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Designing a model for profile monitoring of the supplier cooperation with risk

Poorya Naseri[1], Mortaza Abbasi[2], Karim Atashgar[3]
1 (Malek Ashtar University of Technology, Tehran, Iran
2 (Malek Ashtar University of Technology, Tehran, Iran
3 (Malek Ashtar University of Technology, Tehran, Iran
Corresponding Author: Poorya Naseri

Abstract
The ability to monitor supplier performance is a critical capability to maintain a strong organization-supplier relationship, especially for organizations where the supplier plays a significant role in their end product and market retention. This article examines the cooperation model with the supplier and monitoring the cooperation strategy over time by continuously monitoring the performance of the supplier over time. For this purpose, a multivariate multiple profile monitoring model is presented considering the risk conditions in two stages for monitoring the supplier's unforeseen costs. In the first step, criteria and indicators are extracted to evaluate the delivery process, quality, as well as the risk function according to library resources and the opinion of experts and elites of the industry. In the next phase, in the first phase of monitoring, using the Hotelling's T^2 Statistic Based on the Successive Differences, the parameters of the model are calculated and monitored, and in the second phase, the likelihood ratio method is used to monitor the supplier's unanticipated cost over time, in order to If there is a warning, show the control chart as soon as possible. This model has been implemented in the automotive industry of Iran Khodro Company and the supplier of gearbox parts by Niro Travezah Company.
KEYWORDS; *supplier cooperation, delivery,quality, risk, supplier's unforeseen cost, Hotelling's T^2 Statistic Based on the Successive Differences, likelihood ratio method*

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I. INTRODUCTION

In today's business world, organizations need to improve productivity and innovate to survive. With rapid market changes, organizations in new markets seek to focus on improving productivity, technology development, supplier and relationships. For this reason, buyer-supplier relations play an important role in achieving successful business results [1]. Today, one of the important responsibilities of company managers is to evaluate the performance and monitor the suppliers who provide raw materials, compounds and services necessary for the production of domestic products. Today, supply is no longer based solely on the price and due to the increase in competition and the expansion of relationships, other criteria such as quality, delivery, flexibility, etc. are also included. Therefore, there is a need for robust evaluation models that can actively monitor multiple supplier metrics.

Many researchers have pointed out the important role of buyer and supplier relationships in achieving successful business results [2, 3 and 4]. Long-term partnerships between buyers and suppliers are essential in supply chain operations. In order to establish such a relationship, buyers must continuously monitor the performance of suppliers through various variables and provide feedback for improvement [5]. The Supplier monitoring is an independent but interconnected process that follows the supplier selection process [6]. In addition, in order to be able to provide suppliers with the necessary information about buyers' expectations about performance, buyers should regularly measure and monitor suppliers' performance in terms of tangible and intangible criteria [5]. Morgan and dehurst (2008) evaluates the concept of using control charts to examine the performance of supplier delivery to retail distribution centers and its relationship to availability on retail store shelves [7]. Cousins et al. (2008) develop a model that shows that socialization mechanisms play an important role in mediating the relationship between supplier performance metrics and performance outcomes [8]. Autry et al. (2010) dynamic wheel linkages between the strength of the relationship and the performance of a buyer - supplier relationship in a longitudinal environment, using a spiral model of power-examine the performance of the relationship [9]. Gregory and Colleagues (2010) explore the use of three types of verification strategies - monitoring, guarantees and verification - that may be used to protect against Trust vulnerabilities in buyer-seller relationships [10].

Chen and Wu (2010) showed that companies can minimize transaction costs through strong partnerships. The more companies outsource their non-core business processes, the more important the ability to effectively manage supplier relationships [11]. Storey and Hilmer (2013) examine how in relationships between buyer and supplier two capabilities of PRM systems (communication and completion capabilities) and two mechanisms of partnership governance - formal (certification control) and informal (service support) - reinforce each other [12]. Pernot and Roodhooft (2014) explores the relevance of appropriate management control system design (MCS) of supplier relationships to good performance [13]. Maestrini et al. (2017) propose an innovative buyer-supplier performance measurement system (PMS) (called relationship regulator), with the aim of stimulating cooperation in mutual performance [14]. Li et al. (2017) provide a better understanding of the role of active it interactions in supplier-buyer cooperation. This study presents conceptual distinctions between formal and informal it-based interactions and their various roles in supplier-buyer cooperation [15]. Vilna and Craig head (2017) used dual data to examine the impact of asymmetry on the performance of buyer-supplier relationships [16]. As mentioned by Son (2016), supply chain managers should be equipped with methods to better evaluate aspects of their strategic relationships that should focus their attention [17]. Faraz et al. (2016) cared that both strategic buyer supplier partners (Type A) should have the same understanding in terms of relationships with each other. They thought that when there were disagreements between buyers and suppliers, the performance of the supply chain would deteriorate significantly [18]. Hence, Faraz et al. (2018) designed a T2 control chart to control disputes over time to monitor buyer – supplier relationships [19].

Autry et al. (2014) further divided the literature on buyer-supplier relations into two major research streams. The first focuses specifically on intangible social relationships between the buyer and the supplier, while the second stream focuses on tangible relationships that connect both organizations [20]. However, even with these developments and extensive research streams, important questions remain about how to successfully manage and monitor buyer-supplier relationships. Of particular importance is the identification of methods that provide objective oversight to a process that relies heavily on subjective perceptions. With today's technology, this is certainly possible [19]. Asad Shafiq et al. (2017) provides methods to reduce the risk of supply sustainability. Drawing on agency theory, this research examines the relationship between sustainability and operational risk, supplier sustainability monitoring practices, supply improvement initiatives, and firm performance [21]. Surarksa and Shin (2019) presented a systematic supplier management framework for integrating the selection and monitoring processes of suppliers that are not independent of each other. Their proposed method combines a quantitative and qualitative approach and examines the differences in the set of supplier selection criteria and supplier monitoring. [22].

Gianakis et al. (2019) select and evaluate supplier sustainability by using the ANP method to obtain evaluation criteria related to sustainability and considering mutual relationships [23]. Pradhan and Rotroy (2018) unveil the Interpretive Structural Modeling (ISM) method for monitoring supply chain performance transparency in the presence of supplier development (SD) [24]. Torres-Ruiz and Ravindran (2017) by developing a decision-making model, they propose a supply sustainability risk assessment framework to mitigate potential supply chain sustainability risks for different supplier sectors and to create long-term partnerships by considering monitoring and reducing risk [25]. Mastrini et al. (2018) empirically investigate the relationship between two main methods of performance measurement and management (i.e. monitoring and incentives) and suppliers' operational performance. A theoretical framework is presented to identify the mediating effect of goal congruence and supplier opportunism in the direct relationship between monitoring/incentives and operational performance of suppliers [26].

Dunn et al. (2020) examine the relationship between consumer attitudes and supplier monitoring activities. In the results of this research, they emphasize that consumers value companies' SMA and point to an economic logic for a company's transparency in relation to efforts to monitor its suppliers [27]. In their article, Lee et al. (2020) monitor the environmental efficiency of suppliers in the presence of adverse outputs and dual-role factors with static and dynamic aspects, and their goal is to explain the main reason for the low efficiency of suppliers. They propose a modified data model by considering adverse output and dual factors [28]. Jaaskelianen (2021) explains the impact of strategic supplier relationships on inter-organizational performance management practices and states that in relationships With strategic suppliers, relational governance partially replaces performance information [29]. Asad Shafiq et al. (2022) using strategy literature on the alliances and literature of buyer-supplier relationship management suggest that efforts by a buyer company to actively develop cultural sensitivity and operational awareness to understand operational culture and routine of suppliers can improve some of the shortcomings of supplier monitoring [30]. Hu et al. (2022) examine the performance implications of peer monitoring in a multi-supplier context. Based on social exchange and agency theories, this study examines how, when, and why peer monitoring functions as a critical control mechanism to reduce opportunism among suppliers [31]. Changalima et al. (2023) investigated the role of supplier selection and supplier monitoring in public procurement efficiency in terms of cost reduction in Tanzania [32]. Kraus et al. (2007) and Petersen et al. (2005) suggest monitoring as a prerequisite for evaluating suppliers and then selecting those who are worthy of special relationship investments [33, 34]. Huang and Keskar (2007) and Itner et al. (1999) show that monitoring plays an essential role in the sourcing process. The existing studies that flow in the previous streams are mostly focused on the design of the monitoring system, that is, the proposal of conceptual frameworks and the selection of performance criteria, thus neglecting the real consequences of monitoring practices [35 and 36]. Carr and Pearson (1999) state that quality supplier monitoring has a positive relationship between buyer and supplier, which ultimately leads to improved buyer performance [37]. Other authors such as Prahinski and Fan, Heide et al. have investigated how the characteristics of supplier behavior are affected by the content and frequency or efficiency of behavioral monitoring [38 and 39]. Finally, Prahinski and Fan have studied other variables related to regulatory actions such as supplier commitment, Maham and Joshi, various components of buyer and supplier cooperation [40 and 41] and Cosens et al social mechanisms [42].

