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A new model for continuous evaluation of suppliers with real execution data

Esra Kurt Tekez*, Fatih Kar and Merve Cengiz Toklu

Department of Industrial Engineering, Sakarya University, Sakarya, Turkey
**Corresponding Author: etekez@sakarya.edu.tr*

ABSTRACT

Supplier evaluation is a significant work for a company in order to enhance productivity and profitability. When a well-managed supplier evaluation is developed, this has a significant impact on the competitiveness of the entire supply chain. By examining the literature, it was seen that a great deal of papers are related to evaluation during new supplier selection process. However, there is a scarcity of studies that evaluate performance depending on the difficulty. The purpose of this paper is to focus on performance evaluation of the suppliers that are being currently worked with. In this context, Enterprise Resource Planning usage is investigated in order to collect and track real-time data for supplier evaluation systems, especially examined small- to medium-sized enterprises. With this in mind, this study conducts a questionnaire on the small- to medium-sized enterprises. Subsequently, by referring to the results of this study, a new evaluation model with dynamic structure is developed utilizing Enterprise Resource Planning, which constantly reviews suppliers at each delivery. Moreover, the developed model has been implemented in a medium-sized machine manufacturing company, integrating it into the purchasing module of its Enterprise Resource Planning system. The managers of the company have confirmed the proposed model and the manufacturing company is continuously doing a systematic evaluation with this model, thus facilitating to attain the goals of supply chain management such as reduction of inventory cost, increasing profit margin and customer satisfaction.

Keywords: ERP; purchasing; SMEs; supplier evaluation; supply chain management.

INTRODUCTION

Supplier evaluation is a significant function for a company in order to enhance productivity and profitability. When a well-managed supplier evaluation is developed, it has an important impact on the competitiveness of the entire supply chain such as a sufficient production volume with good quality and reducing operational costs.

There are two distinct aspects in which supplier evaluation happens. Initially, evaluation is made during the new supplier selection process. In this case, the aim of the evaluation process is to select the preferred ones among candidate suppliers. Secondly, after selecting, supplier evaluation is made on a regular basis with the aim of managing and improving the existing suppliers. Unlike the selection phase, the main point of evaluation is to assess the performance of individual suppliers compared to the desired levels of performance (Osiro et al., 2014). The systematic evaluation of existing suppliers considering the purchasing function is extremely important in terms of continuity of the business relation. Although the studies of evaluation on the topic of supplier selection (Humphreys et al., 2005; Chen et al., 2006; Hou and Su, 2006; Ho et al., 2010; Büyüközkan and Çifçi, 2011; Hald and Ellegaard, 2011; Zeydan et al.2011; Zolghadri et al., 2011; Liou et al., 2014; Wang and Li, 2014; Azadi et al., 2015; Mamavi et al., 2015; Al-Ahmari et al., 2016) are well established within literatures, there are limited numbers of studies on performance evaluation of suppliers that are currently being worked with. Because the supplier evaluation is a more complicated process and requires much more effort, there are lots of purchased materials and suppliers in the process and analysing these suppliers with real execution data can be difficult considering the number of factors.

In the literature, a few studies exist, which consider performance evaluation of suppliers that are currently being worked with. For example, Wang (2010) evaluates suppliers through criteria such as supplier's product quality,

supplier's delivery/order fulfilment capability, price/cost minimization performance, and supplier's post sales service. In this study, an expert committee with own knowledge and opinions determines the performance of suppliers on different levels, but execution data is not collected and during the evaluation phase it is not taken into consideration. Similarly, Kumar et al. (2013) propose a model for supplier evaluation; a questionnaire has been used to determine the importance scores of evaluation factors and fuzzy rules were defined to assess on. However, the authors used only the decision maker's judgment that involved consistency in product quality, improvement in incoming components, etc., whereas the realized numerical data should have been collected for the determination of performance. Osiro et al. (2014) present a fuzzy logic approach for evaluation of suppliers for development purposes. This approach follows a procedure for pattern classification based on decision rules that categorize supplier performance according to the item category. But, it seems that the main purpose of this study is limited to the classification of individual suppliers. Moreover, Hu et al. (2015) present a model in order to increase supplier quality performance by using questionnaire for design of ANP and DEMATEL methods. Lima-Junior and Carpinetti (2016) integrate SCOR model and fuzzy TOPSIS methodology that requires few judgments from the decision makers to parameterize supplier evaluation. However, the authors in a manner alike to preceding studies disregard collecting execution data.

Furthermore, evaluating suppliers in long periods such as six months or a year can cause delay for the manufacturer in terms of detecting whether the supplier is problematic or not. This situation yields waste of resources and time that is caused by the suppliers' problems being hidden in the long-time interval. Collecting data at different long-time intervals is prone to information loss and may give rise to incorrect assessment results. For these reasons, there is a strong need of continuous systematic evaluations of suppliers in the manufacturing environment. This paper proposes a new model with a dynamic structure that constantly reviews suppliers and handles the calculating and monitoring of performances during the receipt of each supplied item via Enterprise Resource Planning (ERP). Also, this study differs from previous studies by focusing on performance evaluations of existing suppliers with collecting realized data as to better fulfil the supply needs. Moreover, the real case study that contributes to the literature is carried out in a medium-sized company. Up to now, usually hypothetical data is seen to be used in the literature. Also, indicating this, Wetzstein et al. (2016) reviewed supplier selection methods from 1990 to 2015. They determined that a great majority of the sampled literature are not validated in a real company environment. In addition, a supplier evaluation survey was conducted on small to medium-sized enterprises (SMEs) and another important contribution of this study is to show that the supplier evaluation can be implemented to SMEs.

This paper is organized into multiple parts. Initially, literature search synthesis is provided. Next, main findings and results of research in SMEs are analysed. In the fourth section, the developed continuous supplier evaluation model is expressed and then implementation of the proposed model is presented with a real case study in the fifth section. Finally, conclusions are presented and suggestions for future researches are proposed.

