

A Case Study on Economic Effect of KPI for TPM Performance Measurement

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사례를 통한 TPM 성과측정 KPI의 경제적 효과 산출 방법

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Abstract TPM(Total Productive Maintenance) is a methodology to improve corporations' productivity and has been employed widely. At the initial stage of the TPM, we need to set basic plans and goals of the TPM. Also, quantization of performance is required through the TPM activity measurement indices to achieve the plans and the goals. We analyzed measurement factors of TPM activity by observation of previous researches and suggest a measure methodology of economic effect for the TPM performance measurement based on BSC and quantification of qualitative measurement.

요약 TPM 활동은 TPM의 기본 방침 및 목표의 설정과 이를 달성하기 위한 TPM 활동성과를 측정하는 지표를 통한 성과의 정량화 등이 필요하다. 본 연구에서는 TPM 활동의 측정 요소를 분석하고, BSC 기반의 TPM 성과 측정 방법과 정성적 성과의 정량화를 통한 지표의 경제적 효과 측정 방법을 제시하였다.

Key Words: TPM, BSC, Economic Effect, Quantization, KPI, Performance Measurement

1. Introduction

1.1 Background

In general, most of the companies have been making efforts on cost management for managing profit. Conventional companies, provider oriented manufacturing system, have been adopting the standard cost accounting to focus on several high weight items such as direct material cost and labour cost. However, for those companies with increasing size and complicate cost structure, they are seeking new types of cost management as consumer oriented manufacturing system. This reducing cost activity is

described as 'Productivity'

Recently, Many companies have been increasing investment on informatization to improve productivity [2][13]. However, due to failure of management in investment cost and maintaining cost, numerous failing cases have been reported. [11]. Therefore, research on improving efficiency of equipment in process control has been taking place steadily such as TPM(Total Productive Maintenance). Consequently, discussion of performance measurement and economic value, which is applicable to KPI, after a whole process of TPM has drawn attention.

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1.2 Purpose of study

TPM consists of 5 base principles(5S) : 'Systemizing and Standardization', 'Sorting', 'Sweeping', 'Sanitizing' and 'Self Discipline' and 8 pillars of activities : 'Autonomous Maintenance', 'Equipment and Process Improvement', 'Planned Maintenance', 'Early Management of New Equipment', 'Process Quality Management', 'Administrative and Support Departments', 'Education and Training' and 'Safety and Environmental Management' but it is very difficult to measure the performance. Moreover, several researchers had suggested evaluation tables for the performance measurement, though few methodologies exist to evaluate economic value of TPM[15].

After all, quantization of performance is required through the TPM activity measurement indices to achieve the plans and the goals.

In this study, we analyzed measurement factors of TPM activity through previous researches and suggest a measure methodology of economic effect by TPM performance measurement based on BSC and quantification of qualitative measurement.

2. Theoretical study

2.1 Goals of TPM activity

TPM(Total Productive Maintenance) has been continuously developed as a methodology of improving productivity since its introduction from Japan[6]. The ultimate goal of TPM is to increase benefit. The TPM activities such as zero breakdowns, zero disasters and zero defects during the whole facilities life cycle are able to minimize inventory costs. These systematic executions of maintenance should be done by all employees through small group activities.

2.2 Measure factors of TPM activities

In the previous studies, many researchers stated that quantitative performance measurement is more important than qualitative performance measurement to contribute TPM effect on business management directly[3]. However, we should not underestimate the results of qualitative performance measurement. The Quantitative indices consist of value-added productivity, fault of

equipment frequency, total equipment efficiency, manufacturing defective rate, customer's complain, suspension rate, cost reduction, decreasing inventory, disaster frequency and suggestion frequency while the qualitative indices consist of more diverse factors such as mutual trust between management and labor, culture of the organization, confidence and maintenance ability to Equipment, whole employee's perception of renovation and cost, diffusion of self enrichment movement, efficient and safe operation, clearness of Equipment operation, clean process line, clear line between individual tasks and cooperation between divisions[14].