Most of the reviewed articles examine the effect of the type of selection and the cooperation strategy model with the supplier on its performance, or monitor and evaluate the supplier's performance without considering the cooperation model. But in this article, by combining these two issues with the continuous monitoring of the supplier's performance over time, it investigates the select of the cooperation model with the supplier and the monitoring of the cooperation strategy over time. In fact, with this work, the monitoring of the supplier's performance and the selection and monitoring of the cooperation strategy with it are examined over time. This integration helps the organization to avoid the huge loss of selecting a wrong strategy with the supplier. In this research, despite the previous researches that mostly monitored and evaluated the supplier qualitatively, a fuzzy regression model is used to integrate the performance variables and by considering the effects of these variables together, it monitors the performance of the supplier over time. And it uses the capacity of artificial intelligence to select the type of cooperation model with the supplier.

In reality, to monitor supplier performance, sometimes the relationships are functional and one variable to be monitored is explained with one or more other variables. For example, to monitor the cost variable, it needs to be defined by variables such as order costs, production costs, and logistics costs. Here the cost variable is defined as a dependent variable and order costs, production costs and logistics costs are defined as independent variables. It may be necessary for supplier monitoring to have several dependent variables that are functional relationships of several independent variables, and in some real cases, due to the correlation between the response variables, more complex models such as multivariate profiles, instead of simple linear profiles, is paid to model the performance of the process. In this case, if we ignore the correlation structure of the response variables by assuming separate profiles, misleading results are expected. For example, if we consider the delivery time process without the risk function, it will lead to the removal of efficiency suppliers who are disturbed in the process of delivery of parts and products at some point from the supply chain. The sophisticated approach, in practice, is able to lead professionals to effectively analyze process performance parameters.

II. UNFORESEEN COSTS

One of the things that is very important for strategic industries is to control the unpredictable costs of suppliers. A cost function for supply chain management developed by Elon to monitor relationships and performance of supply chain partners by measuring costs and risks [43]. There are three types of costs for supply chain management. They are: 1) variable costs 2) Fixed costs and 3) Unforeseen costs.

Total Cost = Fixed Costs + Variable Costs + Unforeseen costs

Fixed costs are costs that do not change even if the number of units ordered changes. For example, it includes the buyer's monthly salary, office rent, etc., on the other hand, variable costs are costs that are not fixed costs and depend on the number of units ordered from suppliers. unforeseen costs include costs that arise unexpectedly and cannot be measured based on the number of units produced. An example of unforeseen costs is late delivery of products by suppliers, which cannot be calculated based on the number of units of products and is difficult to measure.

In this article, the focus is on the monitoring and control of unforeseen costs as a performance indicator of the supplier based on monitoring the profile with fuzzy data and choosing the interaction model and the type of cooperation with the supplier and its monitoring. Unknown factors unforeseen costs are measured based on the data of past transactions with suppliers in terms of delivery time and product quality [44]. In other words, historical data on delivery time and product quality are used to evaluate the unknown factors of ordering from the respective suppliers. In the proposed system, if the "safety level" exceeds the permissible limit, a warning is given. This alert indicates an increase or decrease in the next purchase order based on supplier delivery and product quality.

The reason for using the risk function along with the delivery time and quality function is to consider all the conditions and get closer to the existing reality. Also, in this article, information may be incomplete, imprecise, vague, contradictory and each of these different information deficiencies lead to different types of uncertainty. Unlike traditional methods in monitoring profiles, fuzzy set approaches can deal with the inaccuracy and uncertainty without losing performance and effectiveness. Delivery time, quality and risk characteristics are functions of one or more independent variables. In this article, by using multiple multivariate fuzzy profile monitoring, once the two variables of delivery time and risk and once again the variable of quality response and risk are monitored, and based on the separate results of these two monitoring and using the fuzzy inference system, the unforeseeable costs are monitored and deciding on the type of interaction and cooperation model with the supplier is discussed. Figure 1 shows the steps of the framework of this article.

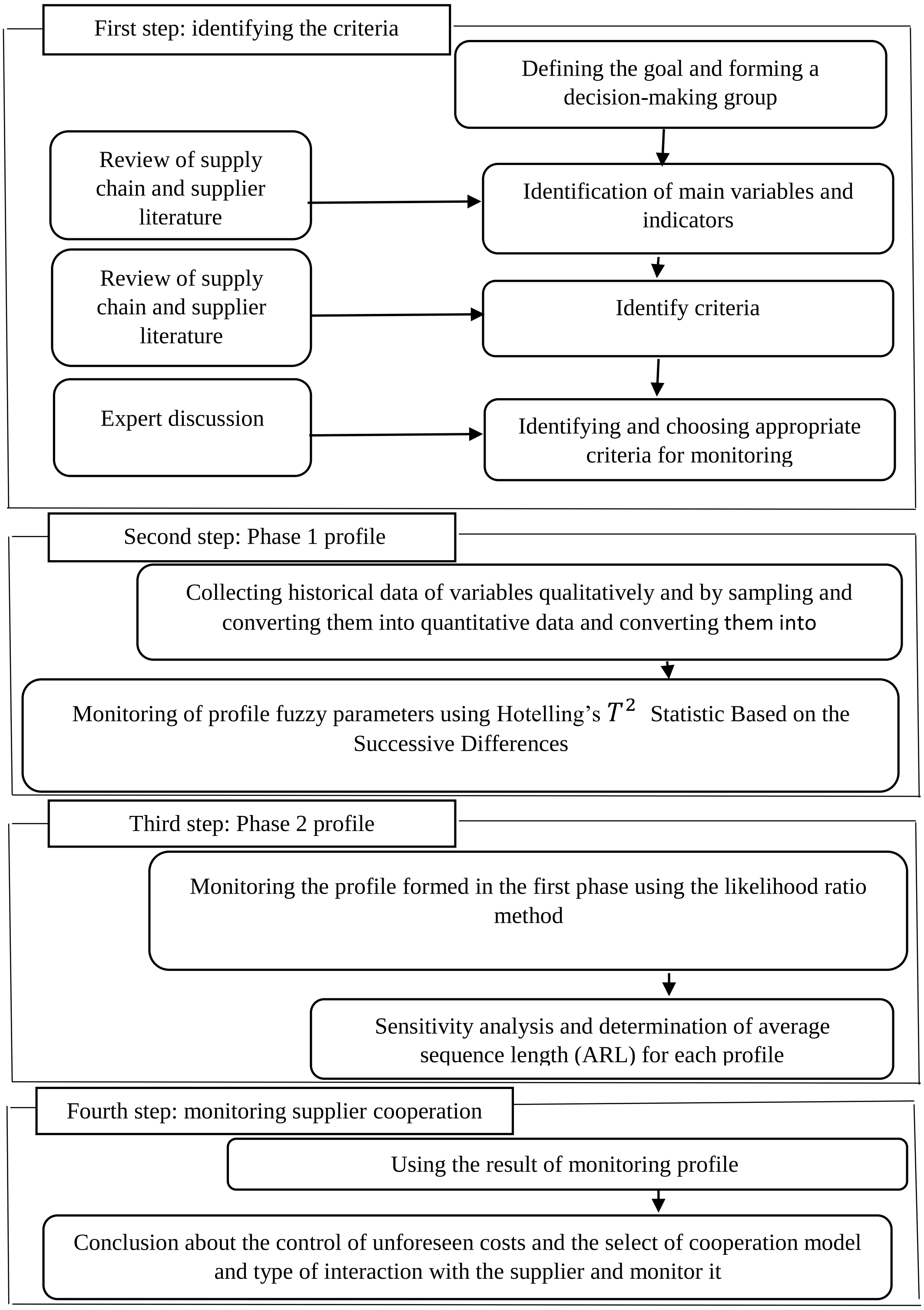


Fig1- The steps of the problem

III. PROFILE MONITORING

In the applications of statistical process control, the quality of a process or product is usually controlled by the distribution of one or more qualitative characteristics and by single-variable or multi-variable control charts. But in some conditions, the quality of a process or product is described by a relationship between the response variable and one or more independent variables, which is known as the profile and has been raised as a topic with many applications in recent years. According to the definition of Kang and Albain (2000) in each step of sampling a set of n>1 monitoring profiles, points are observed, each of which contains a value for 1 such as density as a response variable and thickness (X and one or more values) For the independent variable Y, the response variable is the independent variable and these points collectively represent a curve or profile. For example, in many calibration applications, the profile can be well represented by a linear model, but in many cases, more complex models are needed to show the profile [45].