LITERATURE REVIEW

This study focuses on performance evaluation of suppliers that are currently being worked with while collecting realized data, particularly SMEs. In this context, the literature survey is examined in two phases. Firstly, ERP usage for supplier evaluation systems is investigated. Next, literature especially related to SMEs is examined.

The Use of the ERP System for Supplier Evaluation System

ERP is an information system that combines all the company functions by using a common database. It is characterized primarily by its capability for the services of material planning, order entry, accounting, and shop floor control. Kelle and Akbulut (2005) remark that the capabilities of real-time tracking and the internal process integration are important tools of ERP. However, Ge and Voß (2009) mention that the prospering implementation rate is still low and many firms have not utilized the entirety of benefits that ERP systems yield. In addition, Wu (2011) states that ERP implementations are complicated and pricey. Therefore, ERP systems' capabilities for supplier performance management and supply chain remain as a research issue.

Ho (2007) investigates adopting a lot of sizing rules that can be used in an ERP based supply chain and based on the discussion of experimental results, lead time uncertainty indicates impairment of the performance of ERP based supply chain systems. Similarly, Maguire et al. (2010) examine the ERP system implementation process. They highlight the specific problems of large firms that manage disparate legacy systems. Forslund and Jonsson (2010) focus on ERP system lifecycle phases. They determined that a lot of supply chain performance management improvements can be realized within the usage stage of an existing ERP system. The paper is explorative, and the different premises on larger statements are required to be tested. Furthermore, Lin et al. (2011) suggest an ERP model for supplier selection in electronic industry using multi-criteria methods. However, evidence of implementation showing that this methodology is integrated into ERP software in this paper is not seen. In addition, authors do not consider the supplier performance evaluation process; they are merely focused on the selection problem. Hwang and Min (2013) investigate the role of ERP in the supply chain, developing a series of hypotheses and assessing key factors influencing the ERP adoption. Similarly, Ince et al. (2013) examine the dimensions of supply chain management practices and ERP systems. Their findings show that the dimensions have favourable influences on firm performances and competitive advantages. Boza et al. (2014) focus on the requirements for new developments in ERP systems, aiming at identifying the role that interoperability plays in the evolution of ERP systems. In this study, the authors discuss the initiatives in the ERP field within interoperability frameworks in terms of technological and business perspectives.

It is obvious that ERP systems have an important role in supply chain management practices. However, up to this date in the literature, relative evaluation methods taking advantage of ERP applications in supplier performance have not been fully explored. Many of the previous studies have mostly considered the issues encountered during implementation of ERP. This study evaluates existing suppliers continuously through ERP, considering its capability of real-time monitoring.

Supply Management in SMEs

SMEs are crucial in today's business environment as they are a trigger of innovation and an important input for a country's development. However, small and medium sized companies have restricted resources than larger ones, and therefore, the management of procurement processes can be more complex.

Mudambi et al. (2004) investigate cooperative purchasing practices in SMEs and classified them as follows: (1) firms with long-term management policy, (2) close-but-adversarial type firms, and (3) firms without a formal purchasing strategy. This study helps the reader have a better understanding of how compatible supplier connections are implemented in SMEs. Likewise, Morrissey and Pittaway (2006) analyse the purchasing relationships from the viewpoint of SMEs. They determined the significant role of social factors in the management of suppliers. Considering the adequateness of supplier, Redondo and Fierro (2007) studied the supplier relationships. Their findings show that the termination of a relationship between a firm and its supplier proves the need of a re-evaluation of the supplier. Pressey et al. (2009) investigate SME purchasing practices such as strategic activity, evaluation system,s and supplier capabilities through a survey. They determined that many firms have not been the subject of systematic supplier evaluations.

Jurová and Sutormina (2010) divide the evaluation process into two parts such as for new suppliers and for existing suppliers for small and medium-sized companies. For existing suppliers, they determined evaluation criteria and evaluated a middle value for different suppliers such as manufacturing, services, and markets. However, there is no methodology of calculation for the evaluation of suppliers in their study. For decision making in evaluation for supplier selection, Zhang et al. (2012) propose a hybrid methodology combining the multi-criteria method and activity-based costing. The proposed hybrid model was applied to a small-sized firm in the electronic manufacturing industry to show its feasibility. In their study, the conceptual framework of the hybrid decision model is established but further work is needed to enhance practical implementations.

As the literature reveals, there is little research on SMEs and the current studies are focused on supplier selection rather than evaluation. This paper attempts to consider the supplier performance evaluation from the perspective of SMEs.

A SURVEY ON SUPPLIER EVALUATION AND PROBLEM ANALYSIS IN SMEs

Based on a literature survey, the key issues were identified. The first one, assessing suppliers in the supplier selection process, has been widened, but there is a scarcity of studies on supplier evaluation depending on the difficulty. Secondly, there is a lack of use of ERP to evaluate suppliers in the industry. In addition, there is a paucity of research on SMEs. In light of these, it is seen that the studies mostly focus on supplier selection activities for especially large firms. Similarly, Ellegaard (2006) states that existing literature on SMEs in general pays little attention to supplier performance management. Moreover, the general belief of most of the studies is that supplier development is thought to be of little importance due to many SMEs' limited resources (Pressey et al., 2009; Quayle, 2000; Williams, 2006). To complete these shortcomings, this study contributes to the literature, investigating whether the SMEs in Turkey have been the subject of supplier evaluation activities. This research conducts a questionnaire out of 106 respondents to determine the extent of supplier evaluations and ERP usage in SMEs. Statistical analysis of the survey results was made by SPSS software. Table 1 displays the survey results. According to the results, most respondents, excluding 29.2 percent of them, choose not to be decisive to evaluate their suppliers. Regarding this, 61.3 percent of the respondents evaluate their suppliers but 88 percent of them evaluate once a year. Moreover, 50 percent of respondents, in other words, 82 percent of which evaluate their suppliers, attain the related results according to declarations of their suppliers. Expressly, they conduct a questionnaire to their suppliers to evaluate them. Namely, only 11.3 percent of companies evaluate their suppliers realistically; however, this evaluation is under the initiative of their relevant staff since there is no data in the execution records. Also, whether these companies use historical data about former behaviour of suppliers was researched. It is seen that only 1.88 percent of respondents, which evaluate their suppliers, use past data directly when evaluating them. Moreover, none of the respondents use ERP while evaluating their suppliers.

