The Effect and Influencing Mechanism of TPM Factors to Performance*

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Abstract

This study tries to analyze how TPM works in domestic manufacturing industry by estimating two-stage model. First stage tests the effects of five TPM-factor variables (TFV : (1) Small group activity & Autonomous maintenance, (2) Education & Training, (3) Planned maintenance, (4) improving effectiveness of each piece of facility (5) Safety & Environment) to two TPM-performance variables. Second stage tests how two TPVs affect the industry's productivity level. By combining these two stages, this study uses a model to explain how TPM, represented by TFVs, works to improve productivity via TPVs. Multivariate and univariate regression and correlation analyses were performed.

It is shown that five TFVs works in two different ways to improve the industry's productivity level.

In the second stage, overall equipment effectiveness has relatively more significant effects to the productivity level.

1. Introduction

Plant management has been the pivot of every manufacturer's effort to achieve competitive edges in today's markets. Manufactures already have achieved the manufacturing-line automation and now are trying to apply a management-integrated automation system so calied CIM(Computer Integrated Manufacturing) to optimize the efficiency of management. This rapid development in automation inevitably requires a newly developed maintenance system for its maximum performance. After all, improving productivity and quality is a question of plant management because equipment is an essential part of production process.

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TPM(Total Productive Maintenance) is known as one of new administration techniques that satisfy this need. TPM was introduced to Korea in late '80s, and has been adopted by the manufacturing industry very successfully. However, not many studies have been done to verify TPM's success in Korea and to enhance its ability to improve company's performance.

This study tries to analyze how TPM works by estimating a two-stage analysis model. This TPM analysis model enables us to reveal the process that how TPM factors affect productivity and to estimate the magnitude of the effects. Following three tasks are performed in this study.

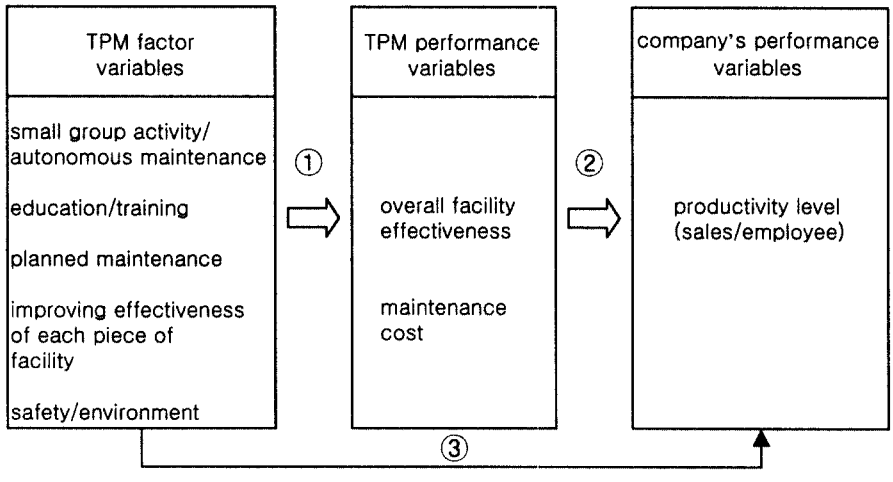
First, to confirm positive effect of TPM, the difference in productivity levels between TPM companies and non-TPM companies is analyzed.

Second, a two-stage analysis model which suggested in this study is tested for TPM companies. For this test, 5 TPM factor variables are selected and then tested whether they improve productivity levels directly or indirectly.

Third, by estimating the magnitude of each TPM factor's influences on TPM performance variables, this study compares contributions of each TPM factor.

