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## QUALITY MANAGEMENT METHODS AND ITS RELATION TO SUPPLIER PERFORMANCE MEASURES

**Abstract:** *This study aimed to investigate whether there is a relationship between the quality management method and the supplier performance measurement system. The results indicate that in some cases, organizations that had implemented lean management or TPS used supplier assessment measures more often and perceived them as more important ones. Moreover, according to the study, the most popular supplier measures are within the scope of process ones, such as timeliness of deliveries and completeness of deliveries. From the product measures, the most important one is the defectiveness level. The environmental measures' importance is, on an average level, much lower than the core-business ones. The most critical environmental supplier measure is using hazardous substances in production.*

**Keywords:** *supplier, measure, indicator, lean management, TPS, ISO 14001, performance*

### 1. Introduction

Quality management can be implemented in enterprises using various methods or combinations of these methods. To the group of flagships among these methods, researchers usually include management systems (primarily ISO 9001 and ISO 14001), lean management and Toyota Production System (Dahlggaard-Park, 2011; Fredriksson & Isaksson, 2018). Many studies have confirmed that the application of these methods has a significant impact on how enterprises function and on their results. It has been shown that these methods have significant and positive effects, among others, on operational performance (Abdallah et al., 2021, Bhadu et al., 2022, Fonseca & Domingues, 2017, Jugend & da Silva, 2012), customers' satisfaction and reduction of defectiveness (Chiarini, 2016), employee involvement (Yang & Yang,

2013), and sustainability performance (Luis Fonseca et al., 2022). It can, however, be noticed that some areas of quality management have not been sufficiently understood. One of them is the impact of quality management methods on the company functioning in supply chains.

Relationship management is one of the seven principles of quality management (ISO, 2015). It concerns relations with various stakeholders, the most important of which include suppliers. Research in this area concerned, among other things, with optimal methods of selecting suppliers (Govindan et al., 2021, Patrucco, Moretto, & Knight, 2021), the relationship between supply chain quality management practices and quality performance outcomes (Kuei et al., 2001, Soares et al., 2017), the impact of supplier orientation on the organizational performance in ISO 9001 certified organizations (L. M. Fonseca & Lima, 2015)

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and the influence of ISO 9001 standard on the supply chain flexibility (Rojo-Gallego-Burin, Llorens-Montes, Perez-Arostegui, & Stevenson, 2020).

In the literature, however, more attention needs to be paid to determine whether the implementation of selected quality management methods influences the expectations of the enterprise towards its suppliers. This information may be helpful for enterprises operating in the B2B market (both for buyers and sellers), as performance evaluation of suppliers is increasingly recognized as a critical indicator in supply chain cooperation (Chen, Cheng, & Lai, 2012) and supply chain performance measurement has emerged as one of the key business areas where companies can gain sustained competitive advantage (Romule, Colicchia, Milano, & Shaw, 2020). Therefore, the purpose of this study is to investigate whether there is a relationship between the quality management method and the supplier performance measurement system used in the company. The performance measurement system is understood as a set of metrics used to quantify the efficiency and effectiveness of suppliers' actions (Maestrini, Patrucco, Caniato, & Maccarrone, 2021). The results of the study will contribute to a discussion on the criteria and methods of supplier evaluation (see, for example, Sang Chin et al., 2006 and Sahu et al., 2022).

## **2. Literature review**

It can be noticed that the purchasing companies use three groups of measures when conducting a periodic assessment of suppliers. These measures focus on the assessment of: the product, the implementation of delivery processes and the improvement of environmental impact. Implementing these assessment measures facilitates the introduction by purchasing companies and their suppliers of quality and environmental and management systems, as well as of such improvement tools as the

Toyota Production System or lean management.