Table 1. Frequency distribution of research data.

		Frequency	Percent
Do you think supplier evaluation is necessary?	Exactly	31	29.2
	Just an obligation of quality sys.	29	27.4
	Loss of time	12	11.3
	May be useful	34	32.1
Do you evaluate your suppliers?	No	41	38.7
	Yes	65	61.3
How frequently you evaluate suppliers?	Once a month	2	1.9
	Once a year	57	53.8
	Twice a year	6	5.7
How do you evaluate suppliers?	by a survey among suppliers	53	50.0
	by asking their relevant staff	12	11.3
	using past data	2	1.88
	by using an ERP system	0	0

Table 2 investigates if a relationship between ERP and supplier evaluation exists. The percentage of companies that have the ERP system is 39.6 percent. There is no ERP system in 92.7 percent of companies that do not evaluate suppliers; in addition, the ERP system is available in 60 percent of the companies that evaluate their suppliers although they do not use ERP while evaluating suppliers.

Table 2. Examination of cross-tabulation for the presence of ERP system and supplier evaluation.

				Is_there_any_ERP_system		Total
				No	Yes	
Do_you_evaluate your_suppliers	No	% within (count)	Do_you_evaluate_your_suppliers	92.7% (38)	7.3% (3)	100,0% (41)
		% within	Is_there_any_ERP_system	59.40%	7.10%	38,70%
		% of Total		35.80%	2.80%	38,70%
	Yes	% within (count)	Do_you_evaluate_your_suppliers	40.0% (26)	60.0% (39)	100,0% (65)
		% within	Is_there_any_ERP_system	40.60%	92.90%	61,30%
		% of Total		24.50%	36.80%	61,30%
Total		Count		64	42	106
		% within	Do_you_evaluate_your_suppliers	60,40%	39.60%	100.00%
		% within	Is_there_any_ERP_system	100,00%	100.00%	100.00%
		% of Total		60,40%	39.60%	100.00%

In this study, the impact of using ERP on the supplier evaluation is tested by using chi-square test of independence method. H_o and H_1 hypotheses are established as follows and Table 3 shows that the p-value, denoted by "Asymp.Sig. (2-tailed)", is .000. It means that if p-value is less than the chosen significance level (0.05) then the null hypothesis (H_o) is rejected.

H_o= Using ERP does not have an influence on the supplier evaluation.

H_1= Using ERP has an influence on the supplier evaluation.

Table 3. Chi-Square Tests.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	29 .168(b)	1	.000		
Continuity Correction(a)	27 .008	1	.000		
Likelihood Ratio	33 .392	1	.000		
Fisher>s Exact Test				.000	.000
N of Valid Cases	106				

a Computed only for a 2x2 table.

b 0 cells (.0%) have expected count less than 5. The minimum expected count is 16.25.

As a result, it is seen that using ERP influences supplier evaluation. Likewise, companies using the ERP system can evaluate their suppliers easier because required data from the database of ERP system can be retrieved and used comfortably during evaluation. With this aim, in this study a model is developed taking advantage of ERP in a manner that can be implemented at SMEs.

THE PROPOSED MODEL WITH DYNAMIC STRUCTURE

This paper presents a dynamic model that makes assessment in each delivery that updates the evaluation score continuously depending on the entry of goods. This offers the possibility to be able to attain the current information at any time. The proposed model named "continuous supplier evaluation model" includes the structures of performance calculation and monitoring. Figure 1 illustrates the continuous performance calculations that comprise the three phases including item-based, waybill-based, and supplier-based evaluations, respectively. The structure starts with the registration of the supplied item to ERP, through the relative phases, and ends with the acquisition of the current performance of the supplier. For all phases, scores over the four fundamental aspects as quality, financial, delivery, and total are derived.

Note that the developed supplier evaluation application is under the purchasing module of ERP. For this, primarily, supplier registration is required to the database, so the supplier card is created consisting mainly of the company name, contact information, and location. Moreover, the performance scores of some evaluation factors such as quality system, lead time, and communication are registered on the supplier card.

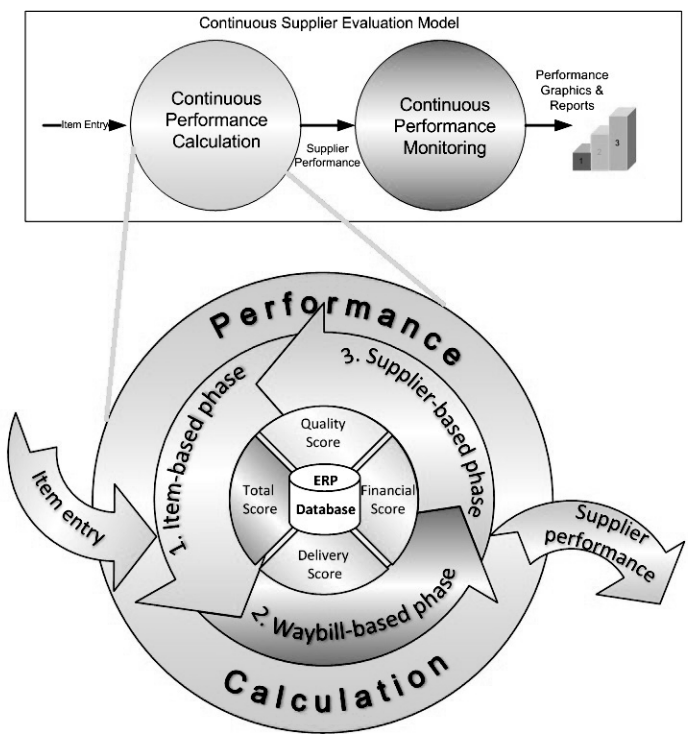

Fig. 1. The structure of continuous performance calculation.

