Examination of mediating effects of safety on the relationship between quality management and live working performance

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It could be argued that reducing costs related to asset maintenance, repair, and ultimate replacement should be considered as one of the top management concerns. Downtime in any network, manufacturing or other system, eventually results not only in high costs, but in stakeholder dissatisfaction as well. In response to these concerns, this paper presents a live working (LW) and its potential to improve its overall performance. Although there is a long tradition of LW, this is a fairly new maintenance method useful in many industry settings, especially in electrical installations in the process of electric power generation, transmission and its distribution (Lovrenčić et al., 2017). Despite the increasing popularity of LW, there is lack of empirical research that would provide insights into the interactions between quality management and LW performance as well as of mediator (i.e. safety at work) of this relationship. Using empirical data based on a large-scale survey among 171 LW experts from 36 countries, this paper utilized method to estimate and test the mediated effects. As such, the sizes of indirect effects of quality management on LW performance through safety at work as a potential mediator are estimated. Results showed that safety at work partially mediates the relationship between quality management and LW performance, namely taking into account three performance measures: reliability and availability, efficiency of LW workers, and overall LW performance. This paper is one of the first attempts to empirically test the proposed interactions. Besides, the analysis of the direct and indirect effects of quality management on LW performance and the impact of safety at work in this relationship has not been yet addressed to a great extent.

Keywords: electrical installations, maintenance, live working, quality management, performance, safety, mediation.

1. Introduction

Live working (LW) could be considered as a tool for preventive maintenance of electrical installations with a long worldwide tradition. In last decades, LW has been implemented actively at low voltage (LV) in the Slovenian electrical companies for distribution, transmission and generation of electricity as well

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as in industry and public (such as health) institutions (Lovrenčić et al., 2015).

Quality, reliability and continuity of supplying electricity have always been a primary consideration for all organizations in power transmission and distribution sector. To ensure high service performance, efficient plant maintenance without service interruption is considered as necessary (Martini, 2017).

This paper broadens our understanding of how to improve LW performance by considering interactions between quality management and safety at work. It addresses how the structuring of quality management activities, specifically standardization and improvement of quality management system impact safety at work and ultimately LW performance. By exploring the mechanism behind above mentioned interactions, we add to the existing body of knowledge on LW (Lovrenčić et al., 2017).

Previous work on LW has predominantly addressed technological aspects of LW (e.g. technical aspects of transmission lines). However, there is lack of research that would address interactions between organizational and human factors. Extending this line of inquiry, our study builds on insights of prior research examining quality management aspects in maintenance (Maletič et al., 2014), safety and maintenance issues (Pintelon and Muchiri, 2009) as well as personnel training for LW (Parise and Hesla, 2002; Lovrenčić and Miletić, 2014).

The remaining part of the paper is organised as follows. Section 2 briefly describes the data acquisition step and outlines mediation analysis. Section 3 illustrates results of mediation analysis, while Section 4 concludes the paper by summarising and interpreting the key findings of the study.

2. Methods

2.1 Sample and data collection

Survey questionnaire was used for the purpose of data collection. Therefore, the questionnaire was designed with the aim of capturing relevant information among global LW settings. We created a questionnaire using a Likert-type scale from 1 - strongly disagree to 5 - strongly agree, and using nominal scales as well. The measurement items for all constructs are based on earlier empirical research (Lovrenčić, 2018). Given different potential biases that may have influenced responses, we followed the recommendations of Podsakoff et al. (2003) regarding the survey design and implementation to reduce the potential influence of common method variance on our findings.

A total of 171 international LW experts from 36 countries responded to this survey. Survey was conducted by two methods: 1) personal face-to-face survey which was carried out among LW experts during several conferences (e.g. ICLIM, CIRED); 2) email survey by means of contacting and sending survey instrument to a respondent via email.

2.2 Mediation analysis

In order to test the mediation effects of safety at work on the relationship between quality management and LW performance, we used macro for estimating indirect effects in mediation model proposed by Preacher and Hayes (2004, 2008).