### **2.1. Supplier evaluation measures related to the product**

Manufacturing companies that are buyers setting requirements for suppliers, particularly focus on ensuring the technical quality of products (Gordon, Mueses, Kennedy, & Ong-a-Kwie, 2020). Guaranteeing technical quality is conditioned by strict compliance with legal requirements by suppliers. These requirements ensure product safety (Jakubowska-Gawlik, Kolanowski, & Trafialek, 2021). Product safety requirements are included, inter alia, in European Union directives and technical standards. Manufacturers who are buyers in supply chains very often require their providers to implement the requirements contained in the ISO 9001 standard (Budayan & Okudan, 2022; Manders, de Vries, & Blind, 2016). The last amendment to this standard in 2015 was based on the risk management concept. Taking this concept into account when implementing quality management system should effectively ensure the safety of products and processes. The guidelines included in the quality management standards focus in particular on the supervision of operational processes. These processes are related to product realization, such as customer service, product design and development, purchasing, manufacturing and delivering products and services to buyers. Guidelines on the quality management system, taking into account the assumptions of the risk management concept in the context of building relationships with suppliers, requires effective supervision over technical quality. This supervision should guarantee the safety of purchased products. Effective assurance by suppliers of product quality is a premise for implementing the sustainability concept (Bartos, Schwarzkopf, Mueller, & Hofmann-Stoelting, 2022). Supervision over

technical quality begins with the definition of specifications by buyers. These specifications refer to guaranteeing the quality of products (constituent elements that are ingredients). Effective supervision over technical quality assurance, in addition to defining the specifications for the supplier, also requires defining the scope of processes relating to the measurement and monitoring of products. This supervision also requires the definition of the scope of quality control and approval of its status, as well as the principles of product identification. The scope of quality control required by customers may relate to the course of activities related to the assessment of technical parameters as well as the use of the necessary equipment for measurement and monitoring. The scope of quality control should guarantee the reliability of the results of product quality control. The scope of controls required by buyers relates to both the acceptance assessment of the purchased materials / infrastructure elements, the assessment carried out at individual stages of product processing, and the final assessment of the finished product. A positive result of this assessment allows for the acceptance of the technical quality parameters of products required by customers (Qiu & Yang, 2018). The negative result of the final assessment does not allow the acceptance of the decision regarding the delivery of products to customers. The negative status of the assessment decision allows for avoiding non-conformities related to the technical quality of the product in the delivery of products to customers. Nonconformities related to technical quality in the delivery of products to customers result in complaints. Such situations increase the defect rate and lower the supplier rating. In the case of complaints, an important measure is the supplier's response time to their clarification. Of particular importance in the processes of quality assessment and finding the reasons for complaints are the records regarding the measurement of the required parameters of materials, semi-finished products, finished

products, and the status of control activities. The scope of supervision determines the safety of products delivered to customers and is essential in the event of complaints. Records of inspection activities can guarantee the credibility of this supervision, assessment status and product identification at different stages of operational processes, allowing suppliers to identify the cause of non-compliance (Priede, 2012). It should also be noted that the reaction time to problems related to product use is also essential for buyers. The provision of efficient and high-quality after-sales service by suppliers is increasingly important for building partnership relations between partners in supply chains.

## **2.2. Supplier evaluation measures related to the delivery process**

Of particular importance in the periodic evaluation of suppliers are measures related to the delivery processes. These measures allow the assessment of the efficiency, reliability and effectiveness of suppliers.

These measures include supplier assessment in terms of:

- accuracy of forecasts for the implementation of orders agreed with the supplier,
- timely deliveries,
- completeness of supplies,
- correctness of documentation (invoicing errors),
- completeness of the delivery documentation,
- delivery time,
- price competitiveness,
- time of restoring continuity of supplies.

Meeting buyers' expectations assessed by the suppliers' performance measures related to the delivery process facilitates the implementation of the Toyota Production System (including Kaizen, 5S and Total Productive Maintenance) concept and the lean management concept. Successful

implementation of these concepts by suppliers is associated with meeting their expectations towards customers in terms of ensuring the reliability and completeness of deliveries, shortening process cycles, and improving the efficiency of operations. The basis of the Toyota Production System is the Kaizen approach, which assumes that when eliminating non-conformities in processes, one should focus on the place where they occur and identify the causes of non-conformities (Jayaram, Das, & Nicolae, 2010). As a result of the effective implementation of 5S (sort, set in order, shine, standardize, sustain) and Total Productive Maintenance, suppliers can improve the efficiency and safety of processes and eliminate losses related to non-compliance as well as failures of infrastructure elements (Tortorella, Fogliatto, Cauchick-Miguel, Kurnia, & Jurburg, 2021). This is of particular importance for ensuring and restoring the continuity of supply. Increasingly, the requirements of enterprises towards suppliers focus on improving efficiency (achieving set goals and increasing efficiency) and effectiveness of activities (reducing unnecessary costs) by eliminating waste. The possibility of increasing the efficiency and effectiveness of the processes carried out by suppliers causes their apparent interest in implementing the lean management concept. This concept is implemented through the implementation of projects aimed at eliminating waste (overproduction, inventory, product incompatibilities, unnecessary activities), and thus shortening the cycle of operational processes to ensure timely and complete deliveries (Venkat Jayanth, Prathap, Sivaraman, Yogesh, & Madhu, 2020) (Mathiyazhagan, Gnanavelbabu, Kumar.N, & Agarwal, 2022).

