



## A SIMPLIFIED, RESULT ORIENTED SUPPLIER PERFORMANCE MANAGEMENT SYSTEM TESTING FRAMEWORK FOR SME

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**ABSTRACT. Background:** Supplier performance management continues to be a significant concern for small & medium enterprises (SME). How can small & medium enterprises better position themselves to check and sustain actual supplier performance improvement? A key framework is the establishment of a value-added supplier performance audit program that places significant emphasis on supplier performance controls. A value-added supplier audit program can help SME mitigate business and regulatory risk while reducing the cost of poor quality (COPQ). Thus a good supplier performance audit program is the cornerstone of supplier performance management integrity.

**Methods:** By acknowledging and addressing the challenges to an effective supplier Performance Audit program, this paper proposes an objective framework of supplier performance audit program, built on a strong, yet versatile statistical methodology - Analysis of variance (ANOVA). This performance audit framework considers process definition, standardization, review of the contemporary literature on ANOVA & its practical application in supplier performance scorecard of one of the reputed Sports Goods Industry in India.

**Results and conclusions:** The advantages of this framework are that: it simultaneously considers multiple supplier performance in multiple time frames and effectively identifies the differences across the suppliers in terms of their performance. Through this framework the organization will be able to increase the odds of performing a predictable and successful implementation of a value-added supplier performance audit.

**Key words:** Supplier Performance Audit, Analysis of variance (ANOVA), Supply Chain, Supplier Performance Management, Small & Medium Enterprises (SME).

### INTRODUCTION

"In today's competitive environment it is impossible to successfully produce high quality, low cost products without considering a satisfactory set of suppliers" [Soukoup 1987]. Supplier performance can be used as a strategic accelerator and to achieve cost savings, which can average 8 percent to 12 percent of total procurement costs, and as much as 40 percent for some categories. Also, Supplier performance improvements can result in shorter cycle times, product innovation and increased revenue. "However, without careful

monitoring of supplier performance, a firm is unable to accurately assess whether its current suppliers are meeting the needs of the firm, and suppliers are unable to respond to unexpressed partner needs" [Simpson et al. 2002].

#### *Purpose*

Each Purchasing organization as per their respective objectives, select different supplier performance metrics & suitable supplier performance management system (IV) to prepare selected suppliers performance scorecards (DV) for effective supplier

performance management. If we do not have a value-added supplier performance management system audit framework in place: How do we know whether used supplier performance management system is really genuine & effective? A value-added supplier performance management system audit framework can help organizations mitigate business and regulatory risk while reducing the cost of poor quality (COPQ). Generally such supplier performance management system audit framework comprises of buyer, supplier and sourcing, supplier performance management system, supplier scorecard and framework for auditing the effect of used supplier performance management system on supplier scores.

In this paper, the author worked as Head Of Materials Department for more than 14 years has proposed & tested an objective framework of supplier performance management audit framework, built on a strong, yet versatile statistical methodology - the 1-Way within Subjects ANOVA in a reputed Indian Sports Goods Industry to audit effectiveness & genuineness of used supplier performance management system (IV) on suppliers performance scores (DV) & move for further improvement suggestions for effective supplier performance management to reduce cost and support a lean procurement organization. This framework audited that implemented supplier performance management system really did have an effect on Supplier Performance Score. Did Supplier Performance Score significantly increase or decrease? Was there no difference in Supplier Performance Score?

### *Question*

Whether a suggested supplier performance management system audit framework, built on the repeated 1-Way within Subjects ANOVA methodology effectively audits the effect of used supplier performance management system (IV) on supplier performance score (DV)?

### *Hypothesis*

It is hypothesized that suggested supplier performance management system audit framework, built on the repeated 1-Way within Subjects ANOVA methodology effectively

audits the effect of used supplier performance management system (IV) on supplier performance score (DV)?

## **LITERATURE REVIEW**

"Supply Management is a process responsible for the development & management of a firm's total supply system - focuses heavily on the strategic aspects of the key elements of a firm's supply system" [Dobler et al. 2002]. As noted by fine, "supply chains are the next source of competitive advantage" [Fine, Charles 1999]. "Supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer & suppliers, but also transporters, warehouses, retailers & customer themselves" [Chopra et al. 2001]. "Good supplier performance is a key ingredient in enabling firms to achieve business performance excellence. But how can firms manage or even influence the performance of outside suppliers? Supplier performance management (SPM) is being widely adopted as a method to understand and improve the performance of the extended enterprise" [Gordon, Sherry 2010]. "Firms should concentrate on strategic suppliers who are integrated business partners as well as core suppliers, who require integration and development plus other suppliers that may supply a high-cost or high-risk item" [Barrett et al. 2008].

