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STATISTICAL METHODS AS A DECISION MAKING TOOL FOR PRODUCTION ENGINEERING – AN EXEMPLARY APPLICATION

7.1 INTRODUCTION

Decision-making in a company is a complex process which requires the use of various information sources pertaining to the individual production processes and areas of management. The market conditions of conducting operational activities lead to the necessity of constantly analysing many pieces of information about the reality in which the company operates. This serves to minimise the risk of mistake when choosing production methods or the type of assortment produced by the company.

According to the definition, the decision-making process in a company can be described as a procedural-technological characteristic of the management process with various economical and socio-psychological determinants. Decision-making can be viewed in the broad and narrow sense [3]. In the broad sense, it is a complex process from the identification of a decision-making problem through gathering information, assessing the available alternatives in accordance with the agreed criteria, making a decision, implementing a measure, to monitoring its results. The narrow meaning of this term refers to one of the abovementioned stages – the conscious act of will of the decision-maker choosing one of the possible solutions available in the given situation. With reference to decisions made by the management of a production company, the choice of one of the available solutions can consist in a decision about engaging in or forgoing a certain production process. According to the above definition, the following stages of the decision-making process are distinguished:

- identification of a decision-making problem,
- identification and development of decision variants,
- assessment of the variants developed in accordance with the agreed criteria and the choice of the rational variant,
- decision implementation,
- control of the decision's effects,

It should be noted, however, that companies nowadays take many highly complex decisions which require taking into account a large number of external and internal factors which could affect the consequences of choosing a given variant. Comparing the impact of individual factors on the observed change in results of the individual variants can be done using various dedicated computer programs for quantitative data analysis. One of such programs is the PS IMAGO suite. The program allows for confirming whether the data gathered meet criteria defined for a chosen statistical test, as well as thoroughly investigating the correlations between the variables analysed.

One of the statistical tests most frequently used for analysing the impact of selected variables on the results is variance analysis.

This analysis was devised by an English statistician and geneticist Ronald A. Fischer, and is comprised of a set of statistical methods, with the most often enumerated ones being [2]:

- single-factor, one-variable (one-dimensional) variance analysis,
- single-factor, multi-variable (multi-dimensional) variance analysis,
- multi-factor, one-variable variance analysis,
- multi-factor, multi-variable variance analysis,
- co-variance analysis, where, apart from factors and measured characteristics, additional variables called confounding factors are input into the model,
- variance analysis for dependent variables (also referred to variance analysis for repeated observations).

The idea behind variance analysis is to check whether the isolated factors (independent variables) have an impact on the variable being measured (dependent variable). The statistical method used allows for separating the observed change in results (variance) into variance stemming from a given factor and variance connected with an error (error variance). Presented below is a brief characteristic of single-factor, one-variable variance analysis as well as an example use for the analysis of hypothetical impact of the type of materials used on the energy consumption of the production process.

7.2 ENERGY CONSUMPTION OF A PRODUCTION PROCESS

Energy consumption is a concept connected mostly with manufacturing. It is defined as the relation between the volume of energy used in a production process in a company, industry or economy and the respective volume of production in which the energy was used, i.e. a relation between expenditure and product.

Three areas can be distinguished to which the concept of energy consumption can refer, namely:

- energy consumption of the national product,
- energy consumption of production of a sector or branch of national economy,
- energy consumption of a product,

Each of the relations enumerated shows the issue of energy consumption on a different plane.

Energy consumption of the national product is the relation of primary energy consumed to the value of the national product. In the other cases the consumption of final energy with relation to the production value of the sector or branch is calculated. The energy consumption level is mostly determined by: the branch structure of industry, manufacturing technologies used, energy prices, production quality [4].

The choice of rational variants (out of many, if they exist) of energy consumption consists in determining the goal function. The following, among others, should be considered when making such a choice:

- minimal financial expenditures,
- minimal values of energy consumed in the production process,
- experiment planning,
- determining and defining the value of energy potential.

This article analyses different materials (three) in the aspect of energy consumption of the production process.

7.3 ASSUMPTIONS FOR THE APPLICABILITY OF SINGLE-FACTOR VARIANCE ANALYSIS

Variance analysis relies on three main assumptions which need to be met in order to properly conduct the statistical proof [1]:

- variable measurements have a normal distribution in each group. Test F is characterised as completely immune to not meeting the normal distribution assumption. This means that in the case of small groups, a slight deviation of the distribution from the norm should not lead to distortion of the results. In the case of large samples, the normality of distribution can be checked using proper statistical tests,
- variance of measurements should be identical in all groups. Significant departures from this assumption result in raising the F statistic, which translates to an unwarranted rejection of the zero hypothesis,
- statistical independence of measurements within a group. Independence of measurements means that knowing the result of one measurement does not provide any clues to the probable result of other measurements. According to the assumption adopted in variance analysis, all measurements obtained from different units are independent when the groups of their origin are unknown.

