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Development of a risk matrix for the assessment of maintenance suppliers: A study based on empirical knowledge

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Abstract: The machinery maintenance plays a significant role achieving the final quality characteristics of the manufactured products. As the concept of quality covers tangible (e.g. dimensional tolerances) and intangible (e.g. lead-time), the assessment of maintenance suppliers is vital in maintaining the quality of a manufactured product at an anticipated level. As the maintenance suppliers play a significant role in the context of the availability of spare parts and other materials needed for the effective realization of the maintenance process in order to assure the overall quality of the manufactured products, it is vital to achieve the aforementioned via minimization of machinery down time and maintenance backlogs. This paper illustrates the adaptation of empirical-knowledge-based development for the assessment of spare parts and maintenance related other material suppliers. That development has been used only in the manufacturing material suppliers' assessment so far. The criteria used in the case study manufacturing firm for the material suppliers' assessment, as well as other relevant criteria published in the literature, are taken into consideration in the current study. The paper also presents a development of a risk matrix for the assessment of maintenance suppliers, which is the core for the risk based assessments, prioritization and control process.

Keywords: maintenance suppliers, manufacturing machinery maintenance, supplier evaluation, risk assessment, maintenance models and services, quality assurance

1. INTRODUCTION

Manufacturing firms, which are certified or to be certified according to ISO 9001, are required to ensure that externally supplied products and/or services meet the particular manufacturing firm's requirements (Ingason, 2015; ISO 9001, 2015). In this context, it is a mandatory requirement to evaluate and select suppliers based on their ability to supply products and services depending on the particular manufacturing firm's requirements and, thus, it involves specifying the criteria for the selection, evaluation, and re-evaluation of suppliers (Sumaedi, and Yarmen, 2015; ISO 9001, 2015). Moreover, it is necessary to establish and implement the control measures or other actions necessary to ensure that the purchased product or services meet the specified requirements (ISO 9001, 2015). Although the risk based criteria for the evaluation of manufacturing/production materials suppliers were reasonably established, such criteria have not been effectively adapted to the manufacturing-facilities -related spare parts and maintenance support materials suppliers (Sheikhalishahi and Torabi, 2014; Ocampo et al., 2016). Hence, it is vital to investigate the possibility of adapting the risk based criteria for the manufacturing/production materials suppliers of spare parts as well as maintenance support material suppliers, and to develop risk matrices to perform the risk based assessments, prioritization and control (Antosz and Ratnayake, 2016).

The first part of this paper reviews the suppliers' evaluation criteria in the published literature (see Hamdan and Cheaitou, 2017). Then, a case study was performed in order to examine the empirical-knowledge-based criteria that were developed for assessing the manufacturing/production materials suppliers. Based on the manufacturing/production materials suppliers' assessment, the criteria in the case study manufacturing firm and the published literature, the authors propose a risk based set of criteria and a risk matrix for the assessment of maintenance process suppliers. The criteria weights were established based on the expert knowledge, which is a recognized method for establishing the criteria weights (see Stadnicka, Antosz, and Ratnayake, 2014). A risk matrix enables to estimate the risk of employing a certain supplier based on: supplier's categorization, importance of the delivered product, and possibility for exchanging the supplier in case of absence and/or any other unacceptable circumstances. Such a risk matrix enables to make the risk based: assessments, prioritization and control of the maintenance related spare parts and support material for practicing engineers, as well as further related research and development tasks focusing on the minimization of variability (Ratnayake, 2014).

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2. COOPERATION WITH SUPPLIERS AND SUPPLIERS' ASSESSMENT

Table 1 illustrates the review of different criteria for the suppliers' assessment in the published literature. It is revealed that most of the authors indicate: quality, price, delivery time, reputation as well as quality, environment and safety programmes within their criteria (Cagnin et al. 2016, Chen and Wu 2013). Moreover, many publications emphasized an environmental aspect as an important criterion (Govindan 2015).

Table 1. The review of the criteria for the supplier assessment presented in the literature.