Based on the above literature review, the following main hypothesis has been formulated:

H1: Companies using lean management have a higher level of supplier assessment measures usage and importance than

companies not using lean management.

H2: Companies using Toyota Production System have a higher level of supplier assessment measures usage and importance than companies not using TPS.

### **2.3. Supplier evaluation measures related to the environment**

The dissemination of the implementation of the sustainability concept by international industrial concerns causes more and more enterprises evaluate their suppliers from the perspective of implementing environmental management (Motevali Haghighi, Torabi, & Ghasemi, 2016). By imposing requirements on their suppliers, these concerns require them to limit the negative impact of processes and products on the natural environment. When setting requirements for their suppliers, purchasing companies often rely on the environmental management system guidelines contained in the ISO 14000 series standards (Zheng et al., 2022). These enterprises often require their suppliers (in the initial assessment) to implement an environmental management system based on the requirements of the ISO 14001 standard (Ferrón-Vílchez, 2016; Johnstone & Hallberg, 2020). An vital element of the assessment of the functioning of this system is the identification of environmental aspects and the related legal requirements. Implementing this system requires suppliers to take actions related to improving the impact on the natural environment contained in the environmental objectives and programs specified by buyers (Mosgaard, Bundgaard, & Kristensen, 2022). These programs include specific goals for suppliers and metrics for their evaluation. Expectations for suppliers relate primarily to improving the environmental impact by assessing the reduction of:

- consumption of raw materials, materials, water, energy agents and packaging (per unit / mass of the product produced);

- application of hazardous substances to processes (including heavy metals such as lead, mercury, chromium or cadmium);
- emission of gases, noise and electromagnetic waves.

The guidelines included in the environmental management standards are more and more often the criteria of the initial qualification assessment and periodic evaluation of suppliers. This assessment is carried out by the supplier completing detailed self-assessment questionnaires and audits. The analysis of data contained in supplier self-assessment questionnaires, preliminary and periodic assessment reports and in audit reports allows for evaluating activities related to implementing the assumed goals focusing on limiting the negative impact on the environment. The audits' purpose is to verify the reliability and credibility of the information provided earlier in the supplier self-assessment questionnaires regarding the fulfillment of buyers' expectations.

### 3. Methodology of research

This study aimed to investigate whether there is a relationship between the quality management method and the supplier performance measurement system. This study was performed using the Computer Assisted Telephone Interview (CATI) technique. The study covered 150 producers operating in the B2B market (employing over 49 employees) from the automotive, electromechanical and chemical sectors. The study was commissioned by a specialized research agency that purposefully selected companies registered in the Bisnode database. All of the business entities participating in the study had an implemented quality management system based on the requirements of the international ISO 9001 standard. Half of the surveyed enterprises (70.7%) had an implemented environmental management system based on the requirements of the international ISO 14001 standard. Almost

half of the respondents (47.3%) were enterprises with foreign capital.

The surveyed companies assigned one of two answers to the indicated supplier evaluation measures: Measure is significant, or Measure does not matter. If the factor was significant for the respondent, it additionally indicated appropriate ranks on a scale from 5 (the most critical criterion) to 1 (the least important). Consequently, each answer was assessed on a 6-point scale. That approach was also used in the Urbaniak et al. study (2022).

In order to verify the research hypothesis, the non-parametric Mann-Whitney U test as well as Chi-Square test of independence was used with the p-value lower than 0,05. When the Chi-Square test of independence was used within the study, the assumptions were made (Weinberg & Abramowitz, 2008): the individual observations were independent of each other; the p-value was below the level of 0,05, the expected column frequencies are of 5 or more. Statistica software was used in the study for all calculations.

### 4. Results

#### 4.1. Use of measures

In the group of 150 surveyed organizations, one of them did not use any measures in the assessment of suppliers and therefore was excluded from further analyses. As a consequence, 149 organizations remained in the study group.