Different types of profiles

There are different types of profiles for which choosing the right model is of particular importance [46]. Any model that is used for a specific example should also simply describe the available data features in an appropriate way. Also, for each model, monitoring methods should be designed to effectively identify changes and preferably be suitable for interpreting out-of-control warnings. Different types of profiles can be classified as follows [47].

Simple linear profile

In this type of profile, there is a simple linear relationship between the response variable and an independent variable, and this relationship shows the process performance and product quality. Usually, in the applications related to this type of profile, the independent variable values are fixed values.

$$Y = A_0 + A_1X + \varepsilon \tag{1}$$

Multiple linear profile

In this type of profile, there is a multiple linear relationship between the response variable and several independent variables. In these profiles, like simple linear profiles, the values of independent variables are assumed to be fixed values. The model of this profile is in relation 2.

$$Y = A_0 + A_1X_1 + A_2X_2 + \cdots + A_nX_n + \varepsilon \tag{2}$$

Multiple multivariate profile

In this type of profile, there is more than one response variable. In this case, each response is defined as a function of an independent variable (s) while the response variables mutually influence each other [48].

Let's assume that for K samples collected over time, observations $(x_{1ik}, x_{2ik}, \dots, x_{qik}, y_{1ik}, y_{2ik}, \dots, y_{pik})$ with $k = 1,2, \dots, m$ and $i = 1,2, \dots, n_k$ where $n_k$is the sample size k, m is the number of samples, and p and q are the number of response variables and independent variables, respectively. A model that represents response variables as functions of independent variables is called multivariate multiple linear regression and is presented as follows:

$$Y_K = X_KB_k + E_k \tag{3}$$

IV. HOTELLING'S T^2 STATISTIC BASED THE SUCCESSIVE DIFFERENCES IN THE FIRST PHASE

In phase one of control, to monitor a multivariate multiple profile, it is necessary to estimate the parameters of the regression model. In fact, estimating these parameters and ensuring the suitability and correctness of the designed regression model in the condition that the process is in steady state, makes the process controllers statistically confident that they can statistically control the process profile in phase two. In other words, the profile that is estimated in phase one, using historical data, is the model that is the basis on which phase two of process control is monitored [49]. There are different methods for monitoring profiles in phase one, one of these methods is based on T^2 control chart. The T^2 statistic based on the mean, variance matrix, and sample covariance has been widely used in statistical process control. One of the methods of monitoring linear profiles is using the T^2 method based on successive differences, and the steps provided in this method are given below.

First step: Using least squares estimates, regression parameters are calculated for the kth sample using equation 7.

$$B_k = (X_K^TX_K)^{-1}X_K^TY_K \tag{4}$$

where X_K is the matrix of independent variables and $Y_k$is the response vector. Considering that the X variables are different in two profiles, the regression parameters for each function are calculated separately, which are defined as follows:

$$\hat{\beta}_k = (\hat{\beta}_{01k}, \hat{\beta}_{02k}, \hat{\beta}_{11k}, \hat{\beta}_{21k}, \hat{\beta}_{12k}, \hat{\beta}_{22k}, \hat{\beta}_{31k}, \hat{\beta}_{32k}) \tag{5}$$

The second step: process parameters in control are estimated using average estimates in the form of equ ,
where m is the number of samples.

$$\bar{\hat{\beta}} = \frac{1}{m}\sum_{k=1}^{m}\hat{\beta}_k \tag{6}$$

The third step: the vector ($\widehat{V_k}$) is formed according to equation 10.

$$\hat{V}_k = \hat{\beta}_{k+1} - \hat{\beta}_k \qquad K = 1,2,\dots,m-1 \tag{7}$$

Fourth step: The covariance matrix of the variance is calculated in the form of equation 11.

$$S_\beta = \frac{\hat{V}^T \times \hat{V}}{2 \times (m-1)} \tag{8}$$

Fifth step: $T2$ statistic is calculated according to equation 12.

$$T_k^2 = \left(\hat{\beta}_k - \bar{\bar{\beta}}\right)^T S_\beta{}^{-1} (\hat{\beta}_k - \bar{\bar{\beta}}) \tag{9}$$

The sixth step: the appropriate upper control limit for the test statistic is determined in order to achieve probability for the first type error. The exact distribution of the statistic T_k^2 in equation 11 has not been reported in the literature, and only some estimated distributions have been reported for it. For more information, see Williams et al. (2007).

V. LIKELIHOOD RATIO METHOD

In phase 2, the emphasis is on the rapid discovery of trends and shifts, and this issue is usually measured by the parameters of the sequence length distribution. The sequence length is the number of samples it takes to see an out-of-control alarm. Often, the average sequence length is used to compare the performance of control charts in phase 2. One of the methods used in phase 2 is the likelihood ratio method. This method is an extension of for the case of multiple multivariate linear profiles, which was carried out by Ivzian et al. (2012). The steps of using this method are given below[50].

First step: the variance covariance matrix (Σ) is calculated.

Second step: C_k is calculated for each profile according to equation 13:

$$C_k = \sum_{i=1}^{n} (y_{ik} - x_i B)\Sigma^{-1}(y_{ik} - x_i B)^T \tag{10}$$

where $(y_{ik} - x_i B)$, i th row of the matrix $(Y_k - XB)$.

Third step: The exponentially weighted moving average statistic $\hat{B}_k$ is calculated as equation 14:

$$E\hat{B}_k = \lambda \hat{B}_k - (1-\lambda)\hat{B}_{k-1} \tag{11}$$

that $\hat{B}_0 = B$.

Fourth step: S_k statistic is calculated according to equation 15:

$$S_k = \frac{(Y_k - X(E\hat{B}_k))^T (Y_k - X(E\hat{B}_k))}{n} \tag{12}$$

The fifth step: exponentially weighted moving average statistics for S_k and C_k are obtained according to relations 16 and 17:

$$E\,S_k = \lambda\, S_k - (1-\lambda)\, S_{k-1} \tag{13}$$

$$E\,C_k = \lambda\, C_k - (1-\lambda)\, C_{k-1} \tag{14}$$

which is $S_0 = \Sigma$ and $C_0 = np$.

The sixth step: the likelihood ratio statistic for each profile is calculated according to equation 18:

$$ELRT_k = n \times log|\Sigma| - n \times log|\,E\,S_k| + E\,C_k - np \tag{15}$$

The upper control limit for the above statistic is determined through simulation to achieve a specified ARL.

VI. CASE STUDY

The automotive supply chain includes all input and output materials, services, and parts associated with business operations. The most common approach in Iran's automotive industry is the assembly of complex parts and systems for car production. the Iran Khodro Automobile Company needs thousands of parts to complete the production processes and provide car devices to their users.

Also, the production of hybrid models increases the complexity in the supply chain. For example, an average passenger car consists of thirty thousand parts and a collection of metal, plastic, rubber parts, electronic circuits and wires, mechanical and motor parts. Therefore, the supply chain of the automotive industry is considered one of the most complex, extensive and global supply chains, and logistics play a unique and important role in these stages.

The profile monitoring of the delivery process and the quality of the products and its process along with the risk by the supplier was investigated to monitor the unforeseen costs in an automotive industry in Iran and monitored the relationship between an automobile manufacturer and its supplier. Iran Khodro is the first major car manufacturer in Iran, whose head office is located in Tehran, Iran. Niro Motive Company (NMI) is a gearbox manufacturing company in Iran and is considered as one of the key companies for supplying parts needed by Iran Khodro Company. In order to have management support in the study of buyer-supplier relations, communication teams were created in each company. Each team has a maximum of 12 members from various departments such as marketing, quality management, production and planning, sales, purchasing, inventory, transportation and supply chain. These teams are responsible for completing successive surveys and taking necessary actions to maintain, monitor and improve the relationship between the two companies. The teams planned and held monthly meetings to discuss the expectations of the partners and to deal with the existing challenges to achieve a win-win approach.