Criterion	Work
Quality, customer satisfaction	Dargi et al., 2014, Zhang et al., 2009, Lima-Junior and Carpinetti 2016, Bottani and Rizzi 2008, Erdem and Göçen 2012, Önüt et al. 2009, Sevkli et al. 2008, Ng 2008
Price, cost	Dargi et al., 2014, Lima-Junior and Carpinetti 2016, Erdem and Göçen 2012, Önüt et al. 2009, Sevkli et al. 2008, Ng 2008
Production capacity	Dargi et al., 2014
Technical capability and facility, technology	Dargi et al., 2014, Erdem and Göçen 2012
Service and delivery, service quality, logistic	Dargi et al., 2014, Zhang et al., 2009, Erdem and Göçen 2012, Sevkli et al. 2008, Ng 2008
Reputation, honesty, reference	Dargi et al., 2014, Lima-Junior and Carpinetti 2016, Önüt et al. 2009, Sevkli et al. 2008
Geographical location, distance	Dargi et al., 2014, Lima-Junior and Carpinetti 2016, Sevkli et al. 2008, Ng 2008
Delivery time	Zhang et al., 2009, Lima-Junior and Carpinetti 2016, Segura and Maroto 2017, Önüt et al. 2009, Sevkli et al. 2008,
Quality, environmental and safety programs and certificates	Lima-Junior and Carpinetti 2016, Segura and Maroto 2017, Sevkli et al. 2008,
Financial situation	Lima-Junior and Carpinetti 2016
Technical and organizational capabilities, execution time, lead time, capacity	Bottani and Rizzi 2008, Önüt et al. 2009, Sevkli et al. 2008
Design capability, product development	Lima-Junior and Carpinetti 2016, Sevkli et al. 2008
Responsiveness to demand change	Lima-Junior and Carpinetti 2016
Ease of communication	Lima-Junior and Carpinetti 2016
Supplier's willingness	Bottani and Rizzi 2008
Company's interest	Bottani and Rizzi 2008
Size of enterprise	Sevkli et al. 2008
Supply variety	Ng 2008

Different methods report a supplier selection together with a set of criteria (Ávila et al. 2015, Toloo and Nalchigar 2011; Chu and Varma 2012; Cagnin et al. 2016, Chen and Wu 2013). Among others, AHP (Analytic Hierarchy Process) and FAHP (Fuzzy Analytic Hierarchy Process) methods are proposed (Liao et al. 2016, Galankashi 2016). Sheikhalishahi (2014) presented a methodology for a maintenance supplier selection. However, it is a challenge for industrial organizations to employ relatively complex methodologies for choosing their suppliers. Hence, it is vital to propose simple methodologies in the suppliers' selection. Therefore, this study focuses on the risk based maintenance supplier selection approach that shall be used in a small or large industrial organization. It was adapted from the manufacturing/production material suppliers' selection methodology.

3. MANUFACTURING/PRODUCTION MATERIAL SUPPLIER ASSESSMENT PROCESS: EMPRICAL KNOWLEDGE BASED DEVELOPMENT

A manufacturing/production material supplier assessment process is selected from a manufacturing firm that manufactures high-quality fasteners for domestic and foreign markets. The selected manufacturing firm (MF) has currently implemented ISO 9001 Quality Management System (QMS) in the areas of sales and manufacturing. The MF developed an empirical–knowledge-based procedure for the evaluation of suppliers. The aim of the assessment procedure is to ensure that the purchased material and/or semi-finished products meet the specified requirements. In addition, it also aims at ensuring an improved cooperation with suppliers.

The evaluation of suppliers is carried out based on the following criteria: 'Price', 'Punctuality', 'Quality', 'Payment Conditions', 'Complaints', 'Period of Cooperation', 'Quality Management System'. Each criterion is evaluated on a point scale from 1 to 6 (see Table 2) (Walas, 2010).

Table 2. The criteria of supplier assessment.

Criterion and its characteristics	Points
Price (*P*)	
Unacceptable – The highest price on the market	1
Very High – One of the highest price on the market	2
High – Very high price compared to the competition	3
Medium – Price compared to the competition	4
Low – Very favourable price	5
Very Low – The lowest price in the market	6
Punctuality (P_u)	
Unacceptable – Very long delays	1
Very Low – Goods are often not delivered on time	2
Low – Several times late in delivery (long delays)	3
Medium – Several times late in delivery (Short delays)	4
High – Deliveries on time, isolated cases of short delays	5
Very High – Deliveries always on time	6
Quality (*Q*)	
Unacceptable – Supplier does not meet the requirements.	1
Very Low – Goods often do not meet the requirements	2
Low – Goods meet only some of the requirements	3
Medium – Goods meet most of the requirements	4
High – Goods meet all of the requirements, isolated cases of non-compliance	5
Very High – The best quality	6
Payment conditions (P_C)	
Unacceptable – no possibility of negotiation, limited payment options	1
Unfavorable – no possibility of negotiation	2
Unfavorable - the possibility of negotiation, conditions in	3