In literature, there exists a lot of contribution in the form of practice and models for evaluating and measuring supplier performance [Tan et al., 1999, Neely, 1999, Anderson, Lee 1999, Tracey, Tan, 2001, Çebi, Bayaktar 2003, Gunasekaran et al. 2004]. Several formal methods for supplier performance evaluation have appeared in the literature, such as the categorical method, weighted point method, cost ratio method [Dobler et al. 1990, Leenders et al. 1981, Timmerman 1986, Zenz 1987], and analytic hierarchic process (AHP) etc. [Narasimhan 1983]. However, to the author's best knowledge, this is the first framework of supplier performance management audit program, built on a strong, yet versatile

statistical methodology - the 1-Way within Subjects ANOVA to audit effectiveness & genuineness of used supplier performance management system (IV) on suppliers performance scores (DV).

### ***The One-Way within Subjects ANOVA***

#### *What is ANOVA?*

Sometimes, we want to compare more than two groups of data to see if more than two groups of data are different. While T-tests could be used to compare the means from two different groups of data, but we need a different kind of test when comparing three or more groups. Here 1-Way ANOVA test can be used to compare three or more groups or conditions in an experiment. A 1-Way ANOVA can find out if the means for each group / condition are significantly different from one another or if they are relatively the same. If the means are significantly different, it means that the variable being manipulated, Independent Variable (IV), had an effect on the variable being measured, i.e. Dependent Variable (DV). In statistics, one-way analysis of variance (abbreviated one-way ANOVA) is a technique used to compare means of two or more samples (using the F distribution). This technique can be used only for numerical data [Howell 2002]. ANOVA allows one to determine whether the differences between the samples are simply due to random error (sampling errors) or whether there are systematic treatment effects that cause the mean in one group to differ from the mean in another.

#### *Variables in ANOVA*

Dependent variable is metric.

Independent variable(s) is nominal with two or more levels - also called treatment, manipulation, or factor.

#### *Types of ANOVA*

One-way ANOVA: only one independent variable (IV) with two or more levels.

#### *Two-way ANOVA: two independent variables (IV) each with two or more levels*

With ANOVA, a single metric dependent variable is tested as the outcome of a treatment or manipulation whereas with MANOVA (Multiple Analysis of Variance), two or more metric dependent variables are tested as the outcome of a treatment(s). The one-way ANOVA is used to test for differences among at least three groups, since the two-group case can be covered by a t-test [Gosset 1908]. ANOVA can analyze and compare the variability of scores between conditions and within conditions. This helps us find out if the IV had a significant effect on the DV.

#### *1-Way between Subjects ANOVA*

This type of test is used to compare more three or more groups of participants that are not related in any way. The groups of participants are independent from one another. So, participants in one group have no relationship to participants in the other groups.

#### *1-Way within Subjects ANOVA:*

This type of test used to compare three or more groups of participants that are related in some way. There are many ways that participants in three or more groups can be related. One of the most common ways is that participants in the first group are the same as participants in the other groups. This is called a repeated measures design. Such type of 1-Way within Subjects ANOVA is also called as 1-Way Repeated Measures ANOVA.

A second way is that participants in the first group are genetically related to participants in the other groups. For example, a pair of triplets could be divided up so one triplet participated with the first group, a second triplet participated with the second group and a third triplet participate with a third group. A third way is if participants in one group are matched with participants in the other groups by some attribute. For example, if a participant in the first group rates low on intelligence, researchers might try to find a participant for each of the other groups who also rates low on intelligence.

### *1-Way Repeated Measures ANOVA:*

A One-Way within subjects design involves repeated measures on the same participants (multiple observations overtime, or under experimental different conditions). The simplest example of one-way repeated measures ANOVA is measuring before and after scores for participants who have been exposed to some experiment (before-after design).

Example: An employer measures employee's knowledge before a workshop and two weeks after the workshop. One-way repeated measure ANOVA and paired-samples t test are both appropriate for comparing scores in before and after designs for the same participants. Repeated-measures designs are considered an extension of the paired-samples t test when comparisons between more than two repeated measures are needed.

### *Hypotheses*

Generally Software like SPSS conducts 3 types of tests if the within-subject factor has more than 2 levels:

- The standard univariate F within subjects
- Alternative univariate tests, and
- Multivariate tests [SPSS Statistics Base 17.0]

All these repeated measures ANOVA tests evaluate the same hypothesis:

- The population means are equal for all levels of a factor.
- $H_0: \mu_1 = \mu_2 = \mu_3 \dots$
- $H_A$ : At least one treatment or observation mean ( $\mu$ ) is different from the others.

### *Sources of Variability*

In repeated measure ANOVA, there are three potential sources of variability:

- treatment variability: between columns,
- within subjects variability: between rows,
- random variability: residual (chance factor or experimental error beyond the control of a researcher).

A repeated measure design is powerful, as it controls for all potential sources of variability.

The test statistic for the repeated measures ANOVA has the following structure:

$$F = \frac{\text{Variance between treatments}}{\text{Variance within subjects + variance expected by chance/error}}$$

### *The logic of Repeated measures ANOVA*

Any differences that are found between treatments can be explained by only two factors:

- Treatment Effect.
- Error or Chance

This formula leaves only differences due to treatment/observation effects.