The mediation procedure provides unstandardized regression coefficients as required to test mediation (Preacher and Hayes, 2008). Path a represents the effect of independent variable X on the proposed mediator M, whereas path b denotes the effect of mediator M on dependent variable Y partialling out the effect of independent variable X (Figure 1). All of these paths would typically be quantified with unstandardized regression coefficients. Direct effect (c′) is the X→Y path coefficient after the addition of M to the model. The indirect effect of X on Y through M can then be quantified as the product of a and b (i.e., ab). The total effect of X on Y is quantified with the unstandardized regression weight c, and can be expressed as the sum of the direct and indirect effects: $\underline{c} = c' + ab$.

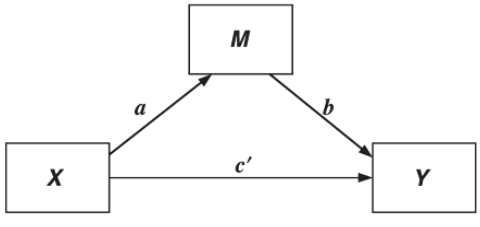

Figure 1. Illustration of a mediation model. X is hypothesised to exert an indirect effect on Y through M (Preacher and Hayes, 2008).

3. Analysis and Results

3.1. Reliability and validity assessment

For the purpose of reliability and validity assessment, various tests were used. First, factor analysis was used to verify convergent validity of each of the constructs used in this study. As shown by the results presented in Table 1, factor loadings range from 0.58 to 0.90. According to

Hair et al. (2010), the loading coefficients of all items should exceed 0.50 to be consistent with convergent validity. Moreover, results indicate that Cronbach's alpha value for each construct is well above the recommended value of 0.70 (Hair et al., 2010).

Table 1. Summary of reliability and validity estimates.

Reliability and validity estimates			
Construct	No. of sub-construct	Loadings	Cronbach's Alpha
quality management	3	0.58 – 0.88	0.72 – 0.86
safety at work	3	0.66 – 0.90	0.87 – 0.92
reliability and availability	1	0.67 – 0.82	0.88
efficiency of LW operators	1	0.66 – 0.87	0.74

3.2. Results of mediation analysis

The purpose of this section is to examine whether quality management affect LW performance indirectly through safety at work. We consider that the predictor variable quality management is related with the criterion variable safety at work, and we take the position that safety at work has mediator function on the relationship between quality management and LW. In the following, we present simultaneous mediation models by multiple variables: quality management as independent variable, LW performance (model 1), reliability and availability (model 2) and efficiency of LW operators (model 3) as dependent variables and safety at work as mediator. The results of the mediation analysis are presented in Table 2 and Table 3.

Table 2. Mediation of the effects of the quality management on LW performance through safety at work.

Coefficients			
(a paths)	(b paths)	Total Effect (c path)	Direct Effect (c-prime path)
Model 1 (F = 114.3680, p = 0.0000)			
0.3539, p = 0.0000	0.8636, p = 0.0000	0.4130, p = 0.0000	0.1073, p=0.0398
Model 2 (F = 93.0579, p = 0.0000)			
0.3539, p = 0.0000	0.7446, p = 0.0000	0.4202, p = 0.0000	0.1567, p=0.0035
Model 3 (F = 50.4233, p = 0.0000)			
0.3539, p = 0.0000	0.9827, p = 0.0000	0.4057, p = 0.0000	0.0579, p=0.4939

Regarding the model 1 and model 2, results suggest that direct effect is statistically significant (0.1073, p = 0.0398; 0.1567, p = 0.0035, respectively). Hence, it is suggested that partial mediation occurs in case of relationship between quality management on the one hand and LW performance as well as reliability and availability on the other hand. Regarding the model 3, the results indicate that direct effect is not statistically different from zero, indicating no relationship between quality management and efficiency of LW operators after controlling for mediators (c' = 0.0579, p = 0.4939). It seems that safety completely mediates the effect of quality management on efficiency of LW operators.

The specific indirect effects are a_1b_1 = 0.3057 (see model 1), a_2b_2 = 0.2635 (see model 2), a_3b_3 = 0.3478 (see model 3) (Table 2).

Table 3. Bootstrap estimates of the mediated effect and its standard error.