In order to monitor the unforeseen costs from the supplier, two key indicators of delivery time and quality were used, which are examined along with the risk function for a more accurate evaluation, and these functions themselves have sub-criteria that are based on library resources and According to the characteristics of the organization in question, the relevant experts, criteria are given in Table 1.

The measurement of delivery time is measured and evaluated based on the number of days later or earlier than the promised day of delivery. Early delivery is considered unacceptable, as it requires additional inventory storage space and manpower to handle inventory placement. In addition, it affects the financial position of the company because the payment is done earlier than expected. On the other hand, late delivery is obviously bad for business. It delays in the entire production process. In fact, it can affect downstream partners in the supply chain and lengthen the production cycle. Also, the quality index has been examined for the basis of the quality level of the products and the reliability and the order defect rate.

A survey is designed on the items presented in Table 1, where the questions address the perceptions of the teams on the respective items using a seven-point Likert scale. We collected a data set (for the supplier side) from m = 15 consecutive sessions (during April 2021 to June 2022). Which is sampled 15 times per month and the results are collected and summarized at the end of each month.

Criterion	Subcriterion	Reference
Delivery	(On time Delivery)	(Faraz, A., Sanders, N., Zacharia, Z., Gerschberger, M., 2018[19] Suraraksa, Juthathip and Sup Shin, Kwang 2019[22] N. Aissaoui,M.Haouari, andE. Hassini,(2007)[51] L. de Boer, E. Labro, and P. Morlacchi(2001)[52] (Pandey, Shah, and Gajjar 2017;[53] Badri Ahmadi et al. 2017b;[54] Moktadir, M. A.et al. 2021[55] Munir, M., 2020, [56] Araz, O. M., et al. 2020, [57] Abdel-Basset, M., et al. 2020, [58] Ghadge, A., et al, 2020, [59] Rao, S., et al, 2009, [60]
	(Delivery reliability)	
	(Responsiveness to urgent deliveries)	
Quality	(Order defect rate)	
	(Quality level)	
	(Reliability)	
Risk	Political and economic risk (currency price fluctuations, economic recession, liquidity needed by industries, collapse of financial markets, disruptions and foreign sanctions and political instability)	
	Legal risk (export and import laws, tax and customs laws, change of commercial laws)	
	Operational risk (devices and equipment failure, human resource risk, low quality of the production line, poor quality control process)	

Table 1– Criteria and sub-criteria for supplier monitoring

Monitoring in phase 1

Historical data of all independent variables and response variable qualitatively and monthly and based on Likerd scale (very poor = 1, very poor = 2, poor = 3, moderate = 4, good = 5, very good = 6, very good = 7) has been collected. The data has been collected for 15 months and 10 sampling times every month from the time of delivery and quality of supplier parts and products to the organization, and scoring has been done based on the collective opinion of experts in the relevant field, which is given in the appendix A.

The correlation coefficient between the delivery response variable (Y_1) and the risk response variable (Y_3) was calculated as -0.91 and between the quality response variable (Y_2) and the risk response variable (Y_3) as -0.807, which indicates the high negative correlation of these two response variables compared to The response variable is risk, and the risk response variable has a great negative impact on delivery performance and quality, and it is necessary to monitor all three variables together for a more accurate analysis.

The Durbin-Watson test was used to determine the independence between the errors, and the minitab software was used to test whether the errors follow the normal distribution, and as can be seen in Figure 2, the errors have a normal distribution.

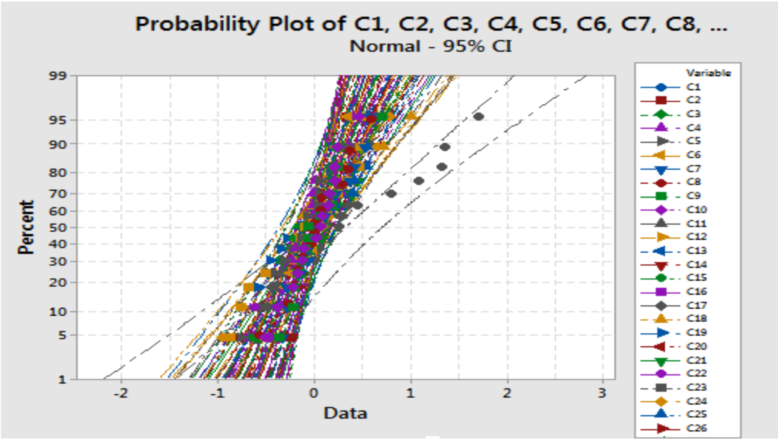


Fig 2 – Test of following errors from normal distribution in minitab software

VIF index (Variance Inflation Factor) has been used to check the collinearity between independent variables. The VIF index shows how much of the variation in the estimated coefficients is increased by collinearity and tests how the behavior of an independent variable changes due to correlation with other independent variables. A variance inflation index above 10 indicates a critical collinearity situation, and a value close to 1 indicates a favorable situation. The acceptable limit of the VIF index is below 5. If the VIF test statistic is close to one, it indicates the absence of collinearity. As an empirical rule, if the VIF value is greater than 5, multiple collinearity is high [61]. According to the regression analysis in the minitab chart and data analysis, the VIF coefficient for all variables was close to 1, which indicates no collinearity between the independent variables.

Also, non-variance tests were used to check the co-variance of the residuals. In examining the covariance of statistical tests, the null and opposite assumptions are defined as follows.

H0: The variance of the errors does not depend on the values of the independent variables (called homoscedasticity).

H1: The variance of the errors does depend on the values of the independent variables (called heteroscedasticity).

In this sense, the null hypothesis states that the data has homovariance characteristics, and the opposite hypothesis seeks to confirm the heterovariance hypothesis. In this problem, using minitab software and data analysis, and according to α=0.05, the hypothesis H0 was confirmed for all profiles.

In the following, according to the steps mentioned in the regression relationship between delivery as a response variable (Y_1) and on-time delivery (x_{11}), delivery reliability (x_{21}), responsiveness to timely and immediate delivery (x_{31}), It is given as an independent variable in the delivery profile and the regression relationship between quality as a response variable (Y_2) and order defect rate (x_{12}), quality level (x_{22}) and reliability (x_{32}) is given as an independent variable in the quality profile and The regression relationship between risk as response variable (Y_3) and political and economic risk (x_{13}), legal risk (x_{23}), operational risk (x_{33}) as independent variables is given in the risk profile. T^2 method based on successive differences has been used to investigate multivariate multiple profiles. In the first step of this method, the $\hat{\beta}_k$ vector is calculated, which is given in Table2.

	β_{01}	β_{02}	β_{03}	β_{11}	β_{12}	β_{13}	β_{21}	β_{22}	β_{23}	β_{31}	β_{32}	β_{33}
1	0.268	2.345	0.087	0.493	0.524	0.312	0.298	-0.419	0.456	0.367	0.452	0.373
2	0.241	1.733	0.376	0.317	0.536	0.258	0.416	-0.404	0.371	0.333	0.523	0.309
3	0.321	1.863	-0.319	0.394	0.511	0.289	0.288	-0.416	0.393	0.358	0.545	0.311
4	0.412	2.395	-0.283	0.401	0.417	0.358	0.315	-0.491	0.392	0.269	0.510	0.343
5	-0.197	2.403	0.228	0.393	0.380	0.294	0.383	-0.417	0.324	0.279	0.470	0.405
6	0.253	2.539	0.287	0.364	0.485	0.256	0.256	-0.508	0.303	0.375	0.470	0.371
7	-0.159	2.265	-0.02	0.422	0.407	0.414	0.371	-0.446	0.253	0.325	0.539	0.394
8	0.575	1.643	0.361	0.331	0.561	0.311	0.323	-0.457	0.332	0.330	0.537	0.315
9	-0.997	2.259	-0.246	0.392	0.500	0.350	0.532	-0.437	0.449	0.377	0.445	0.26
10	0.37	2.3	-0.054	0.439	0.504	0.291	0.271	-0.518	0.291	0.342	0.505	0.44
11	0.355	2.075	-0.04	0.392	0.567	0.299	0.307	-0.556	0.378	0.307	0.480	0.357
12	-0.855	2.671	-0.129	0.362	0.483	0.308	0.339	-0.607	0.311	0.269	0.418	0.37
13	0.201	1.892	0.816	0.324	0.532	0.257	0.323	-0.412	0.290	0.395	0.398	0.291

14	0.412	2.464	-0.02	0.270	0.408	0.338	0.373	-0.555	0.345	0.308	0.592	0.324
15	0.613	1.915	-0.228	0.363	0.471	0.356	0.389	-0.589	0.323	0.298	0.456	0.368