A large F value indicates that the differences between treatments/observations are greater than would be expected by chance or error alone.

### *Univariate Assumptions*

Normality Assumption: ANOVA is a relatively robust procedure with respect to violations of the normality assumption [Kirk 1995].

- The dependent variable is normally distributed in the population for each level of the within-subject factor.
- With a moderate or large sample sizes the test may still yield accurate p values even if the normality assumption is violated except in thick tailed and heavily skewed distributions.
- A commonly accepted value for a moderate sample size is 30 subjects.

### *Sphericity Assumption: Non-Robust*

- The population variance of difference scores computed between any two levels of a within subject factor is the same.
- The sphericity assumption (also known as the homogeneity of variance of differences assumption) is meaningful only if there are more than two levels of a within subjects factor.
- If this assumption is violated the resulting p value should not be trusted.

- Sphericity can be tested using the Mauchly's Sphericity Test. If the Chi-Square value obtained is significant, it means that the assumption was violated.
- If the sphericity assumption is not met, some procedures can be used to correct the univariate results. These tests make adjustments to the degrees of freedom in the denominator and numerator.
- SPSS, computes alternative test which are all robust to violations of the sphericity assumption as they adjust the degrees of freedom to account for any violations of this assumption. These tests include: Univariate Tests (e.g. Greenhouse-Geisser Epsilon, Huynh-Feldt Epsilon, Lower-bound Epsilon) and multivariate tests (e.g. Pillai's Trace, Wilk's Lambda, Hotelling's Trace, Roy's Largest Root)

#### *Independence Assumption: Non-Robust*

-The cases represent a random sample from the population and there is no dependency in the scores between participants.

- Dependency can exist only across scores for individuals.
- Results should be not trusted if this assumption is violated.

#### *Multivariate Assumptions*

Normality Assumption: Non-Robust

- The difference scores are multivariately normally distributed in the population.
- To the extent that population distributions are not normal and the sample sizes are small, especially in thick tailed or heavily skewed distributions, the p values are invalid.

Independence Assumption: Non-Robust

- The difference scores for any one subject are independent from the scores for any other subjects.
- The test should not be used if the independence assumption is violated.

## **METHODOLOGICAL APPROACH**

This Research Study has been undertaken as a single exploratory descriptive case study

with a deductive positivism approach with Cosco (India) Limited, One of the reputed sports & fitness goods company from India for empirical study of whether suggested supplier performance management system audit framework, built on the repeated 1-Way within Subjects ANOVA methodology, effectively audited the effect of used supplier performance management system (IV) on supplier performance score (DV)?

#### *Data Collection*

In this study, both primary and secondary data were collected through direct & participant observation along with documentation & archival records. The primary data were gathered through observations noted from company considered for this case study based research study. The secondary data were collected from literature, journals, articles & internet.

The interpretation of results of the researches can be conducted by various types of tests. The test ANOVA was chosen. It is not the best one from mathematical point of view, but it is the simplest one and at the same time enables the unambiguous interpretation of results. It was stated during the preliminary researches.

## **EMPIRICAL STUDY**

We audited the effect of revised supplier performance management system (IV) on supplier performance score (DV) in six continuous quarters (i.e. groups) from January, 2011 to June, 2012 on a sample of 10 main critical suppliers / participants in comparison with performance score in quarter from October, 2010 to December, 2010 on account of earlier supplier performance management system in Cosco (India) Limited. Each participant participated in all seven groups of the experiment. Each group was separated by ninety day's time. Because the participants in each group were related, they were actually the same exact participants in each group; we used the 1-Way within Subjects ANOVA.

### *Auditing Supplier Performance Management System by ANOVA*

There are three steps in conducting the one-way repeated measures ANOVA:

- Conducting the omnibus test
- Conducting polynomial contrasts (compares the linear effect, quadratic effect, and cubic effect).
- Conducting pair wise comparisons.

#### *Required input*

Repeated measurements variables: the variables containing the different measurements. Note that the order in which we select the variables is important for trend analysis.

#### *Required output*

In this experiment, required output is to know if there is a significant difference between the data collected from each condition/quarter. We want to know revised supplier performance management system really does have an effect on Supplier Performance Score. Does Supplier Performance Score significantly increase or decrease. Is there no difference in Supplier Performance Score?

