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Statistical analysis applied to Safety Culture self-assessment A survey example

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Abstract. Interviews and opinion surveys are instruments used to assess the safety culture in an organization as part of the Safety Culture Enhancement Programme. Specific statistical tools are used to analyse the survey results. This paper presents an example of an opinion survey with the corresponding application of the statistical analysis and the conclusions obtained. Survey validation, Frequency statistics, Kolmogorov-Smirnov non-parametric test, Student (T-test) and ANOVA means comparison tests and LSD post-hoc multiple comparison test, are discussed.

Introduction

One of the main steps on a Safety Culture Enhancement Programme is the assessment of the safety culture in the organization. A tool used to assess the safety culture of an organization is the performance of an opinion survey of important characteristics related to it. Statistical handling of survey results gives the detailed information on the strength and weakness of each safety culture characteristic in the organization. The partition of the population surveyed into background conditions such as 'Area of activity', 'Time experience', 'Education', 'Age' and 'Sex' is used in the survey analysis. Statistical analysis of the survey data on these background conditions provides clear statistical results on which actions for enhancing safety culture can be readily set up.

To demonstrate the statistical analyses, a fictitious organization with 500 employees is used. The surveyed population is 250, 50% of the total amount of employees. The survey is composed of two characteristics here called characteristic 1 and characteristic 2. Characteristic evaluation ranges from 0 to 4.

In section 2 the validation of the survey "representativeness" (its condition to represent the whole universe of the research) is presented. Section 3 shows the application of descriptive and non-parametric statistical tests on the total survey. Section 4 presents the application of means comparison and post-hoc multiple comparison tests on the background conditions. Finally, in section 5 conclusions of statistical analyses application on Safety Culture self-assessment are given.

Representativeness of the survey

The total survey is considered representative of the organization if, at least, 30% of the total amount of employees is surveyed. The representativeness of the survey for each background condition is validated comparing the survey distribution with the employees' distribution in the respective categories of the background condition. The distributions must be consistent for all categories in each background condition. If, for any background condition, the survey is considered not representative, this background condition shall not be used for the assessment of the organization safety culture.

Table I shows an example of a valid and an invalid survey for the background condition 'Sex'. It can be noted that the survey distribution compared to the organization distribution for the valid case is similar (89.20% and 11.80% in the survey and 88.60% and 11.40% in the organization, for categories 'Male' and 'Female', respectively) and strongly different for the

invalid survey (98.00% and 2.00% in the survey and 88.60% and 11.40% in the organization, respectively).

TABLE I. EXAMPLE OF A VALID AND AN INVALID SURVEY FOR BACKGROUND CONDITION 'SEX'

Sex	Total		Surveyed		Sex	Total		Surveyed	
	No.	%	No.	%		No.	%	No.	%
Male	443	88.60	223	89.20	Male	443	88.60	245	98.00
Female	57	11.40	27	11.80	Female	57	11.40	5	2.00
Total	500	100.00	250	100.00	Total	500	100.00	250	100.00

Total survey statistics

A frequency analysis with mean and standard deviation shall be carried out for each characteristic of the total survey. Standard deviation too high in any characteristic indicates a possible lack of conformity with expected normal distributions. In this case, a Kolmogorov-Smirnov test is applied to compare the survey distribution function to the normal distribution. Small significance values (less than 0.05) indicate that the survey distribution does not correspond to the normal distribution. As a result, statistical analyses on the background conditions shall be applied to those characteristics to find out if the evaluation of the characteristics by the categories of background conditions differs significantly and, if this is the case, where and how.

Table II shows the frequency analysis of the survey example. The high standard deviations for both characteristics indicates that, possibly, the survey distribution does not correspond to the expected normal distribution. In this case, the Kolmogorov-Smirnov test shall be applied.

TABLE II. FREQUENCY ANALYSIS OF SURVEY EXAMPLE

		Characteristic 1	Characteristic 2
Number	Valid	250	250
	Missing	0	0
Mean		3.31	3.00
Std. Deviation		.53	.80

Table III shows the Kolmogorov-Smirnov test applied to the survey example. The results confirm that the survey distribution differs significantly from the normal distribution in both characteristics (significance values less than .05). Specific statistical analyses shall be applied on the background conditions.