	Product of Coefficients		Bootstrapping BCa 95% CI	
Point estimate (product ab)	SE	Z	Lower	Upper
		Model 1		
0.3057	0.0493	6.2050	0.1539	0.4821
		Model 2		
0.2635	0.0447	5.8991	0.1079	0.4744
		Model 3		
0.3478	0.0633	5.4904	0.2002	0.5493

BCa - Bias Corrected and Accelerated Confidence Intervals, 1000 bootstrap samples

The difference between the total and direct effects is the total indirect effect as illustrated with particular point estimate ab and corresponding 95% BCa bootstrap CI. As evidenced by the bootstrap results, the product ab representing the differences between the total and the direct effect of independent variable on dependent variables are statistically different from zero.

In addition, we conducted three tests to examine the mediating effect of safety at work: the Sobel test, the Aroian test, and the Goodman test. Results are shown in Table 4. The three tests for all mediation models were significant at the $p < 0.01$ level, thus corroborating the mediating effect.

Table 4. Summary of the results of Sobel test.

	Model 1	Model 2	Model 3
Sobel test	6.18**	5.88**	5.47**
Aroian test	6.17**	5.86**	5.48**
Goodman test	6.20**	5.90**	5.49**

Note. ** $p < 0.01$

4. Discussion and conclusions

Notwithstanding valuable contributions pointed out in previous studies (Lovrenčić et al., 2017)that both, researchers and practitioners, still struggle to understand of how to increase the performance of LW activities. Academic literature has extensively investigated both, the use of different maintenance strategies (Pintelon et al., 2006) and the possibilities to improve company's performance (Al-Najjar and Alsyouf, 2004). Recently, studies (e.g. Maletič et al., 2018; Alsyouf et al., 2018) have provided evidence suggesting that taking a more holistic approach of managing assets leads to improved overall performance. Despite the increasing popularity of LW, there is lack of empirical research provide insights into the interactions between quality, safety and LW performance. There are studies that separately address the above mentioned subjects, but it is difficult to provide any implications without having a holistic approach.

Given the dearth of insight into the mediation mechanisms, our study revealed partial mediation of safety at work regarding the link between quality management and LW performance. In this regard, the present study advances prior studies that have investigated either direct link between quality management and organizational performance (Kafetzopoulos et al., 2015), the link between quality management aspects and maintenance performance (Maletič et al., 2014), or studies that aimed at exploring the link between TPM and organizational performance (Kaur et al., 2013). Therefore, this research adds to the literature by recognizing that safety at work could serve as a mediator on the link between quality management and LW performance. Results of this study could be supported with arguments suggesting that quality management positively influence performance outcomes (Cua, et al., 2001) as well as by arguments indicating that there is synergistic effect between quality management and safety (Azadeh et al., 2014).

More specifically, it can be advocated that efficiency of LW operators can be enhanced by active involvement of operators in system of continuous improvement (Jaca et al., 2012) as well as by suitable training, workplace design, top management commitment and support, etc. (Anitha, 2014). Our study highlights the important role of safety awareness, safety training and safety equipment by extending the conceptualization and operationalization of safety. Furthermore, it provides an empirical evidence that associates these safety domains with quality management and LW performance.

In terms of managerial implications, this study re-emphasizes the importance of LW as a contemporary maintenance concept that aims to reduce downtime and operating costs, as well as to improve maintenance process efficiency, stakeholder satisfaction, especially by taking into account electrical installation maintenance perspective. Nowadays, customers have high requirements regarding the reliability of power supply. LW has a potential to improve the power supply reliability and is effective approach for avoiding and reducing any kind of service interruption. Moreover, LW can be considered as a contribution to safety at work by means of embracing zero accidents philosophy. Its ability to improve the working environment results into improvement of personal safety and equipment safety. Managers should be aware that integrating this method into maintenance processes will be beneficial in terms of service quality and corporate image. However, our study revealed that one should embody a methodical approach to LW so that the safety principles are clearly understood and considered by everyone. There is a need to establish a strong quality management system that should support activities such as work planning, risk assessment, assigning of roles and responsibilities, performance evaluation etc. It should be outlined that quality system needs to integrate the safety issues as well. It can be argued that by incorporating LW into integrated management system (i.e. quality and safety management system), managers can establish continuous improvement mechanisms, such as PDCA cycle, monitoring of key LW activities, internal and external audit of LW process, competence evaluation of LW operators etc. (Lovrenčić and Oman, 2012).

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