### *Let's Start Auditing/Testing*

To answer the research question posed in Introduction i.e. "Whether suggested supplier performance management system audit framework, built on the repeated 1-Way within Subjects ANOVA methodology effectively audit the effect of used supplier performance management system (IV) on supplier performance score (DV)?", an hypothesis was created that It is hypothesized that suggested supplier performance management system audit framework, built on the repeated 1-Way within Subjects ANOVA methodology effectively audit the effect of used supplier performance management system (IV) on supplier performance score (DV)? Here we want to audit the effect of revised supplier performance management system (IV) on supplier performance score (DV). This is now being tested by using Repeated One-Way Analysis of Variance (ANOVA). To test this hypothesis we check & test the effect of revised supplier performance management system (IV) on supplier performance score (DV) by collecting data set of supplier performance score in six continuous quarters (i.e. groups) from January, 2011 to June, 2012 on a sample of 10 main critical suppliers / participants in comparison with performance score in quarter from October, 2010 to December, 2010 on account of earlier supplier performance management system.

Table 1. Data set of supplier performance score  
Tabela 1. Dane oceny dostawcy

	Oct., 10 to Dec., 10	Jan., 11 to March, 11	April, 11 to June, 11	July, 11 to Sept., 11	Oct., 11 to Dec., 11	Jan., 12 to March, 12	April, 12 to June, 12
SP1	60	69.2	75.8	81.6	85	91	92.6
SP2	67	70.4	75.2	79.2	85	92.6	99
SP3	73.2	78	83	84.8	86	90	92
SP4	66.4	73.2	77	80.2	85.2	89.8	97.2
SP5	69.4	74	78	82.2	89	89.8	93.2
SP6	56	67.2	70	79	81.4	88	93.2
SP7	65.6	71.2	72.6	82.2	86.2	89	92
SP8	68.6	75.4	81	84	85.8	90	90.4
SP9	68.6	74.8	79.4	86.2	85.8	91.6	93.6
SP10	57.8	67.6	73.6	81	83	86.8	91

*The null hypothesis:*

There is no difference of supplier performance score among the 7 treatment different quarters (Levels) i.e. have the same  $\mu$ .

$$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6 = \mu_7$$

If we reject null, and say, "no," then at least one of the populations has a different  $\mu$ .

*The alternative hypothesis:*

The alternative hypothesis,  $H_a$ : Is the opposite of the null hypothesis. i.e. there is difference of supplier performance score among the 7 treatment different quarters (Levels) i.e. either greater  $\mu$  or lesser  $\mu$  than one another subsequently but not have the same  $\mu$ .

$$H_a: \mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu_5 \neq \mu_6 \neq \mu_7$$

$$H_a: \mu_1 > \mu_2 > \mu_3 > \mu_4 > \mu_5 > \mu_6 > \mu_7 \quad \text{or}$$

$$H_a: \mu_1 < \mu_2 < \mu_3 < \mu_4 < \mu_5 < \mu_6 < \mu_7$$

A one-tailed test uses an alternate hypothesis that states either  $H_1: \mu > \mu_0$  or  $H_1: \mu < \mu_0$ , but not both. But here we want to test both, using the alternate hypothesis  $H_1: \mu \neq \mu_0$ , then we need to use a two-tailed test.

Here We have used a statistical program MedCalc Software version 12 - © 1993-2012 for conducting Repeated measures analysis of variance to check & test the effect of revised supplier performance management system (IV) on supplier performance score (DV) by analyzing the data set of supplier performance score from 7 different quarters (Levels) from October, 2010 to June, 2012 of 10 critical supplier firms.

*Enter Data*

Data for the different variables are entered in different columns of The MedCalc spreadsheet. In the top row of the columns we entered the names of the variables / groups i.e. OCT 10 TO DEC 10, JAN 11 TO MARCH 11, APRIL 11 TO JUNE 11, JULY 11 TO SEPT 11, OCT 11 TO DEC 11, JAN 12 TO MARCH

12, APRIL 12 TO JUNE 12. All data for each selected critical supplier or case are entered in one row in the spreadsheet. A variable name should not include any spaces. We can use the underscore character `_` to separate words, e.g. GRADE\_A. Also the following characters cannot be used in a variable's name: `- + / * = < > ^ ( ) $ " ' : , .`

*Save the data*

Save data file to a meaningful place with a meaningful name. We decided to save our data file as "Effect of simple & superior supplier performance management system on supplier performance score Data.sav."

*Statistical Analyses*

After entering the data in the spreadsheet, we selected an option in the Statistics menu to perform repeated measures analysis of variance statistical analysis

*Results*

"A one-way within subjects (or repeated measures) ANOVA was conducted with 10 main critical suppliers to compare the effect of revised supplier performance management system (IV) on supplier performance score (DV) in seven continuous quarters (i.e. groups) from October, 2010 to June, 2012."

*Repeated measures ANOVA*

Number of subjects	10
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*Sphericity*

It refers to the equality of variances within each of the populations which is an assumption of ANOVA with a repeated measures factor also called as the assumption of homogeneity of variances. One-way ANOVA assumes that the data come from populations that are Gaussian and have equal variances. MedCalc reports the estimates (epsilon) of sphericity proposed by Greenhouse and Geisser (1958) [17-18] and Huynh and Feldt (1976) [19-20] (corrected by Lecoutre, 1991). The closer that epsilon is to 1, the more homogeneous are the variances of differences, and hence the closer

the data are to being spherical. Both the Greenhouse-Geisser and Huynh-Feldt estimates are used as a correction factor that is applied to the degrees of freedom used to calculate the P-value for the observed value of F.