Table 2 – vector $\widehat{\boldsymbol{\beta}}_{\boldsymbol{k}}$

The mean vector is calculated $\overline{\hat{\beta}_k} =$ $(0.085, 2.166, 0.0636, 0.395, 0.472, 0.327, 0.348, -0.478, 0.334, 0.332, 0.489, 0.336)$ And in the next step, the vector $\hat{V}_k$ is calculated according to equation 7.
In the next step, the variance-covariance matrix is obtained.

$$S_b = \begin{bmatrix} 0.2269 & -0.068 & 0.0505 & -0.002 & 0.0121 & -0.008 & -0.024 & -0.002 & -0.005 & 0.0021 & 0.0028 & 0.0041 \\ -0.068 & 0.1048 & -0.035 & 0.0258 & -0.008 & 0.0030 & -0.003 & -0.004 & 0.0032 & 0.0029 & 0.0019 & 0.0025 \\ 0.0505 & -0.035 & 0.1066 & 0.0042 & 0.0076 & -0.013 & -0.006 & 0.0089 & -0.005 & 0.0093 & -0.002 & -0.0006 \\ -0.002 & 0.0258 & 0.0042 & 0.0192 & -0.0004 & 0.0002 & -0.004 & 0.0019 & 0.0004 & 0.0050 & 0.0005 & -0.0001 \\ 0.0121 & -0.008 & 0.0076 & -0.0004 & 0.0026 & -0.002 & -0.002 & 0.0008 & 0.0009 & 0.0011 & -0.001 & -0.0004 \\ -0.007 & 0.0030 & -0.012 & 0.0002 & -0.002 & 0.0038 & 0.0015 & -0.0009 & -0.0004 & -0.0017 & 0.0011 & -0.0004 \\ -0.024 & -0.002 & -0.006 & -0.004 & -0.002 & 0.0016 & 0.00600 & -0.0006 & 0.0008 & -0.0017 & -0.0002 & -0.0015 \\ -0.002 & -0.004 & 0.0089 & 0.0019 & 0.0008 & -0.0009 & -0.0006 & 0.0036 & 0.0009 & 0.0018 & -0.0013 & -0.0005 \\ -0.005 & 0.0032 & -0.004 & 0.0004 & 0.0009 & -0.0005 & 0.0007 & 0.0009 & 0.0032 & 0.0005 & -0.0010 & -0.0009 \\ 0.0021 & 0.0029 & 0.0093 & 0.0050 & 0.0011 & -0.002 & -0.0017 & 0.0018 & 0.0005 & 0.0032 & -0.0007 & -0.0005 \\ 0.0068 & 0.0019 & -0.002 & 0.0005 & -0.001 & 0.0011 & -0.00002 & -0.0013 & -0.001 & -0.0006 & 0.0036 & -0.0003 \\ 0.0041 & 0.0024 & -0.0006 & -0.001 & -0.0004 & -0.0004 & -0.0015 & -0.0005 & -0.0009 & -0.0005 & -0.0003 & 0.0026 \end{bmatrix}$$

And in the last step, the T^2 statistic is satisfied, which is given in Table 3:

K	T^2	k	T^2	K	T^2
1	22.07557	6	10.68903	11	11.89024
2	14.61903	7	10.52146	12	22.60496
3	21.18239	8	7.859958	13	11.99565
4	12.38964	9	17.95503	14	15.05705
5	14.94749	10	16.2812	15	21.96106

Table 3 - T^2 statistic

The total type 1 error probability is set at 0.05. Based on this, the upper limit of control for this value of the probability of the first error is set equal to 23.5868. Figure 3 shows the control chart for the T^2 statistic, which shows that all samples are in control.

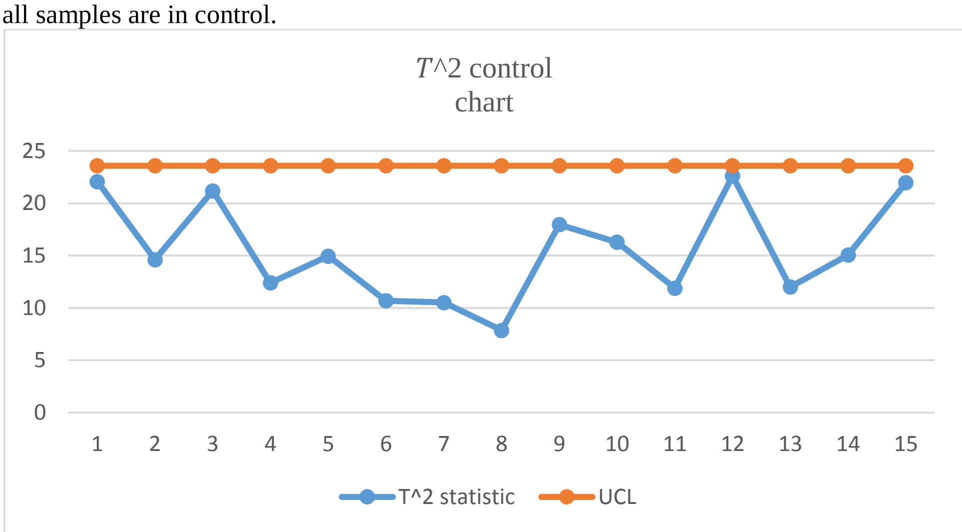


Fig 3 - T^2 statistic control chart

Monitoring in phase 2

Controlling unanticipated supplier costs in phase 2 means that it can be detected if the conditions of parameters in phase 1, defined as natural conditions of delivery time and quality along with supplier risk, deviate. To check how well the proposed model of the article can work, using the simulation for the supplier's unanticipated cost process along with the risk regression function, first for 15 times the data sample under production control and this work for 10000 time simulations. is made As mentioned, the likelihood ratio method was used to monitor the second phase. In the appendix B, the vector $\hat{\beta}_k$ for 15 profiles is given.

In the first step, the variance covariance matrix (Σ) is calculated.

$$\Sigma = \begin{bmatrix} 0.0993 & 0.0110 & -0.0088 \\ 0.0110 & 0.0703 & -0.0057 \\ -0.0088 & -0.0057 & 0.1363 \end{bmatrix}$$

The second step for monitoring in the second phase is to calculate C_k according to equation 10 and it is given in table 4.

In the third step, exponentially weighted moving average statistic $\hat{B}_k$ is calculated according to λ=0.5.

C_1	43.08101	C_6	45.03018	C_{11}	42.25949
C_2	33.3032	C_7	38.444	C_{12}	54.87
C_3	44.00797	C_8	36.73751	C_{13}	45.49359
C_4	61.08832	C_9	39.58264	C_{14}	40.06986
C_5	48.91626	C_{10}	44.13587	C_{15}	57.98009

Table 4 – C_k values

In the next step, the statistic S_k is calculated according to equation 12 and the results are given in table 5.

S_1	1.11916	-0.0604	-0.18063	S_9	0.2002	0.42440	2.5982	S_{17}	0.6839	-0.16098	1.77367
	-0.1806	0.08616	0.97675		0.3266	0.80059	0.4244		-0.1717	0.489552	-0.16098
	-0.0604	0.63905	0.08616		1.2023	0.32667	0.2002		1.8343	-0.17175	0.68392
S_2	0.49719	-0.0688	-0.06805	S_{10}	-0.3441	0.18083	1.6562	S_{18}	-0.3769	0.367332	0.95479
	-0.0680	-0.4178	0.77354		-0.1773	0.94011	0.18083		-0.0505	0.84427	0.36733
	-0.0688	0.92282	-0.41782		1.1201	-0.1773	-0.3441		2.87778	-0.05058	-0.37698
S_3	1.89355	-0.4918	-0.02494	S_{11}	0.0406	-0.17714	1.6778	S_{19}	0.09773	0.074816	1.56636
	-0.0249	-0.0951	0.74848		-0.2306	0.69303	-0.1771		0.14965	0.742168	0.07481
	-0.4918	0.96327	-0.09512		0.7180	-0.23064	0.0406		0.99549	0.149651	0.09773
S_4	1.1692	0.7707	-0.20035	S_{12}	0.4292	0.26611	1.58999	S_{20}	-0.13506	-0.0406	1.20174
	-0.2003	0.15070	0.48136		0.3445	1.05666	0.266111		-0.16554	0.743144	-0.0406
	0.7707	5.73365	0.15070		2.2649	0.34453	0.42927		1.0697	-0.16554	-0.13506
S_5	1.1065	-0.2870	-0.01903	S_{13}	0.1245	-0.08323	1.8297	S_{21}	0.9669	0.54107	5.15997
	-0.0190	-0.0480	0.31224		-0.334	0.86932	-0.08323		-0.3929	1.079685	0.54107
	-0.2870	0.9703	-0.0480		1.777	-0.33416	0.1245		2.9524	-0.39296	0.9669

Table 5 – S_k values

In the next step, considering the results of Tables 5 and 6, the values of EC_k and ES_k are calculated, and in the last step, according to equation 15, the value of $ELRT_k$ is calculated and given in Table 6.