2. Model

Two-stage TPM analysis model suggested in this study actually contains three stages[Figure 1]. The first stage ① represents the effect of TPM factor variables on TPM performance variables and the second stage ② represents how TPM performance variables influence productivity. Stage ③ also represents the direct performance of TPM. In order to



<Figure 1> TPM activity analysis model

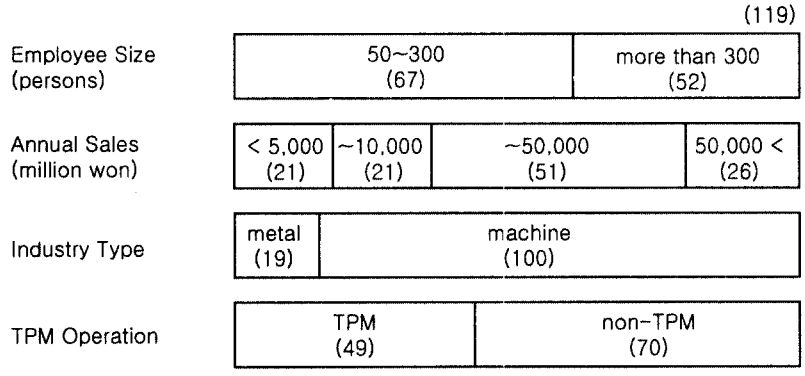
<Table 1> Contents of five TPM factor variables

TPM Factor Variables	Contents
(1) small group activity/autonomous maintenance	① Level of TPM operation via small group activity ② Condition of facility and environment of plant ③ Level of autonomous maintenance activity of employees ④ Level of average maintenance skill of employees
(2) education/training	① Hours of overall TPM education on entire employees ② Hours of professional maintenance education on maintenance staffs ③ Hours of basic maintenance education on production line employees
(3) planned maintenance	① Operation level of regular inspection on facility ② Utilization level of records on maintenance ③ Operation level of MP design and initial management of facility
(4) improving effectiveness of each piece of facility	① Utilization level of equipment improving skill
(5) safety/environment	① Frequency of safety accident ② Level of environmental management

test, if TPM factors affect to TPM performance variables directly, stage ③ is included.

TPM factor improve company's performance through improving TPM performance as an intermediate stage or not.

In real world, TPM is operated mostly by several departments and the performance of these departments are the keys to improve TPM performance. In this study, these several TPM departments are classified into five TPM factor variables ; (1) small group activity/autonomous maintenance, (2) education/training, (3) planned maintenance, (4) improving effectiveness of each piece of facility, (5) safety/environment. These five factors are made from five essential TPM activities recommended by JIPE(Japanese Institute of Plant Engineering), by combining initial management of facility and planned maintenance and adding safety/environment activity, which is operated in most companies in the industries. Survey questionnaires for each TPM factor variable are summarized in Table 1.



<Figure 2> Characteristics of the data set

Values of TPM factor variables are computed by normalizing answers of queationnaires consisting each activity and then by adding these values with equal weight. The validity test, whether questionnaires of each activity are suitable to measure each activity, is performed through correlation analysis and it is proved that most of the questionnaires have validity.

For TPM performance variables, overall facility effectiveness and maintenance cost are used. These variables, indexes related to facility, are selected because facility is the main subject of TPM. Sales per employee, a good measure of a company's productivity level, is selected as a variable that represents company's performance in this study.

3. Empirical Analysis

3.1 Sample characteristics

This study uses survey questionnaires from two domestic manufacturing industries. Questionnaires were distributed to machine and metal companies located in Chang-Won industrial complex and were made out in June '93 as the basic period. Among returned questionnaire answers, 119 were valid and are used as the data set of this study. Characteristics of the data set are summarized in Figure 2.

3.2 The effect of TPM

TPM effect can be analyzed by testing the differences of productivity levels between TPM companies and non-TPM companies. First, F-test on both groups is performed to test if the dispersion of two groups are same. P-value is estimated very significantly as 0.0005, so the dispersions of both groups are analyzed to be different.

Next, one-tail t-test is performed to test

<Table 2> Distribution characteristics of productivity level

	Mean	Variance	Observations
TPM	138.93	8592.67	49
non-TPM	82.62	3633.17	70
F-test	2.3651 (p-value = 0.0005)		
t-test	3.7351 (p-value = 0.0002)		

if TPM companies achieve higher productivity level than non-TPM companies. Because of the different dispersion between two groups according to previous result of F-test, hetero-scedasticity-consistent t-test is performed. Again, test statistics is estimated as very significant with p-value 0.0002. Thus, the basic assumption of this study, operating TPM improves productivity, can be supported strongly.