Item-based evaluation contains a calculation with different criteria weights according to the supplier type such as dealer or manufacturer as seen in Figure 2. After suppliers' types are determined according to the supplier code, the questions of waybill no, stock code, and current packaging status are asked to the user. Then, using this information, the dataset includes due date, delivery date, requested quantity, and delivered quantity, and data are pulled from the database of ERP. Note that pre-setting of waybill is looked for before asking questions about waybill conformity because the question of waybill conformity is asked only for the first item in the waybill and this answer is used for the other items for same waybill. This way, at the item-based phase, each item in each waybill is evaluated one by one and four item scores as quality, financial, delivery, and total are derived. Note that item scores are calculated using evaluation scores of items and the criteria weights (seen Table 4). Definitions of the criteria are explained in detail in the implementation section.

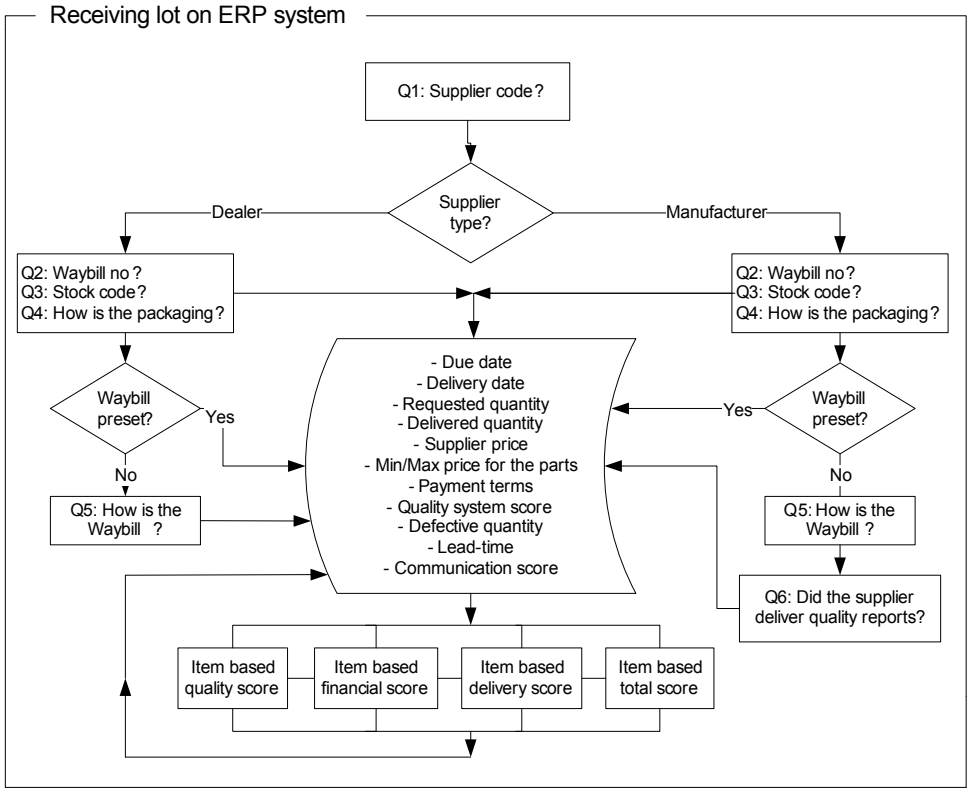

Fig. 2. Flowchart of item-based evaluation.

In the second phase, waybill-based scores, which are derived from item-based evaluation scores and each line in the waybill, are weighted by their costs. By weighting with the costs in the equation, the waybills with higher costs are made more effective in terms of score. The waybill-based scores are calculated as Equation (1) given below.

$$Waybill\ based\ score\ for\ quality\ criterion = WS_Q = \frac{\sum Item\ Based\ Quality\ Score_i \times Cost_i}{\sum Cost_i}$$

$$Waybill\ based\ score\ for\ delivery\ criterion = WS_D = \frac{\sum Item\ Based\ Delivery\ \ Score_i \times Cost_i}{\sum Cost_i} \quad (1)$$

$$Waybill\ based\ \ score\ for\ financial\ criterion = WS_F = \frac{\sum Item\ Based\ Financial\ \ Score_i \times Cost_i}{\sum Cost_i}$$

where i is item number, $score_i$ is the item-based score, and $cost_i$ is the cost for waybill row.

The waybill-based scores are the core of the calculation of supplier evaluation scores. The Waybill Score (S) is the general total of the item based scores as shown in Equation (2).

$$\text{Waybill Score (S)} = WS_Q + WS_D + WS_F \quad (2)$$

In the third phase, supplier evaluation score at any time is calculated by using the waybill scores. Supplier performance score is the cumulative of all waybills of the supplier. The user could check the scores for a supplier at any time in the past. For this, the user has to enter the supplier code and the date they want to check the supplier score. Once the user enters the date, the system checks all the waybills from that supplier up to that entered date and calculates the supplier score by using Equation (3).

$$Supplier\ Score = \frac{\left[\sum(W_p \times S_p \times C_p) + \sum(W_r \times S_r \times C_r) + \cdots + \sum(W_n \times S_n \times C_n)\right]}{\left[\sum(W_p \times C_p) + \sum(W_r \times C_r) + \cdots + \sum(W_n \times C_n)\right]} \quad (3)$$

where *p*, *r*, *n* are time interval, and the parameters of *W*, *S*, *C* indicate:

W = Weight for time interval of the waybill. While calculating supplier score, suppliers' past term scores are taking into account considering the weights for time values.

S= Waybill Score for related time interval derived from Equation (2).

C= Waybill Cost for related time interval.

The developed model also offers the possibility to monitor the supplier's performance. Namely, it initially calculates the supplier performance for any supplier at any time, and the supplier behaviour can be monitored. Figure 3 illustrates the characteristics of performance monitoring. Supplier could be in an improvement or deterioration trend.