K	T^2	K	T^2	K	T^2
1	8.997154	6	10.44937	11	5.526442
2	10.3854	7	2.866946	12	10.19212
3	8.542237	8	6.860707	13	11.14861
4	11.06098	9	0.085331	14	10.07665
5	18.26281	10	2.160656	15	3.44932

Table 6 – $\mathrm{ELRT_k}$ statistic values

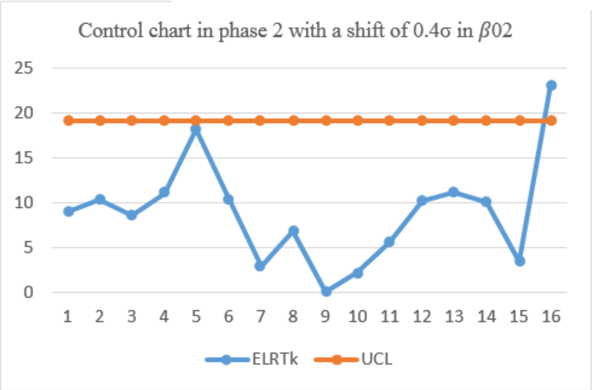
The upper control limit of 19.2 is considered to have a controlled ARL of approximately 200.

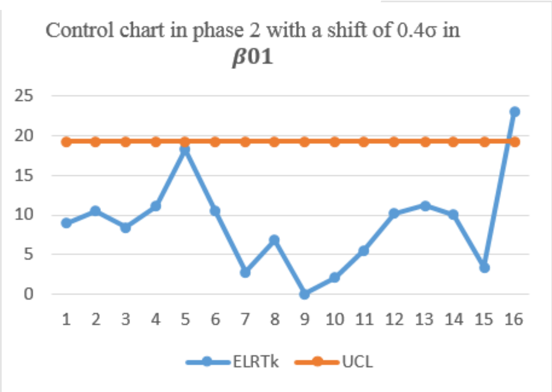
VII. SENSITIVITY ANALYSIS

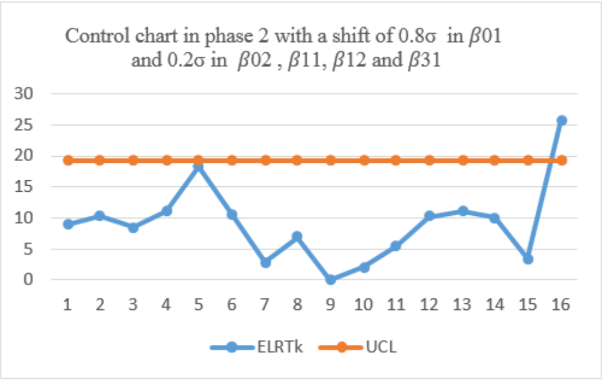
By performing the necessary calculations in Table 6, which was done for 15 samples, it can be seen that according to the changes made in 16 samples, the control chart is able to identify these changes. Considering that the relationship between the independent variables and the response is linear, any change in this line causes identified in the control chart. For example, by making changes in the slopes and width from the origin of this line, the changes made in the case of sample 16 are identified by the graph. In fact, the changes made in the values of the width from the origin and the slope cause changes in the indicators of the supplier's delivery process and quality, and these changes cause disruptions in the cooperation process, which the presented diagram correctly displays. Table 7 shows the sensitivity analysis of the model.

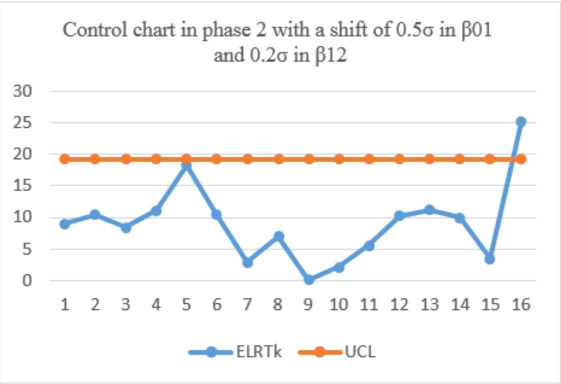
(ARL)	Shift in (*σ) β_{33}	Shift in (*σ) β_{32}	Shift in (*σ) β_{31}	Shift in (*σ) β_{23}	Shift in (*σ) β_{22}	Shift in (*σ) β_{21}	Shift in (*σ) β_{13}	Shift in (*σ) β_{12}	Shift in (*σ) β_{11}	Shift in (*σ) β_{03}	Shift in (*σ) β_{02}	Shift in β_{01} (*σ)	
1	0	0	0	0	0	0	0	0	0	0	0	0.4	1
1	0	0	0	0	0	0	0	0	0	0	0.4	0	2
1	0	0	0	0	0	0	0	0	0	0.4	0	0	4
1	0	0	0	0	0	0	0	0	0.2	0	0	0	5
1	0	0	0	0	0	0	0	0.2	0	0	0	0	6
1	0	0	0	0	0	0	0.2	0	0	0	0	0	7
1	0	0	0	0	0	0.2	0	0	0	0	0	0	8
1	0	0	0	0	0.2	0	0	0	0	0	0	0	9
1	0	0	0	0.2	0	0	0	0	0	0	0	0	10
1	0	0	0.2	0	0	0	0	0	0	0	0	0	11
1	0	0.2	0	0	0	0	0	0	0	0	0	0	12
1	0.2	0	0	0	0	0	0	0	0	0	0	0	13
1	0	0	0	0	0	0	0	0.2	0	0	0.5	0	14
1	0	0	0	0	0.1	0	0	0	0	0.2	0	0.5	15
1	0	0.1	0	0.1	0	0	0.1	0	0	0	0.5	0	16
1	0.1	0	0	0.1	0	0	0.2	0	0.2	0.1	0.2	0.5	17
1	0	0	0.2	0	0	0	0	0.2	0.2	0	0.2	0.8	18
1	0.1	0	0	0.2	0	0.2	0	0.2	0.2	0.2	0.2	0.8	19
1	0	0	0.1	0	0.2	0.2	0.1	0.2	0.2	0	0.2	0.8	20
1	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.4	1	21
1	0.4	0	0	0.4	0	0	0	0	0.4	0	0.4	1	22
1	0	0.2	0	0.2	0	0	0	0.4	0.4	0.2	0.4	1	23
1	0.2	0	0.2	0	0	0.4	0.2	0.4	0.4	0.2	0.4	1	24
1	0	0.2	0	0.2	0.4	0.4	0	0.4	0.4	0	0.4	1	25
1	1	0.4	0.4	1	1	1	1	1	1	1	1	1.5	26
1	1	1	1	1	1.5	1.5	1.5	1.5	1.5	1	1.5	3	27

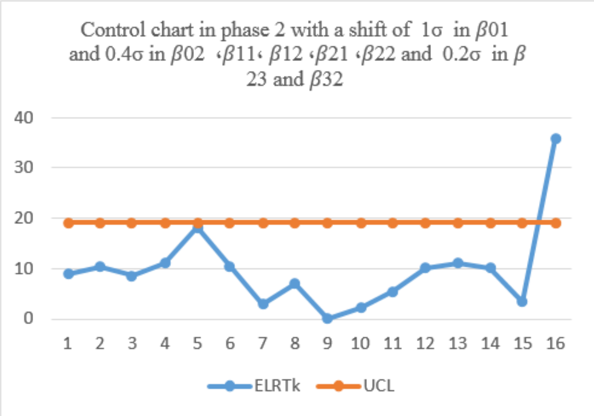
Table 7 - Sensitivity analysis











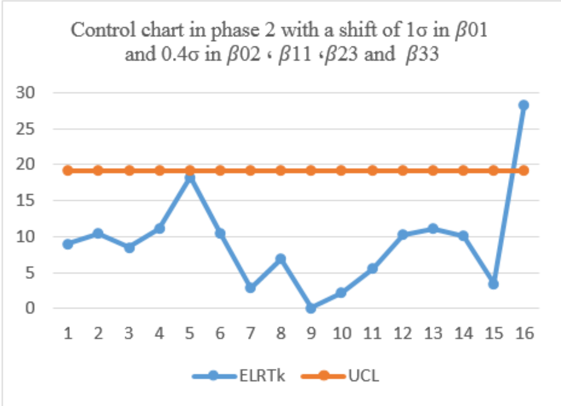


Fig 4 – Control charts based on sensitivity analysis

VIII. DISCUSSION OF THE RESULTS

It should be noted that control at the current level does not necessarily mean that the relationship is good. Rather, it means that the relationship is stable. An alarm indicates that relationship levels have changed, and further investigation is warranted to find the attributable cause(s) of that change Some times, the reasons may indicate early improvement in relationship levels and hence should be encouraged. Otherwise, any changes must be eliminated to improve supply chain performance, and only by monitoring unanticipated costs and taking risk over time is it possible to identify trends and changes that indicate poor performance or Potential for process improvement in the future.