3.3 Relationships among TPM factors, TPM performances, and productivity level

3.3.1. Stage ① and ③ : The relationships between TPM factors and TPM performances, and between TPM factors and productivity

A good starting point to test the TPM analysis model is to see if TPM factor variables affect productivity through improving TPM performance variables as an intermediate stage (stage ①), not by stage ③, improving productivity directly. This can be analyzed if the correlation between TPM factors and TPM performances is stronger than the correlation between TPM factors and productivity. Results of correlation analyses are summarized in Table 3.

First, correlations between small group activity/autonomous maintenance (TPM act .(1)) and TPM performance variables are 0.566 and 0.600. It's stronger than the correlation between small group activity/ autonomous maintenance and productivity level (0.465). Also correlations between safety/environment (TPM act.(5)) and TPM performance variables are stronger than the correlation between safety/ environment and productivity more through improvements of TPM performances.

Second, the correlation between education/training and productivity level (0.198), is higher than the correlation between education/training and maintenance cost, but is relatively lower than the correlation between education/training (TPM act.(2)) and overall equipment effectiveness (0.372).

It shows that the effect of education/ training is not to reduce maintenance cost,

<Table 3> Correlations between TPM factors and TPM performances, and between TPM factors and productivity (pearson correlation coefficient) ( ) : p-value

	TPM act. (1)	TPM act. (2)	TPM act. (3)	TPM act. (4)	TPM act. (5)
overall effectiveness	0.566 (0.000)	0.372 (0.009)	0.441 (0.002)	0.421 (0.003)	0.493 (0.000)
maintenance cost	0.600 (0.000)	0.147 (0.313)	0.660 (0.000)	0.430 (0.000)	0.516 (0.000)
productivity level	0.465 (0.001)	0.198 (0.173)	0.576 (0.000)	0.507 (0.000)	0.163 (0.264)

TPM act.(1) : small group activity / autonomous maintenance
TPM act.(2) : education / training
TPM act.(3) : planned maintenance
TPM act.(4) : improving effectiveness of each piece of facility
TPM act.(5) : safety / environment

but to improve overall facility effectiveness. After all, this activity is poorly related to productivity level.

On the contrary, planned maintenance (TPM act.(3)) has a weaker correlation with the improvement of overall facility effectiveness than with the reduction of maintenance cost. However, planned maintenance has almost even correlations with both TPM performances and with productivity.

Improving effectiveness of each piece of facility (TPM act.(4)) has a stronger correlation with productivity than with both TPM performances. So, it can be predicted that this activity may affect also to other performance variables not selected in this study.

3.3.2 The correlation between TPM performance and productivity

Stage ② of the TPM analysis model can be analyzed by the correlation analysis between TPM performances and productivity. The improvement of overall equipment effectiveness significantly affect to improve productivity but the reduction of maintenance cost has smaller magnitude of significance in affecting productivity. The result is presented in Table 4.

3.4 Effect of TPM factors on performances

In this section, directions and magnitudes of five TPM factor variables on performance variables are estimated. First, joint effect of five TPM factors on performance variables is estimated by

<Table 4> Correlations between TPM performance and Productivity
(Pearson correlation coefficient) ( ) : p-value

	overall equipment effectiveness	maintenance cost
Company's Performance (sales per employee)	0.467 (0.001)	0.189 (0.193)

STEPWISE multiple regression analysis. Because of possible multicollinearity problems among TPM factors, univariate regression analyses are also performed to analyze separate effects of TPM factor variables on performance variables.

3.4.1 Joint effect of TPM factors on performances

Joint effect shows relative attributes of five TPM factors in affecting performance variables. Linear least square estimation is performed to estimate following equations.

