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Publication Details

Maletic, D., Maletic, M. & Gomiscek, B. 2013, 'The role of quality management activities in achieving high performance of maintenance processes', *International Journal of Strategic Engineering Asset Management*, vol. 1, no. 3, pp. 253-264.

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The role of quality management activities in achieving high performance of maintenance processes

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Abstract: In today's highly competitive environment maintenance, quality, and productivity are essentially related components and very important operational issues for a modern, successful, economic, and profitable production system. The focal point in this paper emerges from the lack of understanding how various quality management approaches and practices can contribute to the overall maintenance performance. The aim of this study is therefore, to define the impact of quality management practices on maintenance performance. The questionnaire survey was carried out among Slovenian organizations in order to address the research problem. Several statistical analysis methods including correlation analysis as well as regression analysis are utilized to accomplish the objective of this study. Results of the study indicate that quality management practices incorporated into maintenance processes have positive impact on maintenance performance. We conclude that these results can benefit ~~contribute~~ to organizations seeking for an approach how to improve maintenance performance. This study also contributes to the literature by providing an insight into deployment of quality management practices into maintenance processes.

Keywords: quality management, maintenance processes, maintenance performance

1 Introduction

Many companies are working today in a changing world with competitors all over the globe. To survive and prosper on the market it is essential that they are continuously and cost-effectively improving their operation (Ingwald, 2009).

Much has been written about the relationship between quality management and performance. For example, Sila (2007) found a positive relationship among Total Quality Management (TQM) and business performance measures. Presented results showed that TQM had a significant direct effect on all measures except financial and market results. Other studies (Prajogo and Brown, 2004; Demirbag et al., 2006; Fotopoulos and Psomas, 2010) have also linked quality management practices with performance. Moreover, Zu (2009) investigated relationships between quality management practices and quality performance. Author found that core quality management practices directly leads to improved quality performance. Apart from the relationship between quality management and performance outlined above, several authors have investigated link between maintenance and performance. For instance, Swanson (2001) found a strong positive relationship between proactive and aggressive maintenance strategies and maintenance performance. Cua et al. (2001) presented an empirical study of three manufacturing programs (TQM, Just-in-Time (JIT) and Total Productive Maintenance (TPM)) and their impact on manufacturing performance. The findings from these empirical analyses demonstrated the importance of implementing the practices and techniques belonging to all three programs towards achieving high manufacturing performance.

In the light of the above mentioned, it is also important to outline the intersection between quality management and maintenance, to provide a better understanding of purpose of this paper. Few studies have focused on addressing this issue. For example, Duffuaa and Ben-Daya (1995) presented quality tools and their applications in different maintenance activities in order to improve maintenance quality. Al-Najjar (1996) presented a concept Total Quality Maintenance (TQMain), which enables the user to continuously maintain and improve the technical and economical effectiveness of manufacturing process elements. Furthermore, Vassilakis and Besseris (2009) presented an application of TQM tools into the environment of a maintenance department. Further to this, linking quality management with maintenance performance leads to several other studies. For instance, Ben-Daya and Duffuaa (1995) highlighted and proposed conceptual approaches for linking and modelling the relationship between maintenance and quality. Alsyouf (2007) proposed a conceptual model that tried to link maintenance, productivity and profitability. Author showed how an effective maintenance policy could influence productivity and profitability of a manufacturing process through its direct impact on quality, efficiency and effectiveness of operations. Further, Maletič et al. (2009) presented a conceptual approach for continuous improvement in the field of maintenance, based on the PDCA cycle. In a recent study, Khan and Darrab (2010) presented analytical relation between maintenance, quality

and productivity. They found a positive relation between maintenance and productivity. However, the relation between quality hours and productivity presented in the mentioned research was found to be negative.

Despite several studies on quality and maintenance, there is still a lack of clarity on how quality management practices can affect maintenance performance. Thus, the basic idea behind this paper is that quality management practices are very important when trying to achieve higher maintenance performance. Therefore, the purpose of this paper is to examine the impact of various quality management approaches and specific practices on maintenance performance.