Organizations use an average of 13 measures in the studied sample to evaluate their suppliers. In the surveyed organizations, the minimum number of measures used is 5. The measure *timeliness of deliveries* and *completeness of deliveries* are most often used, which were indicated by 99.3% of the respondents. The least popular measures were *consumption of raw materials* and *response time to problems related to the use of the product*, which was indicated by 73.2% and 76.5% of the respondents, respectively.

Within the three groups of measures:

product, process and environmental, only in the last group (environmental) organizations that do not use any of the measures from a given group were identified (11.45%). The average percentage use of single measures for products, processes and the environment groups were: 90.2%, 96.1 and 76.7%.

Based on the conducted Pearson Chi-square significance tests, pairs of grouping variables and measures were identified, which indicate significant differences assuming the level of  $p < 0.05$ . Table 1. contains the individual dependencies. Additionally, to the relations

from table 1. for the other four cases: capital vs. price competitiveness; capital vs. response time to resolve complaints; TPS vs. response time to resolve complaints; ISO 45001 vs. price competitiveness, the p-value was below 0.05, but the cases were excluded from the analysis due to the predefined assumption of the minimal number of observations. For all other variables, the null hypothesis should be retained and there is no confirmation of the relationship between variables.

**Table 1. Significant relationships between the grouping variable and measures**

Grouping variable	Measure	df	Chi <sup>2</sup>	p-value
Capital	Response time to problems related to the use of the product	2	7,07	0,029
TPS	Use of hazardous substances in production	1	4,00	0,046
Lean management	Time of restoring continuity of deliveries	1	6,31	0,012

Tables 2, 3 and 4 show the distribution of responses divided into the grouping variables and measures indicated in Table 1.

**Table 2. Capital vs response time to problems related to the use of the product**

	Response time [%]		Total [%]
	No	Yes	
Foreign capital	7,4	14,8	22,1
Polish capital	14,1	38,9	53,0
Mixed capital	2,0	22,8	24,8
Total [%]	23,5	76,5	100,0

**Table 3. TPS tools vs use of hazardous substances in production**

	hazardous substances [%]		Total [%]
	No	Yes	
TPS - no	19	55	74
TPS - yes	3	23	26
Total [%]	22	78	100

Individual groups of measures (product, process and environment) were also analyzed and compared with grouping variables, such as TPS tools, lean management and ISO 14001 system. It was

shown that a statistically significant difference occurs in the case of the product category group and lean management as a grouping variable (Whitney's U-Mann test,  $p=0.03$ ).

**Table 4. Lean management vs. time to restore the continuity of supplies**

	continuity of supplies [%]		Total [%]
	No	Yes	
Lean - no	5	79	84
Lean - yes	3	13	16
Total [%]	8	92	100

For organizations using lean management, the average number of metrics used in each group was 2.92, and the average for other organizations was 2.66.

#### 4.2. Importance of used measures

Among the organizations that use individual measures, their importance to the organization varies. Organizations defined them on a scale from 1 to 5. Therefore, the importance of indicators was ranked on a

scale from 0 to 5, where 0 means no usage of the measure. Table 5 presents the results regarding the importance of individual

measures and their values divided into three discussed groups.

**Table 5. The importance of individual measures on a scale of 0 to 5**

Group	Description	Average	Group average
Product	Non-compliances with the technical quality of deliveries (defectiveness level)	4,59	4,08
	Response time to resolve complaints	4,36	
	Response time to problems related to the use of the product	3,30	
Delivery processes	Timeliness of deliveries	4,74	4,43
	Delivery time	4,45	
	Completeness of deliveries	4,69	
	Price competitiveness	4,55	
	Completeness of delivery documentation	4,50	
	Correct documentation (invoicing errors)	4,36	
	Time of restoring continuity of deliveries	4,28	
	Accuracy of forecasts of order fulfillment agreed with the supplier	3,83	
Environment	Consumption of raw materials	3,07	3,26
	Emission of pollutants to the environment	3,33	
	Use of hazardous substances in production	3,36	

As a result of the performed analysis, the *response time to problems related to the use of the product* measure was indicated, as the one that significantly differentiates the group of organizations with and without lean management. That was the only one statistically significant relationship that could be extracted from the source data for a

single indicator. In the case of groups of measures, significant relationships were indicated for the product group, where organizations with lean management and those using TPS indicated higher importance of studied groups of measures – see tables 6. and 7. for details.