$Y_j = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5$
where X_i : TPM factor variables ($1 \leq i \leq 5$)
Y_j : TPM performance variables
(j = 1 : Improving overall facility effectiveness
j = 2 : Reducing maintenance cost)

By the result of STEPWISE (rejection rate = 0.15) analysis, independent variables X2, X3, X4 in Y1 equation and X4 in Y2 equation are estimated insignificant and are excluded. Followings are the final equations. Values in parentheses are p-values.

$Y_1 = 69.819 + 0.442\ X_1 + 0.251\ X_5$
(0.000) (0.002) (0.104)
R-squre =
0.365, F-statistic = 13.238 (p=0.000)

$Y_2 =$
$103.683 + 0.604\ X_1 - 0.387\ X_2 + 0.491\ X_3 + 0.352\ X_5$
(0.000) (0.025) (0.010) (0.027) (0.039)
R-squre =
0.542, F-statistic = 13.018 (p=0.000)

In the first equation, Small group activity/autonomous maintenance and safety/environment are estimated as two significant factors for improving overall facility effectiveness of each piece of facility(TPM act. (4)) was found insignificant. Note that Small group activity/autonomous maintenance affect strongly to both TPM performances but education/training has negative effect on reducing maintenance codt. This can be explained by the fact that eduction/training is poorly related to TPM performances.

3.4.2 Seperate effects of TPM factors on performances

Multicollinearity might be another problem in regression analysis besides heteroscedasticity. As a result of high

correlations among TPM factor varialbes, there's a high possibility of multicollinearity among independent variables. Considering this, it can be more meaningful to estimate separate effects using univariate regression. Following equations were estimated.

$Y_j = \alpha + \beta X_i$

where X_i : TPM factor variables
$(1 \leq i \leq 5)$
Y_j : erformance variables
(j = 1 : Improving overall facility effectiveness
j = 2 : Reducing maintenance cost)

Similar to the result of multiple regression, Small group activity/autonomous maintenance is estimated to have the strongest effect on overall facility effectiveness. Safety/environment comes second. Note that education/training, planned maintenance, and improving effectiveness of each piece of facility, the three TPM factors that are found insignificant in multiple regression, are estimated to have significant influence, but the magnitude of the effects are small(0.306, 0.363, and 0.242, respectively).

On reducing maintenance cost, small group activity/autonomous maintenance, planned maintenance, and safety/

<Table 5> Seperate effects of TPM factors on performance variables

( ) : p-value

	overall t effectiveness			maintenance cost		
	α	β	R-squre	α	β	R-squre
TPM act. (1)	64.703 (0.000)	0.593 (0.000)	0.320	82.157 (0.000)	0.993 (0.000)	0.360
TPM act. (2)	52.337 (0.000)	0.306 (0.006)	0.138	53.630 (0.000)	0.191 (0.308)	0.022
TPM act. (3)	66.850 (0.000)	0.363 (0.001)	0.194	100.91 (0.000)	0.859 (0.000)	0.436
TPM act. (4)	57.254 (0.000)	0.242 (0.001)	0.177	68.917 (0.000)	0.391 (0.001)	0.18
TPM act. (5)	64.335 (0.000)	0.480 (0.000)	0.243	81.143 (0.000)	0.795 (0.000)	0.266

TPM act.(1) : small group activity / autonomous maintenance
TPM act.(2) : education / training
TPM act.(3) : planned maintenance
TPM act.(4) : improving effectiveness of each piece of facility
TPM act.(5) : safety / environment

environment factors are again estimated with very significant statistics. Education/ training is estimate to have very weak influence. Results of univariate regressions are summarized in Table 5.

4. Summary and Conclusions

This study analyzes the effects and the mechanism of how TPM factors affect to improve a company's productivity by analyzing a two-stage TPM analysis model. Major findings of this study are as follows:

First, by comparing productivity levels of TPM companies' with those of non-TPM companies, we found that there exists a significant positive effect of TPM. This finding justifies our basic assumption.