Now, several scenarios can be imagined: in the first scenario, in the monitoring of the supplier's unforeseen costs, sample data of 16, after 15 sampling of the delivery time and the review of the delivery process and the quality of the supplier, and the risk review by experts and Industry experts based on the Likert scale from 1 to 7 in the form of (5,4,6,3,6,4,5,4,3,4,3,3,4,5,4) and (4,4,5,3,5,4,6,4,4,4,2,3,5,5,4) and (3,4,2,5,2,4,3,4,5,4,5,5,4,3,4) for three The response variable is delivery, quality and risk, and also, in that case, the profile of the three multiple variable is as follows:

$$y_1 = 0.2991 + 0.3922x_{11} + 0.3662x_{21} + 0.2993x_{31} \quad (19)$$

$$y_2 = 2.014 + 0.5166x_{11} - 0.4151x_{21} + 0.4623x_{31} \quad (20)$$

$$y_3 = -0.196 + 0.3995x_{12} + 0.3626x_{22} + 0.3344x_{32} \quad (21)$$

This profile means that the indicators of the supplier's delivery process are not out of control according to the risk conditions. The test statistic is 10.3309, which is within the control limits, because it is smaller than 19.2, and the experts are willing to continue cooperation by observing that the unpredictable costs are under control. The next state is when the supplier's unanticipated costs are not stable in the past, for example, the opinion of industry experts for the three response variables of delivery, quality and risk as (4,4,3,4,4,3,4,5,2,6,3,2,4,5,4), (3,5,3,4,32,4,5,3,5,4,3,4,5,4) and (5,3,5,4,4,6,4,3,6,2,5,5,3,4,4). In this case, according to the appropriate scores of the experts, it seems that the supplier has unforeseen costs in control, but according to the multiple multivariable profile, which is in the form of the following relationship:

(22)

$$y_1 = 0.835 + 0.3124x_{11} + 0.3836x_{21} + 0.3218x_{31} \quad (23)$$

$$y_2 = 2.214 + 0.4166x_{11} - 0.5151x_{21} + 0.4623x_{31}$$

$$y_3 = -0.187 + 0.2987x_{12} + 0.4876x_{22} + 0.4232x_{32} \quad (24)$$

This profile means that the unforeseen cost process is out of control, which can be detected by the model. In this case, the test statistic of 25.7746 is obtained, which is more than 19.2, it is out of control and the need to further investigate the status of the delivery process and the quality of the supplier is in accordance with the risk conditions, and the organization, if not corrected, can Revise your relationship with the desired supplier and avoid a huge loss in your industry.

The importance and value of the monitoring model are more understandable here, that in normal conditions and only with the opinion of experts, it is not possible to diagnose out of control, and it is possible that this process is caused by disruptions in unforeseen costs from the supplier and causes loss. Giving the market by the organization can continue for a long time and practically the market share of the organization will disappear and this lost opportunity may not be compensated anymore, but by forming a multivariable multiple regression relationship consisting of all the important variables related to the delivery process, quality and risk for the desired organization and industry and the simultaneous monitoring of all of them can be reached in the shortest possible time to warn that the supplier's unforeseen costs are out of control and make the managers to make a decision regarding the desired supplier and the type of cooperation with the supplier brought to a conclusion.

In the case of monitoring the supplier's unforeseen cost, three situations may arise. The first case is when the control charts show the state under control for a long period of time. The second case is when the control charts give an out-of-control warning and the supplier's problem is solved in a short period of time and the situation reaches a normal and controlled state, and the third case happens if the out-of-control warnings are issued at different times. And it is given repeatedly and practically the performance of the supplier is disturbed over time. In each of the three cases, the managers must adopt the appropriate strategy organization to cooperate with the supplier.

In the first case, if the supplier has conditions under control during the monitoring period, it is possible to enter into a long-term and strategic cooperation with the supplier, which will reduce the organization's costs in both operational and strategic areas, and by creating a stable relationship of concern. It destroys due to the supply of raw materials, products and services. Focusing on building and developing long-term relationships, both parties actively seek to avoid any unnecessary costs that may result from re-bidding, renegotiation or having to exit an existing contract early. Better relationships and increased engagement lead to fewer incidents or poor performance issues, which in turn leads to lower costs for managing the relationship, and long-term relationships provide the organization with the opportunity to engage the supplier in the process. Continual improvement of products and services provided and associated service levels involved. This can be achieved through product development, development of new processes and procedures during the contract.(Strategic and long-term cooperation with suppliers)

In the second case, if there is a warning in the profile monitoring of the control charts, the organization must establish regular and transparent communication channels with its supplier so that the problems of the supplier corresponding to the disturbance are identified and resolved in the shortest possible time, and the effects of the disturbance are minimized as much as possible. be reduced, and the supplier returned to the process of being under control. Meanwhile, the amount of orders from the supplier decreases.(Continue cooperation with the supplier)

In the third case, the supplier is continuously disrupted and an out-of-control warning is issued from the control charts. In this case, the organization can cancel the contract or continuously reduce the amount of orders at each stage and assign the same amount to other suppliers or more reliable suppliers in order to avoid huge losses and get out of the competitive market. (Failure to cooperate with the supplier)

IX. CONCLUSION

A successful relationship requires both suppliers and buyers to be aware of their changing relationships as competitors and the changing market environment and realize that the buyer-supplier relationship is a two-way process. Only by monitoring relationships over time can one identify trends and changes that signal potential underperformance in the future. Before the negative impact on participation, the cause of poor performance should be investigated and resolved. It is clear that companies spend a lot of management resources on monitoring and managing relationships with their important suppliers. Monitoring of suppliers during the period of cooperation can be a strong tool in the hands of organizations and companies so that they can control the supplier's activities towards the organization and the company, and if the supplier does not meet the necessary conditions of the organization at any moment during the cooperation. In order to lose cooperation, change the strategy with the desired supplier.

The value of the monitoring model lies in the fact that under normal conditions and only with the opinion of experts, it may not be possible to diagnose out of control, and it is possible that this process disrupts the delivery process and quality of the supplier and imposes unforeseen costs. It causes the organization to lose the market, and if it continues for a long time, the organization's market share will practically disappear, and in today's competitive world, it will practically destroy the organization and the desired industry, and this lost opportunity may not be compensated. But by forming a multiple multivariable regression relationship consisting of all the important variables of the delivery process and quality for the organization and industry in question and by considering the real world and possible risks and monitoring them all at the same time, it is possible to warn that the costs are out of control in the shortest possible time. Unpredicted, the supplier arrived and gave this opportunity to the managers to make a decision regarding the continuation of the cooperation or the correction of the created process, and practically saved the organization from a huge and irreparable loss.

Unforeseen costs of suppliers are very important in the automotive industry as an organization that is in charge of sensitive and large national projects. The supplier may have the desired conditions at the time of selection by the organization, but during the cooperation period, it may suffer from weakness in various areas for various reasons, and if the organization does not monitor the supplier over time and realizes the weakness of the supplier later than the specified time It may suffer irreparable damages and many challenges will be created and will affect the end customer as well. Therefore, monitoring the supplier during the cooperation period and finding the point of change in the supplier's performance in the shortest possible time can help the organization and the company to obtain the appropriate strategy.