**Table 6. The importance of using measures vs lean management implementation**

	Rank-sum Lean - yes	Average Lean - yes	Sum-rank Lean- no	Average Lean - no	U	Z	p
Response time to problems related to the use of the product	2211	4,08	8964	3,14	1089	2,1198	0,034
Product Group	2275	4,49	8900	4,01	1025	2,4503	0,014

**Table 7. The importance of using measures vs TPS implementation**

	Rank-sum TPS - yes	Average TPS - yes	Rank-sum TPS - no	Average TPS - no	U	Z	p
Group - product	3378,5	4,29	7796,5	4,01	1580,5	2,2995	0,021

Interestingly, the ISO 14001 grouping variable did not show a significant relationship for any single measure or for a

group of measures from the environment category.

All results presented in this section supports the H1 and H2 hypothesis. There is no sufficient evidence to confirm them entirely, but all the statistically significant relation supports the H1 and H2 and no evidence contradicts them.

## **5. Discussion**

Using supplier evaluation measures by the buyers may contribute to improving the efficiency and effectiveness of the processes implemented in the supply chains. These measures focus on product assessment, delivery processes and improving environmental impact. For many companies, relationships with suppliers are not limited only to placing stringent requirements on them and continuous periodic assessment of compliance with the use of measures. By taking actions aimed at improving processes and products, many entities (especially international corporations) also involve their suppliers (in the implementation of process and product improvement tools) by offering them special development programs (Benton, Prahinski, & Fan, 2020). These programs are implemented through the implementation of joint projects. These projects may focus on activities aimed at ensuring and improving the quality of products, as well as improving the quality of processes. The supplier development programs can also be focused on providing basic or specialized support in implementing quality and safety environment management systems, as well as Toyota Production System (Kaizen, 5S, Total Productive Maintenance) and lean management projects (Najwa et al., 2022). These programs are based on offering training and consulting to suppliers (Tran, Gorton, & Lemke, 2022; Yu, Qiu, & Gupta, 2022). Through the transfer of knowledge to suppliers, it is possible to implement joint projects aimed at developing product innovations, reducing risk, solving technical problems, organizing processes and reducing the negative impact on the environment (Bai & Satir, 2020;

Zhou, Bhuiyan, Medal, Sherwin, & Yang, 2022). This allows for greater efficiency and effectiveness in improving the processes implemented in supply chains and the possibility of implementing the concept of sustainability by providers (Coşkun, Kumru, & Kan, 2022; Fan, Xiao, Zhang, & Guo, 2021). Supplier development programs can foster mutual learning processes through the transfer of knowledge and experience. Trust-based collaboration of partners in supply chains can lead to many mutual benefits. Such benefits include: improving the quality of products and maintenance services, shortening order fulfillment cycles, improving communication between the supplier and the recipient, research and development (Kim & Chai, 2017; Quigley, Walls, Demirel, MacCarthy, & Parsa, 2018). Increasingly, buyers see that offering supplier development programs enable them to develop partnerships. These benefits determine the development of further cooperation, building trust and open communication that strengthens the ties between partners. These ties manifest in joint projects in the field of implementing product innovations (improving the technical parameters of products) and organizational ones contributing to limiting the risk of untimely, completeness or defective deliveries) Building partnerships with suppliers also contributes to increased efficiency by reducing costs by increasing the efficiency of processes and infrastructure, improving product safety, or reducing the negative impact on the natural environment.

While the importance of environmental activities is still growing, the data indicate that the core business is the most important. For all studied companies, process and product measures had higher importance than the environmental ones.

## **6. Conclusion**

The use of supplier evaluation measures within the studied organizations is high. The



most popular measures are within the scope of process ones, such as: timeliness of deliveries and completeness of deliveries. From the product measures, the most important one was the defectiveness level. The environmental measures' importance was on an average level. The most important one was the use of hazardous substances in production.

The group of organizations that had implemented lean management or TPS uses studied supplier assessment measures more often and sees them as more important ones. The findings of the study have some limitations. The most important one is that the research was carried out in organizations

operating on the Polish market. However, almost half of the surveyed enterprises were with foreign capital and are very active in international markets. The possible future research from this article is the imbalance in the importance of environmental and other supplier measures. It would also be worth expanding the scope of research to include other quality management methods, such as Six Sigma and the EFQM Model.

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