2 Quality management practices

Quality management practices have been documented extensively in measurement studies that have developed and validated instruments capable of measuring the practices and the studies that have investigated the impacts of quality management practices on performance (e.g. Kaynak, 2003).

Based on extensive literature review Lakhali et al. (2006) classified quality management practices in ten distinct generic practices: top management commitment and support, organization for quality, employee training, employee participation, supplier quality management, customer focus, continuous support, improvement of quality system, information and analysis, and statistical quality techniques use.

After selecting ten generic practices, authors (Lakhali et al., 2006) grouped them into three main categories:

1. Management practice: issued from the top management;
2. Infrastructure practices: intended to support core practices and
3. Core practices: based on tools and techniques specifically related to quality.

Moreover, the quality management literature concurs that quality management practices are developed around two dimensions: core and infrastructure quality management practices. The core quality management practices entail the use of scientific methods and statistical tools and the infrastructure quality management practices create a learning and cooperative environment for quality management implementation (Zu, 2009).

3 Maintenance performance measurement

Performance measurement is a fundamental principle of management. Like other manufacturing functions, performance measurement is important in managing the maintenance function (Muchiri et al., 2011). As noted by Galar et al. (2011), organizations that use maintenance indicators in exchange achieve benefits which include: increased life and availability of equipment, improved product quality, reduced costs of breakdowns and spare parts inventory, and therefore reduction of overall maintenance cost. In addition, performance measures provide an important link between the

strategies and management action and thus support implementation and execution of improvement initiatives (Neely et al., 2005).

Muchiri et al. (2011) stated that for each element important in the management of the maintenance function, the main challenge is to identify the performance indicators (MPIs) that will tell whether the element is managed well. Wireman (1998) defined MPIs as a set of measures used for the measurement of maintenance impact on the process performance. MPIs could, therefore, be used for financial reports, for monitoring the performance of employees, customer satisfaction, the health, safety, security and environmental (HSSE) rating, and overall equipment effectiveness (OEE), as well as many other applications (Parida et al., 2005).

4 Methodology

4.1 Sample

This study utilized a survey of a sample of Slovenian organizations, encompassing various sectors. A random sample was included in the survey on the basis of the Slovenian business register “bizi.si” and Slovenian Maintenance Society’s database. For the purpose of this study data from 53 organizations were used.

The questionnaire was responded by manufacturing, construction, transportation and other type of industry, in portion of 77.4%, 7.5%, 3.8% and 11.3%, respectively. In terms of organizational size, 26.4 % of the sample was made up of small sized organizations employing 50 employees or less, 43.4 % were medium sized organizations, employing 51 - 250 employees, 9.4 % organizations were with 251 – 500 employees and 20.8 % organizations were with more than 500 employees.

4.2 Measures

Several topics (related to quality and maintenance) were conceptualized to formulate questionnaire, each tested on five-point Likert scale (1 = “strongly disagree”, 5 = “strongly agree”). Eight quality management practices were examined in this study. These practices were derived mainly from literature focusing on TQM (e.g. Kaynak, 2003). For the purpose of capturing the aspects of maintenance performance, this study built the construct for measuring maintenance performance on the basis of several criteria, conceptualized in different studies; see for example Muchiri et al. (2011).

4.3 Research methods

4.3.1 Exploratory factor analysis

For the purpose of validating the measurement instrument we used an exploratory factor analysis. Exploratory Factor Analysis (EFA) approach is applied to uncover the underlying structure of a relatively large set of variables (Field, 2005).

4.3.2 Correlation analysis

According to the presumption of the proposed link between quality management practices and maintenance performance, the test of measuring the association of variables is Pearson correlation. A correlation is the measure of the linear relationship between variables (Field, 2005). Bivariate correlations were conducted with all variables involved in this study as presented in Table 2. For example, we were interested to what extent quality management tools and techniques are related to maintenance performance.