2.3 Theories about performance measurement

For organization performance measurement, the balance scorecard(BSC) framework has been widely used since Kaplan and Norton suggested its basic concept[9]. They have suggested four standpoints to develop metrics, collect data and analyze it relative to each of these perspectives The four perspectives are learning and growth perspective, operation process perspective, customer Perspective and financial perspective. Based on BSC, we are also able to draw Key Performance Indicators(KPI) for each of the perspectives. K. L. Sedatole found that non-financial measured values including customer satisfaction and product quality are leading indicators of finance performance[5]. While R. S. Kaplan and A. A. Atkinson insist that the performance measurement is a proper method to motivate employees and improve performances and efficiency of the organizations[9].

2.4 BSC Perspective for TPM

C. Parker(2000)[1] suggested systematic methodology for performance measurement in order to generate liable results. R. L. Lynch, K. F. Cross[7] emphasize the importance of effectiveness to outside and efficiency to inside of a cooperation for the performance measurement and assertion of a reasonable measurement can be accomplished with that point.

For applying BSC to performance of TPM, Manager perspective, customer perspective, performance perspective and activity perspective were selected and each perspective's success factors and measure indices are classified as follow table[14].

[Table 1] BSC perspective and KPI for TPM

Perspective	Success factor	Key Performance Index (KPI)
Managerial view	profitability	Ordinary Income, Performance pay, Staff efficiency
	Determinacy	The Sales
Customer satisfaction	Quality	Incongruent, Claim frequency
	Time	Time for delivery rate, Lead time.
Performance	Manufacture	Total Equipment efficiency, Productivity, MTBF, Factory disaster frequency, COD(Chemical Oxygen Demand)
	Maintenance	Equipment examination equipment, Equipment fault time, MTTR, Equipment fault frequency
Activity	Activity efficiency	Renovation frequency, Suggestion frequency, Incongruent frequency
	Skill Improvement	One Point Lesson(OPL) frequency, Training hours

2.5 The quantification Method

To quantify qualitative value, the Analytic Hierarchy Process(AHP) has been employed widely. This process, developed by T. L. Satty[12], is a decision-making method that observes the hierarchy structure of a decision hierarchy process based on pairwise comparison.

3. Success factors of TPM and KPI

3.1 Extract measure variables

According to Hee J. Cho's research(2007), around 500 indices are used for performance measurement widely[3] and Hee Y. Lee's case study(2009)[4] classified TPM measurement indices as performance perspective, activity perspective and skill improvement perspective. The elements of performance perspective are overall equipment efficiency(%), labor productivity(1000 items), MTBF(time), disaster frequency(item), equipment fault frequency(item), equipment fault time(hour), MTTR(minute). The elements of activity perspective are number of renovation(item), number of suggestion(item), number of absurdity(item). In

addition, the elements of skill improvement perspective are number of OPL(item) and training time per a person(hour).

3.2 Extract factors by BSC Standard

For this study, we surveyed TPM participants of company 'D', which is a mid-sized and has vigorous TPM activity. We conducted a survey at their work places and extracted 53 cases which have more than 90% validity among the collected data. For data analysis, we used SPSS10.1.3 and obtained cronbach α coefficient of 0.915. for the questionnaire structure.

3.3 Exploratory analysis

We removed high correlated variables through correlation analysis. Among the five variables of managerial perspective, selling price was removed because of its strong relation with ordinary income variable. Also, among the six variables of customer perspective, customer's claim variable was selectively adopted despite of its strong correlation with incongruity rate and congruity rate. Among the nine variables of operating perspective, output variable was omitted because of its strong relation with productivity, operation rate and MTTR. Dust density was deleted resulting from its strong independence as well. Among the three strong related variables, suggestion activity rate, suggestion frequency and adoption rate of suggestion in the seven variables of measurement perspective, suggestion activity rate, and suggestion frequency were deleted and education hour variable were omitted because of its strong relation with OPL frequency.

As described above, we solved the problem of multicollinearity and performed a factor analysis. After this, four factors were sampled with eigenvalue greater than 1.0.

After the factor analysis, we named and classified measure variables with BSC standard. The factors are classified as finance, operation, customer satisfaction, education and development section. Through the literature review, we found that this classification is acceptable. In addition, we linked the factors to BSC standard for the performance measurement.