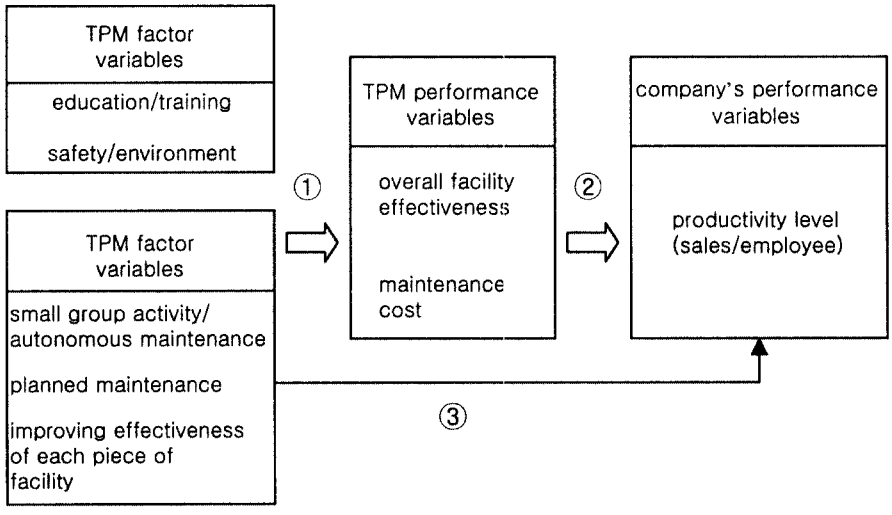
Test of our TPM analysis model shows that five TPM factors affect to improve productivity through two different ways according to each activity's characteristics. Three TPM factors including small group activity/autonomous maintenance, planned maintenance, and improving effectiveness of each piece of equipment affect to improve productivity directly as well as through improving performance variables. In other words, those three factors follow stage ①-② and also follow stage ③. All those three factors involve direct handling of facility, so they can bring immediate effects on performances and also spread their effects to our performance variables.

On the other hand, education/training and safety/environment can be characterized as overall support and backing factors of TPM operation. They are found to affect to improve productivity only through improving overall facility effectiveness as an intermediate stage. These two factors follow only stage ①-② in TPM model.

Small group activity/autonomous maintenance has the strongest effects on both improving overall facility effectiveness and reducing maintenance cost. Education/ training has very weak effects on both TPM performances. This factor is even found to have negative effect on reducing maintenance cost in multiple regression analysis. This also can be explained by the fact that education/training is an ovelall support and backing factor of TPM operation.

On the basis of above findings, we suggest a revised TPM analysis model, illustrated in Figure 3.

Findings of this study could give TPM companies useful information of how they administrate TPM factors to improve TPM performances and productivity level. If a company set a goal to achieve a short-term improvement in productivity, it is suggested to concentrate more in small group activity/autonomous maintenance. However, if the purpose is to achieve improvements on long-term productivity level, education/training and safety/



<Figure 4> Revised TPM analysis model

environment also should be emphasized, since they are the two important overall support and feedback factors of TPM operation.

References

[1] Nakajima, Seiichi(1988), Introduction to TPM, Productivity Press.

[2] Nakajima, Seiichi(1989), TPM development program, Productivity Press.

[3] Rhyne, David M.(1990), Total Plant Performance Advantage through Total Productivity Maintenance, 33rd Int'l Conference Proceedings, American Production and Inventory Control Society, pp. 683-686.

[4] Rhyne, David M.(1991), Total Productive Maintenance - An Integrated Solution to Plant Availability and Maintenance Effectiveness. 34th Int'l Conference Proceedings, American Production and Inventory Control Sociaty, pp. 463-465.

[5] Tajiri, Masaji and Fumio Gotoh(1992), TPM Implementation: A Japanese Approach. New York: McGraw-Hill Inc.

[6] The Korean Industrial Standards Association(1992), TPM for field leaders. Seoul : KISA

[7] The Korean Traders Association(1992), Applications of PM Analysis for TPM. Seoul : KTA

[8] Yun, Duk Kyun(1989), Korean style TPM system. Seoul : Bup-Kyung Press.