The Greenhouse-Geisser & Huynh-Feldt estimates can both range from the lower bound (the most severe departure from sphericity possible given the data) and 1 (no departure from sphericity at all)

Table 2. Estimates (epsilon) of sphericity  
Tabela 2. Szacowana sferowość

Method	Epsilon
Greenhouse-Geisser (1959)	0.358
Huynh-Feldt (1976)	0.473

Source: MedCalc Software version 12

Here above reported epsilon by MedCalc is not closure to 1, resulting in to heterogeneity of variances of differences instead of homogeneity of variances. It means that variances are not equal across groups or samples.

### Test of Within-Subjects Effects

Table 3. Displaying the variation attributed to "Factor" and "Residual" variation  
Tabela 3. Zmienność wartości „Factor” i „Residual”

Source of variation		Sum of Squares	DF	Mean Square	F	P
Factor	Sphericity assumed	5975.792	6	995.965	158.04	<0.001
	Greenhouse-Geisser	5975.792	2.147	2783.403	158.04	<0.001
	Huynh-Feldt	5975.792	2.841	2103.430	158.04	<0.001
Residual	Sphericity assumed	340.299	54	6.302		
	Greenhouse-Geisser	340.299	19.322	17.612		
	Huynh-Feldt	340.299	25.569	13.309		

Source: MedCalc Software version 12

Table 4. Summary of The within-subjects factors  
Tabela 4. Podsumowanie czynników within subjects

Factor	Mean	Std. Error	95% CI
OCT_10_TO_DEC_10	65.2600	1.7512	61.2985 to 69.2215
JAN_11_TO_MARCH_11	72.1000	1.1264	69.5520 to 74.6480
APRIL_11_TO_JUNE_11	76.5600	1.2535	73.7243 to 79.3957
JULY_11_TO_SEPT_11	82.0400	0.7512	80.3407 to 83.7393
OCT_11_TO_DEC_11	85.2400	0.6337	83.8064 to 86.6736
JAN_12_TO_MARCH_12	89.8600	0.5317	88.6572 to 91.0628
APRIL_12_TO_JUNE_12	93.4200	0.8514	91.4940 to 95.3460

Source: MedCalc Software version 12

In table 3, the variation attributed to "Factor" and "Residual" variation is displayed. If the P-value next to "Factor" is low ( $P < 0.05$ ) it can be concluded that there is significant difference between the different measurements. MedCalc produces two corrections based upon the estimates of sphericity by Greenhouse and Geisser (1958)

and Huynh and Feldt (1976) (corrected by Lecoutre, 1991) [21]. Girden (1992) recommends that when epsilon (Greenhouse-Geisser estimate)  $> 0.75$  then the correction according to Huynh and Feldt should be used. If  $\epsilon < 0.75$  then the more conservative correction according to Greenhouse-Geisser is preferred.



Here the P value is less than a preset threshold value 0.05. It can be concluded that the populations really are significantly different.

*Within-subjects factors*

The within-subjects factors are summarized in the following table 4 with Mean, Standard Error and 95% Confidence Interval.