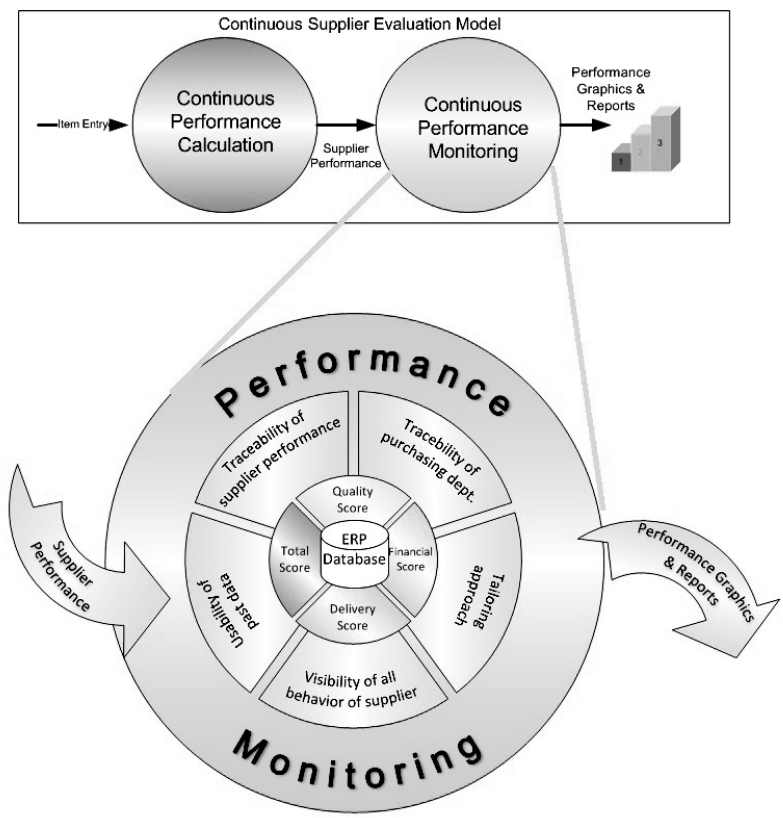

Fig. 3. The characteristics of the structure of continuous performance monitoring.

With the feature of traceability, the manufacturer can take proactive actions and prevent probable problems caused by the supplier. This helps the manufacturer and the supplier save time while reducing costs.

As seen in Figure 3, the proposed system also allows traceability of purchasing department as well as supplier performance. The major goal of the purchasing department is to make the suppliers perform better, have better delivery times, and deliver high quality material with appropriate financial situations. So, concisely it could be said that the purchasing department is as successful as the suppliers, and the supplier scores are performance criteria for the purchasing department. With this aim, a single score is calculated as if all suppliers were a single company in this model for the performance of purchasing department.

Another characteristic of the proposed model is tailoring approach considering the particular requirements; hence a company can establish their evaluation systems. For example, in case that a company wants to avoid very old records, the time interval should be changed into a shorter time period using zero weights before a certain date. Besides, the company can make all waybills in the past have the same effect by setting these weights equal. In other words, it is up to the company to decide the interval weights according to their conditions. This system also permits using past data on the historical performance of suppliers and determines if the supplier falls below a minimum rating based on the predefined criteria. If traditional methods were used, only the current situation of the supplier would be seen. Moreover, if the supplier is under the lower limit at the time of evaluation, they could directly be eliminated without evaluating its previous dispatches. Furthermore, suppliers may know when they are going to be evaluated and be more cautious during the evaluation period if they are evaluated periodically. In such a case it is difficult to evaluate the supplier fairly. The developed system provides an opportunity of monitoring the whole behaviour of the supplier from the date on which it was started to work with the supplier to desired date.

IMPLEMENTATION OF THE PROPOSED MODEL

The real case study is carried out in a middle-sized enterprise. The company is one of the leading band saw machine manufacturers in Turkey and has a wide market including North America, Europe, Middle East, and domestic market.

Description of the Case

The company where the case study was carried out has 133 active suppliers and the cost of components bought by the company per product from suppliers approximately makes up of 60% of total production cost. So, it is very crucial for the company to handle purchasing activities properly.

Purchasing orders issued to suppliers contain the information of delivery time and the delivery amount of related parts. According to this, all the parts are controlled in terms of quantity and time as well as quality, when they are delivered by the supplier. In the company, before entering to the stocks, each part must be accepted by quality controllers. If they fail to pass from an incoming inspection they are marked as defective or rejected.

Continuous Supplier Evaluation at Each Delivery via ERP

The developed model makes it possible to determine the appropriate score in the calculation of performance by analysing the company's needs. In this case, the suppliers are evaluated out of 100 score, determining the proper values to the related criteria according to expert opinions.

The proposed model evaluates the suppliers according to three main criteria including quality, financial, and delivery affecting the supplier performance. Moreover, there are sub-criteria that are used to determine performances on each main criterion as seen in Figure 4.

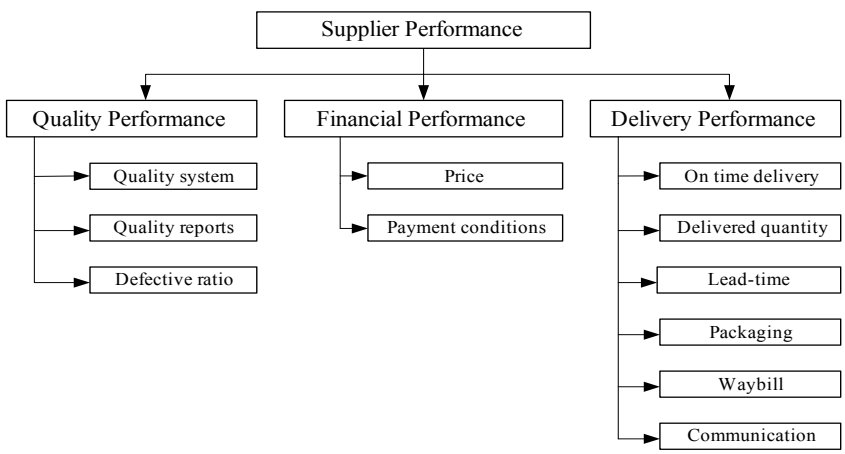

Fig. 4. Supplier evaluation criteria.