4.3.3 Regression analysis

Regression analysis was used in order to analyse the relationship between a dependent variable (maintenance performance) and independent or predictor variable (quality in maintenance). Therefore, in simple regression analysis we seek to predict an outcome variable from a single predictor variable by fitting a linear equation to observed data. Overall fit of the model can be assessed by R^2 and F statistics (Field, 2005). The term R-squared refers to the fraction of variance explained by a model, while on the other hand the F statistics refers to the overall significance of the regression model.

5. Results

5.1 Construct validity and reliability

In order to confirm the latent factor structure for measured variables, an exploratory factor analysis was performed. To test the reliability, the internal consistency of the questionnaire was measured using Cronbach's alpha coefficient. The results of validity and reliability are presented in Table 1.

Table 1 Construct validity and reliability

| Factor | Items | Factor loading | Cronbach's alpha | Mean (S.D.) |
|------------------------------------|-------|----------------|------------------|--------------|
| Quality in maintenance | QMM1 | .881 | .922 | 3.36 (1.438) |
| | QMM2 | .876 | | 3.62 (1.289) |
| | QMM3 | .842 | | 3.25 (1.343) |
| | QMM4 | .841 | | 3.23 (1.293) |
| | QMM5 | .830 | | 3.77 (1.031) |
| | QMM6 | .795 | | 3.63 (1.189) |
| | QMM7 | .763 | | 3.83 (1.438) |
| | QMM8 | .613 | | 3.34 (1.037) |
| % of variance | 65.5 | | | |
| Maintenance performance indicators | MPI1 | .895 | .909 | 3.61 (.954) |
| | MPI2 | .894 | | 3.41 (1.087) |
| | MPI3 | .878 | | 3.39 (1.145) |
| | MPI4 | .858 | | 3.22 (.987) |
| % of variance | 77.7 | | | |
| S.D. - standard deviation | | | | |

The Pearson correlation matrix (Table 2) shows that »quality in maintenance« variables are positively and significantly related with maintenance performance. As can be seen in Table 2, the strongest relationship was found between QMM4 and maintenance performance ($r = .751$, $p < .01$). Variable QMM5 is also strongly related to maintenance performance ($r = .744$, $p < .01$). Furthermore, our results support a moderate correlation between QMM1 ($r = .697$, $p < .01$), QMM3 ($r = .681$, $p < .01$), QMM2 ($r = .677$, $p < .01$), QMM6 ($r = .652$, $p < .01$) and QMM8 ($r = .477$, $p < .01$) and maintenance performance. Moreover, the correlation analysis revealed that weakest correlation is between QMM7 ($r = .437$, $p < .01$) and maintenance performance, but still significantly positive.

Table 2 Correlation matrix

| Construct | Correlation matrix | | | | | | | | |
|-----------|--------------------|--------|--------|--------|--------|--------|--------|--------|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| QMM1 | 1 | | | | | | | | |
| QMM2 | .841** | 1 | | | | | | | |
| QMM3 | .705** | .710** | 1 | | | | | | |
| QMM4 | .706** | .611** | .620** | 1 | | | | | |
| QMM5 | .613** | .687** | .666** | .696** | 1 | | | | |
| QMM6 | .639** | .606** | .590** | .707** | .612** | 1 | | | |
| QMM7 | .668** | .753** | .709** | .466** | .544** | .519** | 1 | | |
| QMM8 | .462** | .385** | .395** | .641** | .541** | .462** | .220 | 1 | |
| MPI | .697** | .677** | .681** | .751** | .744** | .652** | .437** | .477** | 1 |

** Correlation is significant at the 0.01 level (2-tailed)

A table 3 show that the linear model tested is significant ($p < .05$). The regression analysis accounted for 65.7% change is caused by quality in maintenance which is dependent variable. Value of beta also shows that quality in maintenance is important predictor of maintenance performance (Beta = .810, $p = .000$).