In this article, the focus is on monitoring and controlling unforeseen costs. Unknown Factors unforeseen costs are measured based on past transaction data of suppliers in terms of delivery time and product quality. A model for multi-variable multi-profile monitoring of delivery process and quality along with existing risks to control unforeseen supplier costs is presented, which makes delivery process and quality risk-adjusted for organizations where delivery time and quality of supplier products play a significant role. It monitors and reviews the production and price of their final product and maintaining their market over time. By studying the library and using the opinion of elites and industry experts, indicators related to the delivery process and quality, as well as risks were considered as independent variables of extraction and delivery, quality and risk as response variables in the form of a multivariable multiple regression.

To monitor the profile, the T^2 method based on sequential differences was used in phase 1 and the likelihood ratio method was used in phase 2, and historical data was used to score based on the Likert scale by industry experts by sampling the delivery process, quality and risk. And it was done with the discussion. In the first phase, model parameters were obtained and monitored. In the second phase, by simulating the data in the control, the efficiency of the model was investigated in finding the warning, so that in the future, if there is any dissatisfaction with the unforeseen costs, the organization will be warned as soon as possible to investigate the problem. And make a decision to continue or terminate cooperation with the supplier. Finally, the sensitivity analysis of the model was done.

In this research, due to the importance of the quality variable and its effect, the quality of the supplier's products could be considered as a variable and entered into the model, and due to the non-parametric nature of the data, fuzzy theory can be used to increase the accuracy of the model. These two issues can be considered in future research. Also, check and monitor the supplier realistically, other supplier evaluation indicators can be used along with the delivery process index.

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Appendix A:

Data collected from the delivery process and quality

	Yj11	Yj21	Yj31	Yj41	Yj51	Yj61	Yj71	yj81	Yj91	Yj101	Yj111	Yj121	Yj131	Yj141	Yj151
1	2	3	3	6	3	6	5	4	5	5	5	6	4	6	4
2	6	7	5	5	3	3	4	5	5	4	4	4	4	4	2
3	5	5	4	4	2	6	5	6	4	6	5	3	5	5	3
4	5	4	3	4	3	4	4	5	5	3	4	4	4	5	7
5	5	6	4	5	4	4	4	5	5	6	3	4	4	5	5
6	5	4	5	3	2	6	6	3	5	4	3	6	6	5	4
7	3	5	6	5	2	5	5	4	4	5	6	6	6	6	4
8	4	3	3	5	3	5	4	4	5	4	3	4	5	2	4
9	3	5	4	4	6	6	4	5	6	3	5	3	3	5	6
10	4	5	3	2	5	6	3	5	5	4	4	4	3	4	7
11	5	4	6	4	4	5	3	3	6	6	6	5	4	4	5
12	6	4	4	2	5	6	5	6	3	4	5	5	2	5	5
13	3	6	3	3	5	4	2	3	3	4	5	5	4	4	4
14	4	4	7	3	4	3	4	5	4	6	6	3	4	6	3
15	6	5	3	5	6	2	5	5	4	4	4	3	4	6	3

Table 8 - Data collected from the delivery process

	Yj12	Yj22	Yj32	Yj42	Yj52	Yj62	Yj72	yj82	Yj92	Yj102	Yj112	Yj122	Yj132	Yj142	Yj152
1	3	3	3	5	3	5	5	4	5	6	5	6	4	6	4
2	5	6	4	5	3	3	4	5	4	3	5	4	4	4	2
3	6	6	4	4	2	7	5	6	4	6	4	4	5	5	4
4	5	4	3	4	4	4	5	5	4	3	4	3	4	5	6
5	5	5	3	5	5	5	4	5	5	5	3	4	3	5	5
6	4	4	5	3	2	6	6	3	5	4	3	6	6	5	3
7	3	5	5	5	3	5	5	4	4	4	7	6	6	6	4
8	4	4	3	5	3	4	4	4	5	3	3	4	5	2	4
9	3	5	4	4	5	6	4	4	5	3	6	3	3	5	7
10	4	4	3	2	5	6	3	6	5	4	4	4	5	4	6
11	6	3	6	4	5	5	4	2	5	6	6	5	4	4	5
12	6	3	4	2	5	6	5	5	3	4	5	5	2	5	5
13	3	5	4	4	5	4	3	3	3	3	4	4	5	4	4
14	4	4	7	3	4	3	4	5	4	6	6	4	4	6	4
15	5	4	3	5	5	2	5	5	4	4	4	3	4	5	3

Table 9 - Data collected from quality

	Yj13	Yj23	Yj33	Yj43	Yj53	Yj63	Yj73	yj83	Yj93	Yj103	Yj113	Yj123	Yj133	Yj143	Yj153
1	7	5	5	3	5	3	3	4	3	3	3	2	4	3	4
2	2	2	3	3	5	5	4	3	3	4	4	4	4	4	6
3	3	3	4	4	6	2	3	2	4	2	3	5	3	3	5
4	4	4	5	4	5	4	4	4	3	5	4	4	4	3	1
5	4	2	4	4	4	4	4	4	3	2	5	4	4	3	3
6	4	4	3	5	6	3	2	5	3	4	5	2	3	3	4
7	5	3	2	3	5	3	3	4	4	3	2	3	3	2	4
8	4	5	5	4	5	3	4	4	3	4	5	4	3	6	4

9	5	3	4	6	2	2	5	3	2	5	3	5	5	3	2
10	4	3	5	4	3	2	5	3	3	4	3	4	5	4	1
11	2	5	2	6	4	4	6	5	3	4	2	3	4	4	3
12	2	5	4	6	3	3	3	3	6	4	3	3	5	3	3
13	5	3	5	5	3	4	6	5	5	4	3	3	4	4	4
14	4	4	3	4	3	5	4	3	4	3	3	5	4	3	5
15	2	3	5	3	3	6	3	3	4	4	4	5	4	2	5

Table 10 - Data collected from risk

Appendix B:

	$\boldsymbol{\beta_{01}}$	$\boldsymbol{\beta_{02}}$	$\boldsymbol{\beta_{03}}$	$\boldsymbol{\beta_{11}}$	$\boldsymbol{\beta_{12}}$	$\boldsymbol{\beta_{13}}$	$\boldsymbol{\beta_{21}}$	$\boldsymbol{\beta_{22}}$	$\boldsymbol{\beta_{23}}$	$\boldsymbol{\beta_{31}}$	$\boldsymbol{\beta_{32}}$	$\boldsymbol{\beta_{33}}$
1	0.291	1.911	-0.298	0.4152	0.5321	0.4313	0.3647	-0.3934	0.3663	0.2936	0.4526	0.3302
2	0.241	1.733	0.376	0.3171	0.5366	0.258	0.4169	-0.4045	0.3712	0.3335	0.5231	0.3092
3	0.414	1.863	-0.319	0.3945	0.4692	0.3628	0.2884	-0.4265	0.4234	0.3082	0.5453	0.411
4	0.412	2.395	-0.283	0.4011	0.4177	0.3581	0.3157	-0.4915	0.3924	0.269	0.5103	0.3437
5	-0.197	2.403	0.228	0.3938	0.3804	0.2945	0.3839	-0.4172	0.3241	0.2798	0.4707	0.405
6	0.253	2.539	0.287	0.3648	0.4857	0.2567	0.2569	-0.5088	0.3031	0.3755	0.4701	0.3714
7	-0.159	2.265	-0.02	0.4229	0.407	0.4144	0.3714	-0.4466	0.2535	0.3255	0.5391	0.3942
8	0.575	1.643	0.361	0.3312	0.561	0.311	0.3238	-0.4574	0.3322	0.3307	0.5372	0.3159
9	-0.997	2.259	-0.246	0.3925	0.5006	0.3501	0.5329	-0.437	0.4492	0.3774	0.4451	0.26
10	0.37	2.3	-0.054	0.4398	0.5049	0.2912	0.2712	-0.5185	0.2916	0.3428	0.505	0.44
11	0.355	2.075	-0.04	0.3929	0.567	0.2995	0.3078	-0.5566	0.3786	0.3071	0.4806	0.3573
12	0.555	2.971	-0.129	0.3622	0.483	0.3082	0.339	-0.6073	0.3115	0.2697	0.4188	0.37
13	0.201	2.392	0.816	0.3244	0.5323	0.2572	0.3232	-0.4121	0.2903	0.3959	0.3989	0.2913
14	0.812	2.464	-0.02	0.2701	0.4082	0.3388	0.3739	-0.5555	0.3456	0.3082	0.5927	0.3242
15	-1.503	2.897	0.215	0.662	0.4234	0.3348	0.2682	-0.5479	0.3845	0.4616	0.4807	0.2915

Table 10 – vector $\boldsymbol{\widehat{\beta}_k}$ in phase 2

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