TABLE III. ONE-SAMPLE KOLMOGOROV-SMIRNOV-TEST OF THE SURVEY EXAMPLE

		Characteristic	Characteristic
Number		250	250
Normal Parameter	Mean	3.31	3.00
	Std. Deviation	.53	.80
Most Extreme Differences	Absolute	.189	.338
	Positive	.128	.270
	Negative	-.189	-.338
Kolmogorov-Smirnov Z		2.988	5.344
Significance Value		.000	.000

Background condition statistics

Specific statistical analyses are applied on each background condition to determine which categories differ significantly from the others. Significant mean differences, between categories are interpreted demonstrating which category has higher or lower perception of the safety culture than other(s).

Student means comparison, called T-test, is applied on the background conditions with only two categories. Table IV gives the result of the T-test for background condition ‘Sex’ of the survey example. Levene’s test high significance value (greater than .05) for characteristic 1 indicates that the results assuming equal variances for both categories shall be used. For characteristic 2 (significance value smaller than .05) the results not assuming equal variances shall be used. Analysis of T-test results shows that, in characteristic 1, there is no significant difference between ‘Male’ and ‘Female’ evaluation (significance value .368). In characteristic 2, however, the results show a significant evaluation difference (significance value .023). The positive mean difference (.039) demonstrates that ‘Male’ gave significantly higher evaluation than ‘Female’ for this characteristic.

TABLE IV. T-TEST OF BACKGROUND CONDITION ‘SEX’ FOR THE SURVEY EXAMPLE

		Mean Difference	Levene's test		T-test	
			Significance Value	Significance Value	95% Confidence Lower	Upper
Characteristic 1	Equal variances assumed	.08	.152	.368	-9.11E-02	.25
	Equal variances not assumed			.510	-.16	.31
Characteristic 2	Equal variances assumed	.039	.000	.002	.14	.64
	Equal variances not assumed			.023	5.54E-02	.73

ANOVA means comparison is applied on the background conditions with more than two categories. Table V gives the result of the ANOVA test for background condition ‘Area of activity’ of the survey example. Results show that, in characteristic 1, there is no significant

difference between the categories (significance value .138). In characteristic 2, however, the results show a significant evaluation difference (significance value .031). For this characteristic, a post-hoc analysis shall be performed to verify which categories differ and how.

TABLE V. ANOVA-TEST OF BACKGROUND CONDITION 'AREA OF ACTIVITY' FOR THE SURVEY EXAMPLE

		Sum of Squares	df	Mean Square	F	Significance Value
Characteristic 1	Between Groups	1.556	3	.519	1.855	.138
	Within Groups	68.803	246	.280		
	Total	70.360	249			
Characteristic 2	Between Groups	5.614	3	1.871	3.001	.031
	Within Groups	153.382	246	.624		
	Total	158.996	249			

Post-hoc LSD test is then applied on the characteristic 2 of background condition 'Area of activity', for which ANOVA test has indicated significant differences on categories evaluation. Table VI gives the result of the LSD test for characteristic 2 of background condition 'Area of activity'. Results show that categories 'Operation' and 'Engineering' gave significant different evaluation from category 'Maintenance' (significance values .014 and .020, respectively). Positive means differences demonstrate that 'Operation' (mean difference .30) and 'Engineering' (mean difference .40) gave significant higher evaluation than 'Maintenance' (mean differences -.30 and -.40, respectively).

TABLE VI. LSD-TEST OF BACKGROUND CONDITION 'AREA OF ACTIVITY' FOR THE SURVEY EXAMPLE

Dependent Variable	Area of activity (1)	Area of activity (2)	Mean Difference (1-2)	Significance Value	95% Confidence Interval	
					Lower	Upper
Characteristic 2	Operation	Engineering	-9.74E-02	.577	-.44	.25
		Maintenance	.30*	.014	6.00E-02	.54
		Administration	5.92E-02	.677	-.22	.34
	Engineering	Operation	9.74E-02	.577	-.25	.44
		Maintenance	.40*	.020	6.18E-02	.73
		Administration	.16	.398	-.21	.52
	Maintenance	Operation	-.30*	.014	-.54	-6.00E-02
		Engineering	-.40*	.020	-.73	-6.18E-02
		Administration	-.24	.080	-.51	2.88E-02
Administration	Operation	-5.92E-02	.677	-.34	.22	
	Engineering	-.16	.398	-.52	.21	
	Maintenance	.24	.080	-2.88E-02	.51	

* The mean difference is significant at the .05 level

Conclusion

Some statistical tests, if appropriately selected and applied, form a very robust tool for analysing any kind of opinion survey. This study gives an example of the application of statistical analyses in the safety culture self-assessment as part of the Safety Culture Enhancement Programme.

The whole path of the analysis is shown from the validation of survey representativeness up to the identification of safety culture perception differences between categories of background conditions.

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