Table 3 Regression analysis

| R - Square | F - Change | N | Sig. F - Change |
|------------------------|---------------------------------|-------|-----------------|
| .657 | 84.100 | 53 | .000 |
| Independent variable | Standardized coefficient (Beta) | t | Sig. |
| Constant | | 2.546 | .014 |
| Quality in maintenance | .810 | 9.171 | .000 |

Predictor: Quality in maintenance

Dependent variable: Maintenance performance

Table 4 shows the results of independent t-test. Mean values were estimated in order to show the relationship between quality management

approaches and maintenance performance. The results show that the mean value is higher within the group of organizations that have implemented TPM in comparison with organizations that don't have implemented TPM. According to t-test, the difference between means is significant ($t = 2.049$, $p = .046$). For other differences between two group means this cannot be confirmed, regarding the t-test.

Table 4 T test results for quality management approaches with maintenance performance

| QM approach | | Mean value | Mean Difference | t-value | p-value |
|-------------|-----|------------|-----------------|---------|---------|
| ISO 9001 | Yes | 3.4706 | .24142 | .779 | .440 |
| | No | 3.2292 | | | |
| TPM | Yes | 3.8864 | .62922 | 2.049 | .046* |
| | No | 3.2571 | | | |
| 5S | Yes | 3.8333 | .57598 | 1.921 | .061 |
| | No | 3.2574 | | | |

*Significant at the 0.05 level (2-tailed)

6 Discussion

In this study we have provided empirical evidence that quality management practices have a positive impact on maintenance performance. As shown by the regression results (Table 3), quality in maintenance is important predictor of maintenance performance ($\text{Beta} = .810$, $p = .000$). This result therefore, corroborates the studies (Ben-Daya and Duffuaa, 1995; Al-Najjar, 1996 and Khan and Darrab, 2010) in which authors have linked quality and maintenance. This finding, however, also contribute to the understanding of the impact of quality management practices on performance of processes. In one sense, our findings are somewhat similar to the findings of Kaynak (2003) who found a positive correlation between quality management practices and organizational performance. One possible explanation of this is that high maintenance process performance could lead to better manufacturing performance and nevertheless to better organizational performance. Therefore, incorporating quality management practices into maintenance processes could reflect in better maintenance performance and consequently in better manufacturing performance. More specifically, the finding highlights the role of quality management practices in maintenance processes and substantiates the idea of the deployment of quality management practices directly into maintenance processes in order to achieve high maintenance performance.

The results of our empirical study also clarify the role of different quality management practices on maintenance performance. Considering our findings, the most important practice regarding the maintenance performance is informing employees in the field of maintenance about the quality of processes and products, with the purpose of maintenance processes improvement ($r = .751$, $p < .01$). This finding suggests that information about quality is important part of maintenance processes improvement. Moreover, this result also supports the discussion in quality management literature concerning the continuous improvement (CI), especially from the point of view that not all organisations have equal CI

abilities (Bessant et al., 2001). Given the fact that CI abilities include different problem-solving skills in which information certainly represent important role, our finding therefore, provides insight on the interaction between CI and maintenance performance. With respect to Bessant et al. (2001) who stated that CI is viewed as a particular set of routines that can help an organization to improve performance, this finding implies that information about quality could improve CI abilities and could therefore lead to better maintenance performance.

As evidenced by the correlation analysis presented in Table 2, teams are shown to have a significant and positive relationship with maintenance performance ($r = .744$, $p < .01$). This result acknowledges various arguments concerning the team-based maintenance strategy. As cited by Sharma et al. (2006), TPM is defined as a team-based maintenance strategy designed to maximize equipment effectiveness by establishing a comprehensive maintenance production system covering the entire life of equipment, spanning all equipment related fields and involving every one, i.e. from top management executives to the production operators. In the light of this argument, our finding can be understood in the sense that teams in the field of maintenance can improve production effectiveness through achieving high maintenance performance.