Table 5. The Pair wise comparisons table  
 Tabela 5 Porównanie par

Factors	Mean Difference	Std. Error	P <sup>a</sup> <sup>a</sup> Bonferroni corrected	95% CI <sup>a</sup>	
OCT_10_TO_DEC_10	- JAN_11_TO_MARCH_11	-6.840	0.791	0.0002	-10.145 to -3.535
	- APRIL_11_TO_JUNE_11	-11.300	0.985	<0.0001	-15.417 to -7.183
	- JULY_11_TO_SEPT_11	-16.780	1.407	<0.0001	-22.661 to -10.899
	- OCT_11_TO_DEC_11	-19.980	1.311	<0.0001	-25.458 to -14.502
JAN_11_TO_MARCH_11	- JAN_12_TO_MARCH_12	-24.600	1.528	<0.0001	-30.987 to -18.213
	- APRIL_12_TO_JUNE_12	-28.160	1.852	<0.0001	-35.899 to -20.421
	- OCT_10_TO_DEC_10	6.840	0.791	0.0002	3.535 to 10.145
	- APRIL_11_TO_JUNE_11	-4.460	0.488	0.0002	-6.500 to -2.420
APRIL_11_TO_JUNE_11	- JULY_11_TO_SEPT_11	-9.940	0.741	<0.0001	-13.035 to -6.845
	- OCT_11_TO_DEC_11	-13.140	0.831	<0.0001	-16.613 to -9.667
	- JAN_12_TO_MARCH_12	-17.760	1.036	<0.0001	-22.090 to -13.430
	- APRIL_12_TO_JUNE_12	-21.320	1.473	<0.0001	-27.477 to -15.163
JULY_11_TO_SEPT_11	- OCT_10_TO_DEC_10	11.300	0.985	<0.0001	7.183 to 15.417
	- JAN_11_TO_MARCH_11	4.460	0.488	0.0002	2.420 to 6.500
	- JULY_11_TO_SEPT_11	-5.480	0.841	0.0023	-8.993 to -1.967
	- OCT_11_TO_DEC_11	-8.680	1.010	0.0003	-12.900 to -4.460
OCT_11_TO_DEC_11	- JAN_12_TO_MARCH_12	-13.300	1.126	<0.0001	-18.003 to -8.597
	- APRIL_12_TO_JUNE_12	-16.860	1.611	0.0001	-23.591 to -10.129
	- OCT_10_TO_DEC_10	16.780	1.407	<0.0001	10.899 to 22.661
	- JAN_11_TO_MARCH_11	9.940	0.741	<0.0001	6.845 to 13.035
JAN_12_TO_MARCH_12	- APRIL_11_TO_JUNE_11	5.480	0.841	0.0023	1.967 to 8.993
	- OCT_11_TO_DEC_11	-3.200	0.704	0.0294	-6.143 to -0.257
	- JAN_12_TO_MARCH_12	-7.820	0.812	0.0001	-11.215 to -4.425
	- APRIL_12_TO_JUNE_12	-11.380	1.387	0.0004	-17.177 to -5.583
APRIL_12_TO_JUNE_12	- OCT_10_TO_DEC_10	19.980	1.311	<0.0001	14.502 to 25.458
	- JAN_11_TO_MARCH_11	13.140	0.831	<0.0001	9.667 to 16.613
	- APRIL_11_TO_JUNE_11	8.680	1.010	0.0003	4.460 to 12.900
	- JULY_11_TO_SEPT_11	3.200	0.704	0.0294	0.257 to 6.143
JAN_11_TO_MARCH_11	- JAN_12_TO_MARCH_12	-4.620	0.626	0.0009	-7.235 to -2.005
	- APRIL_12_TO_JUNE_12	-8.180	1.060	0.0006	-12.610 to -3.750
	- OCT_10_TO_DEC_10	24.600	1.528	<0.0001	18.213 to 30.987
	- JAN_11_TO_MARCH_11	17.760	1.036	<0.0001	13.430 to 22.090
OCT_10_TO_DEC_10	- APRIL_11_TO_JUNE_11	13.300	1.126	<0.0001	8.597 to 18.003
	- JULY_11_TO_SEPT_11	7.820	0.812	0.0001	4.425 to 11.215
	- OCT_11_TO_DEC_11	4.620	0.626	0.0009	2.005 to 7.235
	- APRIL_12_TO_JUNE_12	-3.560	0.707	0.0147	-6.513 to -0.607
JAN_11_TO_MARCH_11	- OCT_10_TO_DEC_10	28.160	1.852	<0.0001	20.421 to 35.899
	- JAN_11_TO_MARCH_11	21.320	1.473	<0.0001	15.163 to 27.477
	- APRIL_11_TO_JUNE_11	16.860	1.611	0.0001	10.129 to 23.591
	- JULY_11_TO_SEPT_11	11.380	1.387	0.0004	5.583 to 17.177
APRIL_11_TO_JUNE_11	- OCT_11_TO_DEC_11	8.180	1.060	0.0006	3.750 to 12.610
	- JAN_12_TO_MARCH_12	3.560	0.707	0.0147	0.607 to 6.513

Source: MedCalc Software version 12

*Pair wise comparisons*

In the Pair wise comparisons table, the different measurements are compared to each other. The mean difference with standard error, P-value, and 95% Confidence Interval of the

difference is given. Bonferroni correction for multiple comparisons is applied for P-values and confidence intervals.

The Bonferroni method is a simple method that allows many comparison statements to be

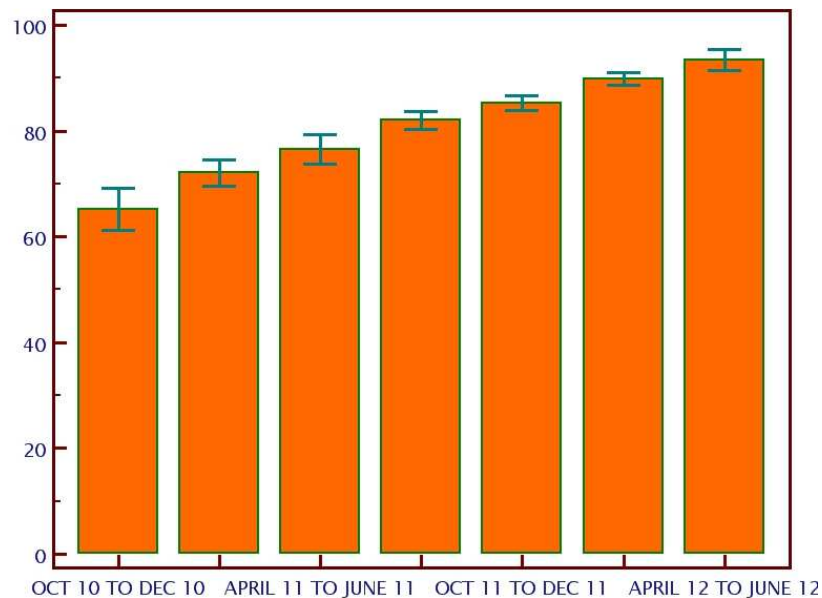
made (or confidence intervals to be constructed) while still assuring an overall confidence coefficient is maintained. Which pairs of means differ? The Bonferroni Test is