The below example shows the use of a single-factor, one-variable variance analysis for estimating the impact of the material used for the production of final goods on the energy consumption of the production process. The analysis conducted can be useful in the decision-making process pertaining to the choice of materials used for production. According to the data, the energy consumption of the production process was analysed for three different materials: 1, 2 and 3. To that end, data illustrating the energy consumption of the production process when the three materials discussed are used were input to the PS IMAGO program and an analysis was launched. Figure 7.1 shows the screen a choice of single-factor variance analysis.

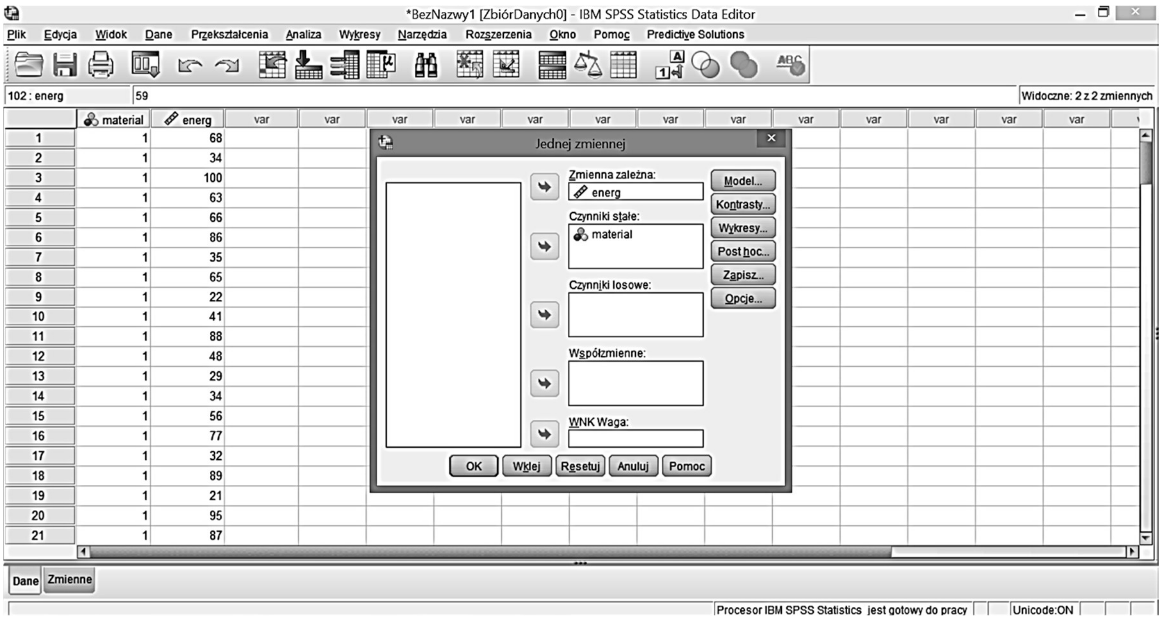

Fig. 7.1 Single-factor variance analysis in the PS IMAGO program – analysis choice

In accordance with the variance analysis feasibility principles listed above, before beginning the calculations, it should be checked that the data meet those assumptions, which can also be done using the aforementioned program (Analysis menu: Statistical description). This article presents only the analysis without the preliminary calculations.

In order to conduct the variance analysis, one must choose the One variable option under the General linear model option from the Analysis menu. After a new window opens, the dependent variable must be chosen (production process energy consumption) as well as the constant factor (material).

Upon confirming the choice, a variance analysis will be conducted followed by the results being displayed, as shown in Table 7.1.