The case company primarily assesses the suppliers according to their types. There are three supplier types: manufacturers that have manufacturing process, dealers that keep the parts for the company and procure them, and hybrid companies that have both manufacturing process and sell goods. Evaluation criteria weights according to the supplier type are determined based on expert opinions in the case company and are given in Table 4. The weights of evaluation criteria could be changed according to their importance for the company. Also new supplier types with different evaluation weights can be derived.

Table 4. Weights of the evaluation criteria according to the supplier type.

Evaluation Criteria		Weights for Supplier Type		
Main Criteria	Sub-criteria	Manufacturer	Dealer	Hybrid
Quality Performance	Quality System	7	10	5
	Quality Reports	8	-	10
	Defective Ratio	20	10	20
Financial Performance	Price	20	25	20
	Payment Terms	5	5	5
Delivery Performance	On-time Delivery	18	23	18
	Delivered Quantity	7	8	7
	Lead Time	4	5	4
	Packaging	4	6	4
	Waybill	4	5	4
	Communication	3	3	3
Total		100	100	100

As mentioned before, three main criteria together with sub-criteria are determined to evaluate the suppliers. For instance, "quality performance" main criterion is examined by three sub-criteria namely; quality system, quality reports, and defective ratio. *Quality System* indicates its existence and effectiveness. Quality system documents are requested from each supplier and quality system score is determined according to this. Note that a supplier card is defined in the database in which information about the supplier exists for each supplier. Also, quality system score is located in the supplier cards. *Quality Reports* indicate whether or not the supplier provided related quality documents together with the parts at the delivery. The activity of this sub-criterion is carried out in each delivery.

Defective Ratio stands for the defective part percentage in the relevant lot. It depends on both initial inspection and defects detected during the production process. Table 5 shows the probable choices for the defective ratio and their related scores determined by expert opinions.

Table 5. The elaborated rates of defective ratio.

Defective Ratio	**Score**	**Defective Ratio**	**Score**	**Defective Ratio**	**Score**
% 0-0.5	100	% 2-3	60	%6-10	20
% 0.5-1	85	% 3-4	50	%10-20	10
% 1-2	70	%4-6	30	>%20	0

There is no doubt, financial parameters are very important for supplier evaluation. Financial evaluation is based on two sub-criteria, namely, price and payment conditions. *Price* sub-criterion is for making a comparison between the prices of the relevant supplier and the other suppliers defined in the database. If the supplier is unique, there is not any other supplier for the part; it takes 80 points. If the price is lower than the lowest price in the system, it takes 100 points. If the price is higher than the lowest price in the system, Equation (4) is applied to calculate the score.

$$PS = (1 - (SWP - LP)/LP) \times 100 \quad (4)$$

where PS is price score for non-negative values, SWP is supplier waybill price, and LP is the lowest price.

Payment Conditions are also an important criterion while evaluating a supplier. Companies prefer long payment terms. Therefore, the scores for different payment conditions are defined in the database according to the company's needs.

Delivery performance is the third main criterion in the proposed methodology and is considered as six sub-criteria as follows:

- *On time delivery* sub-criterion indicates the delivery of parts exactly on time. Both early and late deliveries are avoided. If a delivery is on time, the supplier gets full points. If the delivery is late, some points are deducted from the on-time delivery points and on time delivery performance (ODP) is calculated according to Equation (5) below. If the delivery is early, fewer points are deducted from the ODP according to Equation (6) below.

$$ODP = 100 - \frac{\left(100 \times (delivery\ date - requested\ date)\right)}{Lead\ time} \quad (5)$$

$$ODP = 100 - \frac{\left(50 \times (requested\ date - delivery\ date)\right)}{Lead\ time} \quad (6)$$

In both cases, on-time delivery performance score should not be lower than zero.

- *Delivered Quantity* sub-criterion indicates the delivery of parts with the exact quantity ordered. Both excessive and incomplete deliveries are avoided. If a delivery is of exactly ordered quantity, the supplier gets full points. If the delivery is incomplete, some points are deducted from the requested quantity points and delivered quantity performance (DQP) is calculated according to Equation (7) below. If the delivered amount is excessive, fewer points are deducted from the DQP score according to Equation (8) below. Note that, in both cases, ordered quantity performance score should not be lower than zero.

$$DQP = 100 - \frac{\left(100 \times (requested\ \text{quantity} - \text{delivered quantity})\right)}{requested\ \text{quantity}} \quad (7)$$

$$DQP = 100 - \frac{\left(50 \times (\text{delivered quantity} - requested\ \text{quantity})\right)}{requested\ \text{quantity}} \quad (8)$$

- *Lead-time* sub-criterion indicates the evaluation of conformity of the lead times offered by the supplier. It is also located on the supplier cards and this score is acquired depending on the type of the piece procured. For example, one week is a long lead-time for some parts that do not have a manufacturing process, whereas it is very short for the parts that have a manufacturing process. Note that every supplier has a supplier card in the database in which information about its company exists.
- *Packaging* sub-criterion indicates shipping with proper packaging and the packaging score is determined according to Table 6.
- *Waybill* sub-criterion indicates the preparation of the appropriate waybill together with the related stock codes for the parts. The waybill status is evaluated whether it is appropriate, adequate, or not appropriate (scored as 100, 50, and 0, respectively). The waybill score does not alter from item to item in the same waybill.
- *Communication* sub-criterion indicates the evaluation of how well the communication with the supplier is. The communication score is determined according to answers given in Table 6.

Table 6. The elaborated sub-criteria and related scores.