Furthermore, as seen in Table 2, our results support a moderate correlation between quality management tools and techniques and maintenance performance ($r = .697$, $p < .01$). The importance of taking into consideration the quality management tools and techniques in the field of maintenance is an idea already accepted in the TQM literature. The study of Vassilakis and Besseris (2009) supported this by implementing the basic principles of TQM by means of statistical process control (SPC) quality tools and Cause and Effect diagram into the environment of a maintenance unit of large aerospace company. This argument is substantiated by the study finding that the use of quality management tools and techniques in the field of maintenance is positively correlated to maintenance performance.

The findings of the study have also produced important insight into the benefits resulting from the implementation of TPM. According to t-test, the difference between means is significant ($t = 2.049$, $p = .046$). As seen in Table 4 mean value is higher within the group of organizations that have implemented TPM in comparison to organizations that have not yet implemented TPM. This means that there is a positive relationship between TPM and maintenance performance. Hence, this result is consistent with the argument of Ahuja and Khamba (2008), who stated that an effective TPM implementation program can focus on addressing the organization's maintenance related problems, with a view to optimize equipment performance.

Based on the study findings, the least important, but still significantly positive ($r = .437$, $p < .01$) quality management activity is deployment of the principles of ISO 9000 in maintenance processes. But on the other hand, according to t-test, the difference between mean values of the relationship between ISO 9000 and maintenance performance (Table 4) can not be statistically confirmed. As found in a study (Maletič et al., 2012), this result is somewhat consistent with the finding of study (Singels

et al., 2001) in which authors found no significant difference on the improvement of the production process between organizations that have a quality management system certificate and those which have none.

7 Conclusion

This study has investigated the effect of different approaches, as well as specific quality management practices on maintenance performance using data from Slovenian organizations. Taken together, these results not only provide interesting insight into the role of quality management in the field of maintenance, but also point to a relationship among quality management practices and their correlation with maintenance performance. To summarize the main findings, our results show that quality management practices are positively and significantly related with maintenance performance. Our findings, therefore, demonstrate that organizations benefit from quality management activities in the field of maintenance. Results also clearly reveal that the quality management activities can facilitate the manufacturing organization's quest for achieving enhanced maintenance performance.

Some limitations of this study should be discussed in this section. First, despite the overall findings gained in this study, we believe that this topic still opens opportunities for further studies. Future studies should consider more complex measures of quality management practices. Second, all the aspects of maintenance performance (for instance measures of cost performance) are not captured in our study. Therefore, future research could also broaden the investigation to identify more complex measures of maintenance performance. In addition to the limitations already mentioned, future studies should consider larger sample size in order to increase the generalizability of the results.

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Appendix 1

Quality in maintenance

Respondents were asked to indicate the extent to which they agree or disagree with each of the following statements (1 = “strongly disagree”, 5 = “strongly agree”).

QMM1: We include quality management tools and techniques in the maintenance processes

QMM2: On the basis of the quality management system we have established a process for managing maintenance processes

QMM3: The audit is used to determine the effectiveness of maintenance

QMM4: We continuously inform the employees in the field of maintenance about the quality of processes and products, with the purpose of maintenance processes improvement

QMM5: The teams are used in the field of maintenance

QMM6: Management is committed to continuous improvement in maintenance

QMM7: We deploy the principles of ISO 9000 in maintenance processes

QMM8: Operators feel responsible for their assets

Appendix 2

Maintenance performance

Respondents were asked to indicate the extent to which they agree or disagree with each of the following statements (1 = “strongly disagree”, 5 = “strongly agree”).

MPI1: We are achieving high availability of assets

MPI2: Repair times (MTTR) are consistent with the plan

MPI3: We are achieving high Overall Equipment Effectiveness (OEE)

MPI4: We are achieving times between failures (MTBF), which are in accordance with the manufacturer’s specifications