done for all possible pairs of means [<http://www2.fiu.edu/>].

Table 6. Bonferroni Test for Differences between Means  
 Tabela 6. Test Bonferroni dla różnicy średnich

Bonferroni Test for Differences Between Means					
Alpha/N	0.0024				
Groups	Difference	Test Statistics	p-level	Accepted?	
1 vs. 2	-6.84	3.2851	0.0041	rejected	
1 vs. 3	-11.3	5.247	0.0001	accepted	
1 vs. 4	-16.78	8.806	0.	accepted	
1 vs. 5	-19.98	10.7284	0.	accepted	
1 vs. 6	-24.6	13.4416	0.	accepted	
1 vs. 7	-28.16	14.4619	0.	accepted	
2 vs. 3	-4.46	2.6465	0.0164	rejected	
2 vs. 4	-9.94	7.342	0.	accepted	
2 vs. 5	-13.14	10.1672	0.	accepted	
2 vs. 6	-17.76	14.2588	0.	accepted	
2 vs. 7	-21.32	15.1	0.	accepted	
3 vs. 4	-5.48	3.7499	0.0015	accepted	
3 vs. 5	-8.68	6.1796	0.	accepted	
3 vs. 6	-13.3	9.7676	0.	accepted	
3 vs. 7	-16.86	11.1263	0.	accepted	
4 vs. 5	-3.2	3.2561	0.0044	rejected	
4 vs. 6	-7.82	8.4971	0.	accepted	
4 vs. 7	-11.38	10.023	0.	accepted	
5 vs. 6	-4.62	5.5849	0.	accepted	
5 vs. 7	-8.18	7.7072	0.	accepted	
6 vs. 7	-3.56	3.5466	0.0023	accepted	

Source: MedCalc Software version 12



Source: MedCalc Software version 12

Fig. 1. Continuously increasing population means  
 Rys. 1. Stale wzrastające średnie populacji

*Trend analysis*

The Trend analysis table shows whether the measurements show a linear or non-linear (quadratic, cubic) trend. A trend analysis tests the hypotheses that the means of the ordered groups change in a linear or higher order (e.g., quadratic or cubic) fashion.

Table 7. Trend analysis table  
 Tabela 7. Analiza trendu

Trend	t	DF	Significance
Linear	15.8651	9	P < 0.0001
Quadratic	-2.5030	9	P = 0.0337
Cubic	1.5379	9	P = 0.1585

Source: MedCalc Software version 12

There is a significant linear trend ( $p < 0.0001$ ), shown in Figure 1. The results suggest that there is a linear increase in population means.

*Decision Rule*

The populations really are significantly different. Therefore our Null Hypothesis  $H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6 = \mu_7$  is not true. We have to reject this & accept following alternative hypothesis:

$$H_a: \mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu_5 \neq \mu_6 \neq \mu_7$$

$$H_a: \mu_1 < \mu_2 < \mu_3 < \mu_4 < \mu_5 < \mu_6 < \mu_7$$

Audit result can be concluded that a one-way within subjects (or repeated measures) ANOVA was conducted on a sample of 10 critical suppliers to compare the effect of revised supplier performance system on supplier performance score in seven continuous quarters / conditions i.e. from Oct., 10 to June, 12. There was a significant effect of supplier performance system in continuously increasing supplier performance score. Thus supplier performance management system audit framework, built on the repeated 1-Way within Subjects ANOVA methodology effectively audited the effect of used supplier

performance management system (IV) on supplier performance score (DV).

**CONCLUDING REMARKS**

This research paper was aimed to develop & implement an objective framework of supplier performance audit program, built on a strong, yet versatile statistical methodology - Analysis of variance (ANOVA). The empirical study of this supplier performance management system audit framework has been undertaken as a single exploratory descriptive case study with a deductive positivism approach with one of the reputed Sports Goods Manufacturing Industry from India i.e. Cosco (India) Limited.