Packaging		**Communication**	
Conditions	**Score**	**Conditions**	**Score**
Perfect	100	Very good. We can easily get in contact with the responsible, they frequently visit us, and they can easily understand our concerns.	100
Good	75	Good. We can easily get in contact with the responsible, but they do not frequently visit us, they can easily understand our concerns.	75
Adequate	50	It's OK. We can get in contact with the responsible by phone, but they do not frequently visit us. Also sometimes we have problems about explaining our concerns.	50
Bad	25	Problematic. Usually we cannot get in contact with the responsible. We have problems about explaining our concerns.	25
Very Bad	0	Very bad! It is impossible to find a responsible. They don't even care about our concerns.	0

In order to calculate the supplier performance, the weights as shown in Figure 5 **(**representing number 1) are used in this case to make newer waybills more effective on the score. The weights 120, 60, 30, 10, and 2 are used considering for time intervals, respectively, in the last one month, two to three months, four to six months, seven to twelve months, and older than a year. While evaluating suppliers, a reference date that is desired to check the supplier score from the supplier performance screen shown with number 2 is determined.

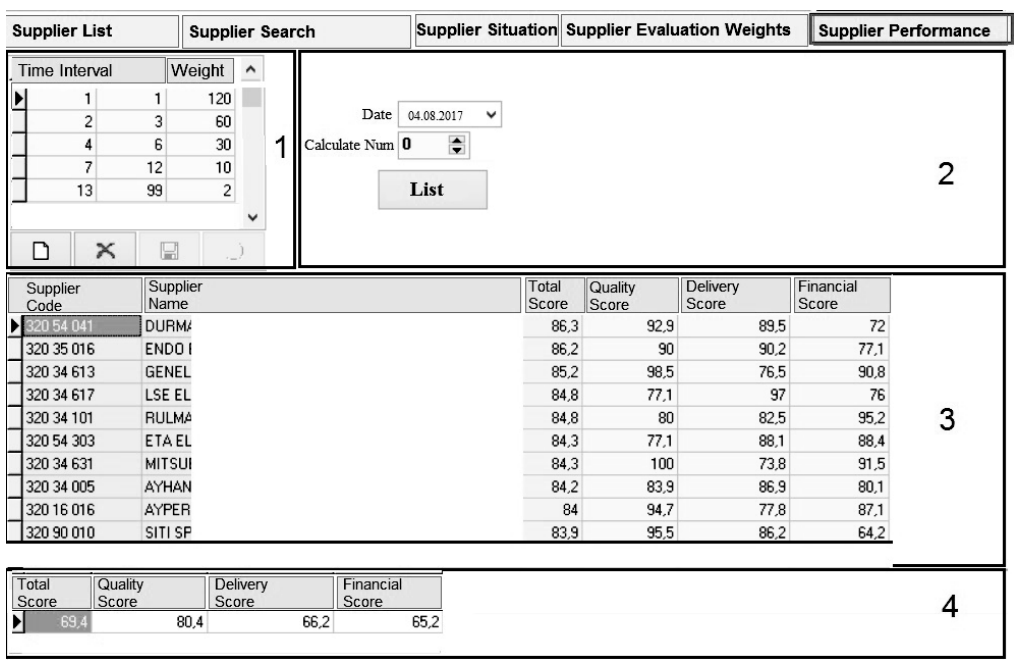

Fig. 5. The screen of performance calculation for supplier evaluation in ERP.

For example, the system checks all the waybills up to the entered date of 4 August 2017 as seen in Figure 5. Then, using Equation (3) given in section 4, the system calculates the supplier scores, which are also shown in the same screen with number 3. So, the scores of total, quality, delivery, and finance are obtained separately as the cumulative performance since the date was started to be worked with the supplier. Lastly, the evaluation score for the purchasing department could be seen with number 4 in Figure 5.

To trace the behaviour of supplier, once the user selects a supplier and desired time interval in the supplier situation screen, the supplier scores in the selected period are calculated and the related monthly graph is created as seen in Figure 6.

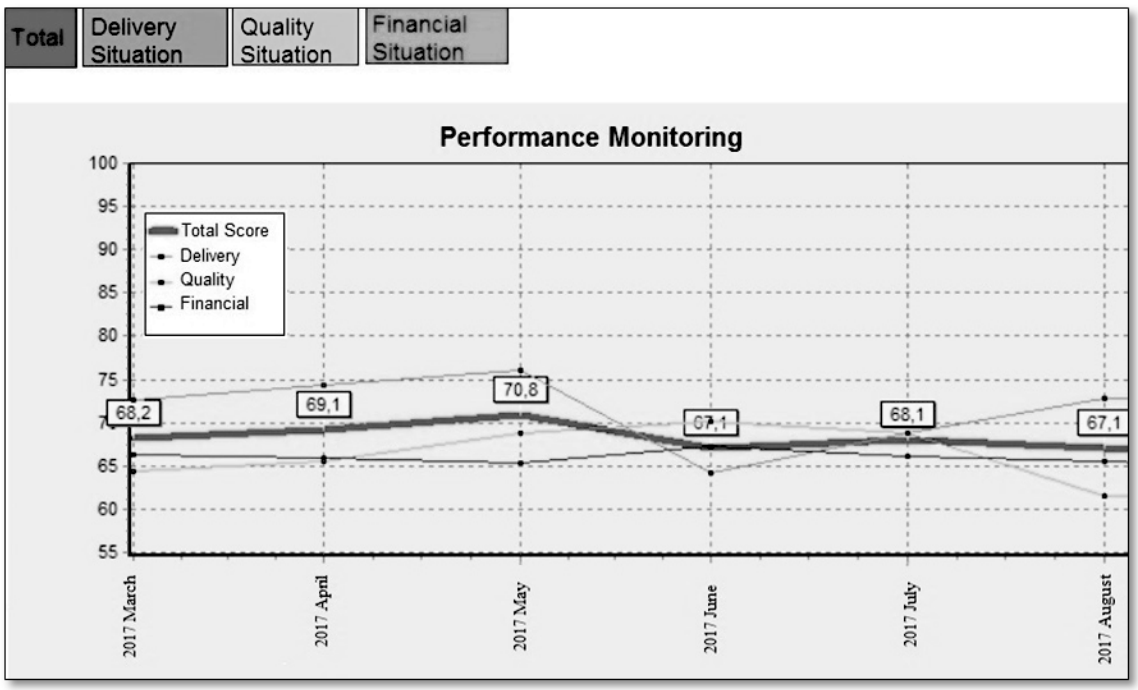

Fig. 6. A sample graphic of performance monitoring for a supplier in ERP.