[Table 2] Factor analysis result of the TPM activity's importance

Factors	Measure Variables	Composition				Commonness
		Fac.1	Fac.2	Fac.3	Fac.4	
Financial Factors	Ordinary Income(1) ^b	0.880	0.056	0.083	0.220	0.833
	Manufacturing Cost(2)	0.811	0.138	0.308	0.093	0.781
	Cost reduction (10)	0.749	0.158	0.336	0.100	0.709
	HR Efficiency (15)	0.507	0.108	0.295	0.496	0.602
Operation Process Factors	Equipment Efficiency (3)	0.069	0.816	0.314	0.145	0.790
	MTBF(8)	-0.037	0.780	0.120	0.131	0.642
	Equipment Productivity (9)	0.090	0.686	0.402	0.039	0.642
	Number of Disaster(11)	0.491	0.634	-0.073	0.234	0.702
	Disaster Ration (13)	0.455	0.631	-0.182	0.151	0.661
	MTTR(17)	0.263	0.551	0.224	0.355	0.548
Customers Satisfaction Factors	Number of Claim (4)	0.058	0.216	0.829	0.099	0.747
	Customer Satisfaction (7)	0.193	0.169	0.798	0.050	0.705
	Time delivery Ratio (14)	0.226	0.223	0.696	0.308	0.680
	Inventroy period(16)	0.276	-0.116	0.599	0.431	0.635
Training and Growth Factors	Number of renonovation (5)	0.064	0.219	0.111	0.824	0.743
	Suggestion Adoption Ration (6)	0.539	0.155	0.186	0.568	0.672
	Number of Irrationality y(12)	0.171	0.202	0.360	0.561	0.515
	Number of OPL (18)	0.510	0.275	-0.017	0.544	0.632
Eigen value		3.534	3.233	3.010	2.460	

* ^bNumber of Questionnaire

3.4 Definition of KPI

3.4.1 KPI of TPM performance measurement

Selection of KPI should be done in accordance with the organizations' goals and focused on core activities of the organizations. Also, relationship among the core success factors should be considered and every single activity should be examined. Validity of performance measurement should be proved and control possibility of performance indicators, which are distributed as top-down model should be provided.

To make the performance measurement clear by KPI

indicators, there are six items for consideration. 1) Proper number of KPI should be suggested 2) strategy and CSF should be linked 3) change and flow of past, present and future should be reflected 4) The indices should be amendable. 5) It should be able to motivate the organization. 6) It should be able to classify responsibility effectively[15].

4. Case Study

4.1 Selection KPI for company 'D'

H.Y Lee research(2009), a study focus on TPM of Equipment-dependant cooperation, applied for analyzing the first term of TPM(2001~2008) of the company 'D', which is also very equipment dependant. The analysis proved that the first term of TPM activity was the core of the management renovation. We surveyed 'D's managers about the importance of KPI and we were able to extract the KPI for the performance measurement of the 'D'.

4.1.1 KPI Analysis

As table 3, we used 18 KPI, as questionnaires about importance and data collection. We interviewed 17 managers of the 'D' from May 25th to May 31st. At the first time, we had a group interview with all the participants to explain the purpose of this survey. Also, the managers were given time to review reported problem during the last term of the TPM activity. Consequently, we had individual interview and omitted disaster frequency, man power efficiency and OPL frequency due to their relatively lower mean value and lower standard deviation(SD).

[Table 3] Result of factor importance analysis for KPI selection

No	Factors	Ma	SD	Ma rank	SD rank	Acceptance
1	Ordinary income	3.98	0.951	11	15	Acc.
2	Manufacturing cost	4.19	0.942	2	14	Acc.
3	Equipment efficiency	4.06	0.842	7	5	Acc.
4	Claim frequency	4.02	0.888	9	7	Acc.
5	Renovation Frequency	4.26	0.738	1	1	Acc.
6	Suggestion adoption rate	4.11	0.800	5	2	Acc.

7	Customer satisfaction rate	3.87	0.941	13	13	Acc.
8	MTBF	4.13	0.810	4	4	Acc.
9	Productivity	4.00	0.899	10	8	Acc.
10	Amount cost reduction	4.06	0.908	6	11	Acc.
11	Disaster frequency	3.70	0.972	18	16	Rej.
12	Number of Irrationality	4.13	0.810	3	3	Acc.
13	Disaster rate	3.91	0.925	12	12	Acc.
14	Timely delivery rate	3.81	0.878	15	6	Acc.
15	HR efficiency	3.75	0.998	17	18	Rej.
16	Inventory period	4.06	0.908	8	10	Acc.
17	MTTR	3.87	0.900	14	9	Acc.
18	OPL frequency	3.77	0.974	16	17	Rej.