To check the findings of this supplier performance management system audit framework, during the case study the effect of earlier as well as revised Supplier Performance Management System on supplier performance scores on a sample of 10 critical suppliers in seven concerned & continuous quarters i.e. from Oct., 10 to June, 12 were analyzed & audited/tested through a one-way within subjects (or repeated measures) ANOVA. Test result can be concluded that there is a significant effect of supplier performance system in continuously increasing supplier performance score. Thus this supplier performance management system audit framework effectively audited the effect of used supplier performance management system (IV) on supplier performance score (DV).

From the outset, this supplier performance management system audit framework had the advantages of simplicity, understandability and ease of implementation. It is highly reliable and its implementation costs are moderate & hence suitable for small & medium enterprises (SME).

*Research Contributions*

This study will help Supply Chain practitioners to take necessary steps to reference their existing or actual facts of prevailing Supplier Performance Management

activity in the organization in order to make it more effective. This will also provide guidance to anyone who wants to develop a result oriented supplier performance management system in any organization.

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## UPROSZCZONA METODA OCENY ZARZĄDZANIA DOSTAWCAMI DLA MAŁYCH I ŚREDNICH PRZEDSIĘBIORSTW

**STRESZCZENIE. Wstęp:** Zarządzanie oceną dostawców jest obszarem o istotnym znaczeniu dla małych i średnich przedsiębiorstw. Jak tego typu przedsiębiorstwa mogą uzyskać lepszą pozycję rynkową poprzez poprawę systemu oceny dostawców? Kluczową sprawą jest zbudowanie systemu oceny wartości dodanej wniesionej przez dostawców opartego na grupie wskaźników. Taki system audytowania może pomóc małym i średnim przedsiębiorstwom obniżyć poziom ryzyka oraz obniżyć koszty wynikające ze złej jakości. Dlatego też dobrej jakości program oceny dostawców jest istotnym narzędziem zarządzania dla przedsiębiorstwa.

**Metody:** Aby sprostać wymaganiom stawianym programom efektywnej oceny dostawców, w pracy zaproponowano ogólne zasady takiego programu opartego na silnej i jednocześnie wszechstronnej analizie wariancji (ANOVA). Zaprezentowano definicję procesu, standaryzację, przegląd współczesnej literatury oraz praktyczne zastosowanie na przykładzie przedsiębiorstwa Sports Goods Industry z Indii.

**Wyniki i wnioski:** Zaletą proponowanej metody jest uwzględnienie różnorodności działań przedsiębiorstwa oraz jednocześnie efektywnej identyfikacji różnic pomiędzy dostawcami. Dzięki stosowaniu tej metody możliwe jest podniesienie jakości pracy przedsiębiorstwa.

**Słowa kluczowe:** audit dostawcy, analiza wariancji (ANOVA), łańcuch dostaw, zarządzanie dostawcami, małe i średnie przedsiębiorstwa

## EINE VEREINFACHTE METHODE FÜR DIE BEURTEILUNG DES MANAGEMENTS VON LIEFERANTEN FÜR KLEIN- UND MITTELSTÄNDISCHE UNTERNEHMEN

**ZUSAMMENFASSUNG. Einleitung:** Das Management der Beurteilung von Lieferanten stellt für die klein- und mittelständischen Unternehmen einen Bereich von wesentlicher Bedeutung dar. Auf welche Art und Weise können solche Unternehmen eine bessere Marktposition durch die Verbesserung des die Lieferanten anbetreffenden Beurteilungssystems erlangen? Die Schlüsselfrage dabei ist das Aufbauen eines auf die Gruppe von Kennziffern gestützten Systems für die Beurteilung der durch die Lieferanten erbrachten Wertschöpfung. Solch ein Auditing-System kann bei der Verminderung des Risikoniveaus und der Herabsetzung der aus der schlechten Qualität resultierenden Kosten in den klein- und mittelständischen Unternehmen eine Hilfe leisten. Daher stellt ein hochqualitatives Programm für die Beurteilung der Lieferanten ein brauchbares Tool für das Management im Unternehmen dar.

**Methoden:** Um den an die Programme der effektiven Beurteilung der Lieferanten gestellten Anforderungen das Genüge zu leisten, hat man die allgemeinen Prinzipien eines solchen Programms, das auf eine strenge und gleichzeitig universale Varianten-Analyse (ANOVA) gestützt ist, vorgeschlagen. Es wurden die Definition des Prozesses, Standardisierung, der Überblick über die gegenwärtige Gegenstandsliteratur und die praktische Anwendung am Beispiel des Unternehmens Sports Goods Industry von Indien projiziert.

**Ergebnisse und Fazit:** Der Vorteil der vorgeschlagenen Methode besteht auf der Berücksichtigung der Unterschiedlichkeit von Aktivitäten des Unternehmens sowie einer effektiven Identifikation von Differenzen zwischen den Lieferanten. Dank der Anwendung dieser Methode ist die Erhöhung der Arbeit-Qualität des Unternehmens möglich..

**Codewörter:** Auditing des Lieferanten, Varianten-Analyse (ANOVA), Lieferkette, Management von Lieferanten, klein- und mittelständische Unternehmen.

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