The thick curve in the graph indicates the total score of the supplier where other curves indicate delivery, quality, and financial scores. The advantage of this system is its ability to display all sub-scores for the supplier. So, the decision maker is able to see the drawbacks of the supplier more clearly. Also, benefiting from the suppliers monitoring structure, at the beginning of every month, the purchasing department of the case company prepares the reports indicating the score of related month for each supplier and sends them a warning if there is a drop in the scores.

CONCLUSIONS

Supplier evaluation is one of the important components in the effective management of the supply chain. Especially in SMEs, the evaluation of suppliers and long-term cooperation with the right suppliers have a strategic significance due to their limited resources. This paper proposes a continuous supplier evaluation model showing that it can be implemented in SMEs. The implications or benefits of the proposed model are described below.

- This research conducts a questionnaire to determine the extent of supplier evaluations and ERP usage in SMEs. The findings demonstrated that using ERP influences supplier evaluation. This result encouraged the development of a model taking advantage of ERP in a manner that can be implemented at SMEs in this study.
- This study differs from previous studies by focusing on performance evaluations of suppliers that are currently being worked with, while collecting realized data during the receipt of each supplied item via ERP. Based on a literature survey, assessing suppliers in the supplier selection process has been widened, but there is a scarcity of studies on supplier performance evaluation depending on the difficulty. Moreover, they would ignore taking execution data and use only decision makers' opinions, but these include subjective judgments. In this regard, this study contributes to the literature in order to complete these shortcomings.

- An important novelty of this model is that suppliers can be continuously evaluated from the date was started to be worked with them to desired date. This model can calculate the supplier score at each delivery that updates the evaluation score continually depending on the entry of goods. This offers the possibility to be able to attain the current information at any time. This enables the managers to realize the problems as early as possible and to make supplier development action plans, providing the opportunity to constantly review suppliers.
- Another contribution of the proposed model is tailoring approach considering the particular requirements; hence a company can establish their evaluation systems. For example, in case a company wants to avoid very old records, the time interval should be changed into a shorter time period using zero weights before a certain date. Besides, the company can make all waybills in the past have the same effect by setting these weights equal. In other words, it is up to the company to decide the weights for time interval according to their conditions.
- The developed system provides an opportunity of monitoring the whole behaviour of the supplier over the four different performance scores including quality, finance, delivery, and total. Moreover, it helps to follow the trend of the supplier; thus, it allows managers to take precautions about matters that may be troubled.
- This study also considers the calculation of evaluation score for the purchasing department. A single score is calculated as if all suppliers were a single company in this model for the performance of purchasing department.
- The proposed model is implemented to prove the validity in a middle-sized band saw machine company. All of the above calculations have been successfully embedded in the ERP system. Figures 5 and 6 are screenshots of the ERP system.

There may be some improvements on the proposed model in the future studies. This model already has a user warning system. Some additional warning conditions may be added. It could warn the purchasing supplier also if:

- The supplier has consecutive unsuccessful deliveries,
- The supplier score is decreasing for some months or deliveries,
- The supplier score is increasing for some months or deliveries,
- One or more of quality, delivery, or financial scores is below a certain level.

Another study for future work would be a dynamic part evaluation for supplied items that permit the decision maker to analyse critical items and identify strategic items. Also, alternative suppliers during the selection of the main supplier for specific parts can be compared.

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نموذج جديد من أجل التقييم المستمر من الموردين مع التنفيذ الحقيقي للبيانات

اسرا كورت تيكس، فاتح كار وجنجيز توكل
قسم الهندسة الصناعية، جامعة ساكاريا، ساكاريا، تركيا

الخلاصة

يعتبر تقييم المورد عملاً هاماً للشركة من أجل تحسين الإنتاجية والربحية. عندما يتم تطوير تقييم المورد الذي يتم إدارته بشكل جيد، يكون لذلك تأثير كبير على القدرة التنافسية لسلسلة التوريد بأكملها. من خلال دراسة الأعمال المنشورة، فقد لوحظ أن الكثير من الأبحاث ترتبط بالتقييم أثناء عملية اختيار الموردين الجديدة. ومع ذلك هناك ندرة في الدراسات التي تُقيم الأداء حسب الصعوبة. إن الغرض من هذا البحث هو التركيز على تقييم أداء الموردين الذين يتم العمل معهم حالياً. وفي هذا السياق، تمت دراسة استخدام تخطيط موارد المؤسسة من أجل جمع وتتبع البيانات في الوقت الحقيقي لأنظمة تقييم الموردين، وخاصة فحص المؤسسات الصغيرة ومتوسطة الحجم. بعد ذلك، وبالرجوع إلى نتائج هذه الدراسة، تم تطوير نموذج تقييم جديد بهيكل ديناميكي باستخدام تخطيط موارد المؤسسة الذي يراجع الموردين باستمرار في كل عملية تسليم. وعلاوة على ذلك، تم تنفيذ النموذج المُطور في شركة تصنيع الماكينات متوسطة الحجم، حيث تم دمجه في وحدة الشراء لنظام تخطيط موارد المؤسسات. وأكد مديرو الشركة النموذج المُقترح، وتقوم شركة التصنيع باستمرار بإجراء تقييم منهجي بهذا النموذج، مما يُسهل تحقيق أهداف إدارة سلسلة التوريد مثل تخفيض تكلفة المخزون، زيادة هامش الربح ورضا العملاء.