	0,30996

Indicators and sub-indicators are weighted by experts respectively, and normalized points belong the clusters are given in Table 2 and 3.

Table 2. Weights of the indicators

Indicators	**Weights**
F1: Productivity	0,617506
F2: ROI	0,085641
F3: Cost Reduction Rate	0,296854
C1: Market Share	0,636964
C2: Customer Complaint (Daily)	0,258287
C3: Customer Satisfaction	0,104749
P1: Flexibility	0,222506
P2: Availability	0,126818
P3: Delivery	0,650677
P4: Speed	0,095044
P5: Quality	0,116025
L1: Labor Training	0,142874
L2: Time Spent On Cont. Improvements (Weekly Per Person)	0,196187
L3: Investment Rate on Improvements	0,44987

Table 3. Weights of the sub-indicators

Sub-indicators	Weights
P1_1: % Of Multi Purpose Equipment	0,650642
P1_2: Lot Size	0,222491
P1_3:Vendor Lead Time	0,126867
P2_1: % Of Machine Up Time Rate	0,333333
P2_2: Usage Of Formalized Preventive Maintenance	0,333333
P2_3: Ratio Of Maintenance Cost Repair	0,333333
P3_1: % Of On-Time Delivery	0,600028
P3_2: % Of Delivery Damage Complaints	0,199986
P3_3: Delivery Speed	0,199986
P4_1: Set-Up Time	0,382761
P4_2: Manufacturing Lead Time	0,086349
P4_3: Cycle Time	0,099042
P4_4: Waiting Time	0,431848
P5_1: First Pass Yield	0,199996
P5_2: Assembly Line Defects Per 100 Units	0,199996
P5_3: Defects Rate	0,600009

The weights of the indicators are applied to a manufacturing firm's data for two periods. Points for the periods are obtained with normalization of the values on the columns Period I and Period II on Table 4.

Table 4. Calculations

	Weights	Mea. Unit	Min Value	Max Value	Period I	Period I Point	Period II	Period II Point
FINANCE								
F1: Productivity	0,132367509	%	0%	100%	45%	45,00	60,00%	60,00
F2: ROI	0,053674566	%	0%	30%	20%	66,67	20,00%	66,67
F3: Cost reduction rate	0,021767925	%	0%	10%	3,00%	30,00	3,50%	35,00
CUSTOMER								
C1: Market share	0,181163828	%	10%	30%	20%	50,00	22,00%	60,00
C2: Customer complaint (daily)	0,025125278	unit	10	0	3	70,00	2	80,00
C3: Customer satisfaction	0,087090894	%	0%	100%	75%	75,00	80,00%	80,00
PROCESS								
P1: Flexibility								
P1_1: % of multipurpose equipment	0,011678467	%	0%	70%	35%	50,00	45,00%	64,29
P1_2: Lot size	0,003993526	unit	75	25	50	50,00	45	60,00
P1_3:Vendor lead time	0,002277159	day	10	3	5	71,43	5	71,43
P2: Availability								
P2_1: % of machine up time rate	0,007303765	%	0%	100%	90%	90,00	93,00%	93,00
P2_2: Usage of formalized preventive maintenance	0,007303765	%	0%	100%	75%	75,00	80,00%	80,00

Table 4. Calculations (Cont.)

	Weights	Mea. Unit	Min Value	Max Value	Period I	Period I Point	Period II	Period II Point
P2_3: Ratio of maintenance cost repair	0,007303765	%	0%	100%	65%	65,00	70,00%	70,00
P3: Delivery								
P3_1: % of on-time delivery	0,016189761	%	0%	100%	85%	85,00	90,00%	90,00
P3_2: % of delivery damage complaints	0,005395957	%	100%	0%	20%	80,00	15,00%	85,00
P3_3: Delivery speed	0,005395957	day	10	40	30	66,67	27	56,67
P4: Speed								
P4_1: Set-up time	0,014181287	hour	16	3	6	76,92	5	84,62
P4_2: Manufacturing lead time	0,003199241	hour	72	56	70	12,50	65	43,75
P4_3: Cycle time	0,003669495	hour	7	2,5	5	44,44	3	88,89
P4_4: Waiting time	0,015999982	hour	5	0	4	20,00	3,5	30,00
P5: Quality								
P5_1: First pass yield	0,016991197	%	0%	100%	80%	80,00	85,00%	85,00
P5_2: Assembly line defects per 100 units	0,016991197	Unit	40	0	18	55,00	14	65,00
P5_3: Defects rate	0,050975479	%	0%	2%	0,03	150,00	0,03	150,00
LEARNING and GROWTH								
L1: Labor training	0,068967807	hour	0	40	30	76,13	31	76,50
L2: Time spent on cont. improvements (weekly per person)	0,039308431	hour	2	6	4	50,00	4	37,50
L3: Investment rate on improvements	0,201683762	%	0%	15%	5,00%	33,33	7,00%	46,67

Finally, in Table 5 the improvements occurred among periods are calculated.

Table 5. Overall calculations

		Period I Points	Period II Points	Improvement
FINANCE		49,02497501	59,10318232	10,07820731
CUSTOMER		59,13415332	67,64988558	8,515732265
PROCESS		86,56466505	92,61554153	6,050876477
	P1: Flexibility	52,71858375	64,23837576	11,51979201
	P2: Availability	76,66666667	81	4,333333333
	P3: Delivery	80,33365999	82,33386999	2,000209996
	P4: Speed	43,56131819	57,92438241	14,36306423
	P5: Quality	117,0007336	120,0006669	2,999933313
LEARNING and GROWTH		44,96834409	52,1422516	7,173907512

Overall Points		57,82278289	65,78181307	

The results show that significant improvements occurred in each perspective. Finance has the greatest improvement point where process has the least one. Company can decide the strategies among these improvement points easily.

5. Conclusion

Performance measurement systems have become more important with the globalization and increased competition. Institutions want to measure the improvements of their systems to easily take actions on the problematic departments or features immediately.

In this study we determined performance criteria and sub-criteria of a manufacturing firm. We used analytical hierarchy process to measure performance on a manufacturing firm's data and calculate the improvements occurred among two periods consecutively. In this method not only overall improvement points but also improvement points of criteria are obtained. With this functionality decision makers can find the root problems of their system.

As a further research, the performance criteria can be extended and this method can be applied to different sectors.

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