Table 7.1 One-variable variance analysis (UNIANOVA) – results

Inter-object factors

		N
Material	1	49
	2	49
	3	49

Inter-object effect tests

Dependent variable: energy consumption

Source	Square sum type 3	df	Average square	F	relevance
Adjusted model	7100.177[a]	2	3550.088	4,277	.016
Constant	343215.027	1	343215.027	413,492	.000
Material	7100.177	2	3550.088	4,277	.016
Error	119525.796	144	830.040		
Total	469841.000	147			
Adjusted total	126625.973	146			

a. R squared = .056 (Adjusted R squared = .043)

According to the calculations, a significant influence of the material used was observed on the energy consumption of the production process (F = 4.28; p < 0.02). This result, however, does not indicate which of the groups differ from the rest. In order to check the relevance of the differences between groups, *post hoc* tests need to be conducted, available upon clicking the Post hoc icon shown in Fig. 1. Many tests are available in the PS IMAGO program; the results of two of them – Tukey's and Scheffe – have been shown below (Table 7.2).

Table 7.2 Post hoc test results
Repeated comparisons

Dependent variable: energy consumption

	(I) material	(J) material	Difference of averages (I-J)	Standard error	relevance	95% confidence interval Lower limit	Upper limit
Tukey's test HSD	1	2	17.02*	5.821	.011	3.24	30.80
		3	8.22	5.821	.337	-5.56	22.01
	2	1	-17.02*	5.821	.011	-30.80	-3.24
		3	-8.80	5.821	.289	-22.58	4.99
	3	1	-8.22	5.821	.337	-22.01	5.56
		2	8.80	5.821	.289	-4.99	22.58
Scheffe test	1	2	17.02*	5.821	.016	2.62	31.42
		3	8.22	5.821	.371	-6.17	22.62
	2	1	-17.02*	5.821	.016	-31.42	-2.62
		3	-8.80	5.821	.322	-23.19	5.60
	3	1	-8.22	5.821	.371	-22.62	6.17
		2	8.80	5.821	.322	-5.60	23.19

Developed on the basis of observed averages
A factor of error is the average square (Error) = 830.040
* Difference of averages is significant at a 0.05 level

Uniform groups

Energy consumption

	material	N	Groups 1	2
Tukey's test HSD	2	49	39.71	
	3	49	48.51	48.51
	1	49		56.73
	relevance		.289	.337
Scheffe test	2	49	39.71	
	3	49	48.51	48.51
	1	49		56.73
	relevance		.322	.371

The results of *post hoc* tests indicate that using material 2 significantly contributes to the decrease in energy consumption of the production process (M = 39.71). There is, however, no difference in this respect between materials 1 (M = 56.73) and 3 (M = 48.51).

7.4 CONCLUSION

The (example) program presented is comprehensive and can be a useful tool for the statistical analysis of a number of data sets used in the decision-making process in a company. In the example discussed one of the many analyses available was used, which can also be utilised in production engineering.

Analysis of the energy consumption of a production process has a significant impact on the production costs and, therefore, a company's profitability. This is why before launching a production process (as long as no specific material is indicated) the available materials that could be used for manufacturing should be analysed with regard to the energy consumption of the production process.

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STATISTICAL METHODS AS A DECISION MAKING TOOL FOR PRODUCTION ENGINEERING – AN EXEMPLARY APPLICATION

Abstract: *Production engineering is the term given to the issues of planning, designing, implementing and managing production systems, logistics systems and securing their functioning (IIE, 1989). According to this definition, production engineering is focusing on the decisions aiming at maintaining the decision processes within the organization. Therefore, decision makers use different tools to ensure the accuracy and efficiency of this process. One group of methods than can be useful in production engineering are statistical methods organizing data collecting, presentation an processing. The article presents samples of statistical methods used in production engineering.*

Key words: *statistical methods, decision, organization, production engineering*

METODY STATYSTYCZNE JAKO NARZĘDZIE PODEJMOWANIA DECYZJI W INŻYNIERII PRODUKCJI – PRZYKŁADOWE ZASTOSOWANIE

Streszczenie: *Inżynieria produkcji jest dyscypliną, która swoją uwagę skupia na kwestiach planowania, projektowania, wdrażania i zarządzania systemami produkcyjnymi, logistycznymi, w celu zapewnienia ich prawidłowego funkcjonowania (IIE, 1989). Zgodnie z tą definicją, inżynieria produkcji koncentruje się na decyzjach mających na celu utrzymanie procesów decyzyjnych w organizacji. Dlatego decydenci stosują różne narzędzia, aby zapewnić dokładność i efektywność tego procesu. Jedną z grupy metod która może być przydatna w inżynierii produkcji są metody statystyczne bazujące na zbieraniu danych, ich prezentacji, przetwarzaniu. W artykule przedstawiono propozycję metody statystycznej która może znaleźć zastosowanie w inżynierii produkcji.*

Słowa kluczowe: *metody statystyczne, decyzja, organizacja, inżynieria produkcji*