*Low factors are highlighted.

Based on the above results, we selected analysis factors for the performance measurement and KPI for the company 'D'. The KPI perspectives and descriptions are shown in the below table.

[Table 4] Formulas for KPI to measure TPM performance of company'D'

Perspective	KPI	Formula
Financial view	Ordinary income	$(\text{This year ordinary income} - \text{Last year ordinary income}) / \text{Last year ordinary income} * 100$
	Manufacturing Cost rate	$(\text{This year manufacturing cost} - \text{Last year Manufacturing cost}) / \text{Last year Manufacturing cost} * 100$
	Amount of Cost Reduction	$(\text{This year manufacturing cost} - \text{Last year amount of cost reduction}) / \text{Last year amount of cost reduction} * 100$
Operation	Overall equipment efficiency	Equipment operation rate × Equipment Performacne rate × non-defective parts or products ratio
	MTBF	$(\text{Equipment uptime} - \text{Time to failure}) / \text{Number of equipment fault}$
	Equipment productivity	$(\text{This year equipment productivity} - \text{Last year equipment productivity}) / \text{This year equipment productivity} * 100$
	Disaster Frequency	$(\text{Number of this year disaster} - \text{Number of last year disaster}) / \text{Number of last year disaster} * 100$
	MTTR	Total suspended time/suspended item

Customer satisfaction	Claim Frequency	Number of Claim
	Customer Satisfaction Rate	Customers feedback (Qualitative measure)
	Timely delivery rate	Delayed delivery dates
	Inventory period	Inventory period after production
Learning and Growth	Renovation Frequency	$(\text{Number of this year renovation} - \text{Number of this year renovation}) / \text{Number of this year renovation} * 100$
	Suggestion Adoption rate	Number of Yearly Adoption / Number of Whole period Adoption * 100
	Irrationality Frequency	Number of Yearly Irrationality / Number of Whole Irrationality * 100

4.2 Performance decision by economic value analysis

Ordinary income and reduction cost are economic variables and the rest of the variables are quantitative or qualitative variables among the above 15 measurement variables.

We used AHP method to draw weight of KPI by the perspectives. Two responses, with higher consistency rate than 1.0, among the 12 respondents were deleted. With the 10 responses, we drew weight of the variables first as shown in the table 5. Also, we selected 5 respondents who have longest work experience to decide the weight of KPI again. All the Consistency rates of the selected weights are less than 0.1.

[Table 5] The Weight of the KPI by perspectives

Perspective	Weight (%)	KPI	Weight (%)	Total weight (%)
Financial view	25.8	Ordinary income	0.58	14.9
		manufacturing cost rate	0.12	3.2
		Amount cost reduction	0.30	7.7
Operation Process	43.5	Equipment efficiency	0.10	4.5
		MTBF	0.26	11.3
		Equipment productivity	0.34	14.6
		Disaster Frequency	0.12	5.0
		MTTR	0.19	8.0

Customer satisfaction	19.9	Number of Claim	0.24	4.7
		Customer satisfaction	0.42	8.3
		Timely delivery rate	0.24	4.9
		Inventory period	0.10	2.0
Learning and Growth	10.8	Number of renovation	0.35	3.8
		Suggestion adoption rate	0.36	3.9
		Number of irrationality	0.29	3.1

To measure economic value of performance measurement factors, we calculated all the contribution degree of variables through the conducted interview with the 12 respondents. The results are shown in the table 6 which were rounded up.

[Table 6] Contribution weight of measure variables

no	Financial view			Operation process				Customer satisfaction				Learning and Growth			
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	5	4	6	5	4	8	3	3	4	4	2	2	4	4	2
2	4	3	6	5	3	7	3	3	5	5	2	2	4	3	3
3	3	3	6	4	3	7	3	3	3	5	2	2	3	4	2
4	5	4	6	5	5	7	3	3	4	5	2	2	4	4	2
5	4	4	5	4	4	6	4	2	3	4	3	1	3	3	1
6	5	4	4	6	3	5	2	3	4	5	1	3	4	4	3
7	4	2	5	4	3	6	2	2	3	4	1	1	3	3	1
8	5	3	7	5	4	6	2	2	3	4	1	1	3	3	1
9	4	1	4	5	2	5	1	1	3	5	1	3	3	4	2
10	4	3	6	5	4	7	3	3	4	4	2	2	4	4	2
11	4	3	6	4	4	7	3	3	3	5	2	2	4	4	3
12	7	3	6	4	4	6	3	3	4	5	3	2	4	4	2
Average	5	3	6	5	4	6	3	3	4	5	2	2	4	4	2

* A:Ordinary income, B:Manufacturing Cost rate , C::Amount of Cost Reduction, D:Overall equipment efficiency, E::MTBF, F:Equipment productivity, G: Disaster Frequency, H: MTTR, I: Number of Claim, J: Customer satisfaction, K: Timely delivery rate, L: Inventory period, M: Number of renovation, N: Suggestion adoption rate, O: Number of irrationality

Then, we estimated economic value by comparing analysis of quantification ratio based on contribution and weight of analyzed qualitative and qualitative effect.

However, ordinary income is the only economic factor. Consequently, we recalculated the weight including the ordinary income factor to find out the economic value by each perspective.

Finally, table 7 shows expectation of economic effect based on the four perspectives.

[Table 7] Economic effect of financial perspective

Classification	Weight of index (a)	Contribution (b)	(a)*(b)	Quantization of Qualitative variables	
				Quantitative rate	economic value(Mill on Won)
Economic Index	Ordinary income (62.0%)	5	3.10	1.00	1,200
Quantitative Index	Manufacturing Cost (15.6%)	3	0.47	0.15	181
Quantitative index	Amount of cost reduction (22.4%)	6	1.35	0.43	521
Total					1,902

[Table 8] Economic effect of operation process perspective

Classification	Weight of index (a)	Contribution (b)	(a)*(b)	Quantization of Qualitative variables	
				Quantitative rate	economic value(Mil lon Won)
Economic Index	Ordinary income (28.7%)	5	1.44	1.00	1,200
Quantitative Index	Overall equipment efficiency(5.4%)	5	0.27	0.19	225
Quantitative Index	MTBF (18.4%)	4	0.73	0.51	614
Quantitative Index	Equipment productivity (32.4%)	6	1.94	1.35	1,625
Quantitative Index	Disaster Frequency (6.4%)	3	0.19	0.13	160
Quantitative Index	MTTR (8.8%)	3	0.26	0.18	220
Total					4,044

[Table 9] Economic effect of customer satisfaction perspective

Classification	Weight of index (a)	Contribution (b)	(a)*(b)	Quantization of Qualitative variables	
				Quantization rate	Economic value (Million Won)
Economic Index	Ordinary income (31.4%)	5	1.57	1.00	1,200
Quantitative Index	Number of Claim (11.7%)	4	0.47	0.30	358
Qualitative Index	Customer satisfaction (23.6%)	5	1.18	0.75	902
Quantitative Index	Timely delivery rate (17.5%)	2	0.35	0.22	267
Quantitative Index	Inventory period (15.8%)	2	0.32	0.20	242
Total					2,699

[Table 10] Economic effect of learning and growth perspective

Classification	Weight of index (a)	Contribution (b)	(a)*(b)	Quantization of Qualitative variables	
				Quantitative rate	economic value (Million Won)
Economic Index	Ordinary income (66.9%)	5	3.35	1.00	1,200
Quantitative Index	Number of renovation (13.9%)	4	0.56	0.17	1.99
Quantitative Index	Suggestion adoption rate (9.8%)	4	0.39	0.12	1.41
Quantitative Index	Number of irrationality (9.4%)	2	0.19	0.06	0.67
Total					1,607

5. Conclusion

In conclusion, we extracted 15 KPI from performance perspective and activity perspective for the TPM performance measurement of the company 'D'.

The 15 selected factors were divided into 4 perspectives according to the result of factor analysis for the BSC based activity performance measurement. We also used pair comparison analysis of AHP to calculate relative weight of each perspectives and the KPI of each standpoints and then measured economic value of each KPI based on the weights.

When corporations apply the study's methodology, selection of their own measure variables should be considered first to reflect its characteristics. We also suggest to refer to the indicated KPI selection used in this study. Overall, the corporation should be aware of the importance of performance measurement through conversion of qualitative value into economic value.

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