COMPUTER-AIDED DESIGN OF EXPERIMENTS IN THE FIELD OF KNOWLEDGE-BASED ECONOMY

Dorota Dejniak, Monika Piróg-Mazur

Abstract: *This article is devoted to chosen aspects of designing experiments in the innovative economy. The contemporary theory of experiment has become a vast field of knowledge. Its methods and applied mathematical devices often surpass the capabilities of researcher's perception, who does not wish to waste time comprehending them. Computer systems that aid to the experiment are a solution to this problem. STATISTICA that contains the used in this article module named Design of experiments finds place among those computer programs.*

Keywords*: planning experience, knowledge-based economy,*

ACM Classification Keywords*: K. Computing Milieux, K.1 THE Computer Industry, Statistics, J.7 Computers In Other Systems, Industrial control*

Introduction

The rapid development of science and technology means the need for introducing more and more radical changes almost in every sphere of life. It concerns, above all, the field of business activity. To develop effectively and dynamically, changes of an innovative character are required: new organizational and management systems, marketing, new manufacturing technologies but, above all, new products that would better satisfy the more and more rapidly changing consumer's needs.

In the field of knowledge-based economy, those organizations achieve success that manage well the process of seeking new ideas and technologies, and transferring them to the solutions that constitute the market value. Innovation in activities finds reflection in a better evaluation and perception of enterprises by markets. Economy relying on production, distribution and the use of knowledge and information – the most important factors that result in economy development.

Advanced technologies (like computer science and telecommunications), as well as sectors employing qualified employees (like finances or education) constitute the foundation of the Knowledge-Based Economy. Four pillars of Knowledge-Based Economy can be distinguished: institutional and legal surrounding, innovation, communication infrastructure, education and trainings, which allow to take pride of qualified employees.

During the recent years, many enterprises have made great investments in the development of modern computer devices that aid to planning and production control. Majority of solutions oversimplified the modelling of production reality both in case of modelling the objects as well as the processes they were subject to, which constituted their shortcoming [Euve, 1997, Knosala, 2007]. A new approach to working out planning systems, which could solve complex problems of contemporary production, appeared to be indispensable [Knosala, 2007]. Computer systems that aid to an experiment has appeared to be a solution. Design of Experiment (DOE) is a method that by means of eliminating external factors allows to find such an arrangement of controlled process parameters that the process can be as optimal as it is possible.

Design of experiments

Theory of experiment was formulated to gain in a relatively short time and at limited costs knowledge needed for a new or improved technological process. It is highly significant in case of knowledge-based economy. During each technological process, questions about the quality of the product as well as the optimisation of costs emerge. Only scientific research studies result in experiments that need to be carried out as quickly as it is possible and aim to obtain a product of desired qualities. Design of experiments (DOE) is an interdisciplinary field of science, which combines applied mathematics, statistics and computer science. Its aim is to answer the question: how to design an experiment to gather as much information as it is possible at the lowest possible costs.

Studying the role of the theory of experiment in the knowledge-based economy, two circumstances need to be taken into consideration [Polański, 1984]:

- In the event when the concept of creating new quality emerges, the theoretical and empirical research studies are required the most frequently. Each of these researches is important and indispensable; the empirical studies are, in addition, expensive and time consuming.
- In the event when it is important to cut the costs and carry out empirical studies in shorter time, the methods of the theory of experiment need to be applied, including the design of experiment and statistical analysis of results.

The subject of a research may, for instance be a device, a technological process as well as an economic dependency etc. Input parameters specified by a researcher, as well as output parameters that are observed and measured characterize the quality of a selected product. Despite the controlled inputs, the investigated process is influenced by factors that are beyond the researcher's control.

The aim of the research is to determine an approximate relation that describes the reaction of the object to the introduced input changes. The relation is an approximation of a connection inside the object. Calculations of the methods of the theory of experiment are so complex that computer is indispensable to make them. Once the input parameters have been determined, it is checked whether there is a qualitative relation between them and the output quantities. The relation needs to be described by means of a model, and the values of input parameters that will ensure optimal output values have to be found. For that purpose, for instance fractional factorial design, compositional design, Latin square, Taguchi method can be applied.

During the research studies, it is indispensable to carry out a series of experiments that aim to investigate the response of an object to specified input values. In a traditional meaning, the variation interval of each input variable would be divided into equal segments and all the possible combinations of their values would correspond to particular experiments. The complexity of the contemporary processes has made the traditional method ineffective. For instance, an object of 8 input parameters would constitute 28=256 of experiments. An analogical program of researches, designed in compliance with the theory of experiments, consists of only 16 experiments. ANOVA analysis of variance and Pareto chart are used to analyse results obtained by means of computer-aided design of experiments.

A quality management systems certification needs to be mentioned at that point. The methodology of designing experiments has become one of the devices that aim to design a process that meets a standard. In the result, the standard – ISO 35344-3 that covers statistical methods was extended by a part referring to the design of experiments.

Computer experiment and data analysis

The aim of the research is to improve the efficiency of a certain technological process. The process is controlled by four input variables. The investigation of it can be carried out by applying the so called complete block design that covers all the possible variations (16 combinations) or the fractional factorial design that embraces only the chosen part of the complete block design (8 combinations) [Pietraszek, 2004]. It needs to be assumed that factors influencing the process acquire two values. In figure 1. is describe two values -1,1. The fractional factorial design was chosen and the obtained results of measurements are displayed below.

	variable 1	variable 2	variable 3	variable 4	performance
1	-1	-1	-1	-1	45
2	1	-1	-1	1	31
3	-1	1	-1	1	44
4	1	1	-1	-1	32
5	-1	-1	1	1	50
6	1	-1	1	-1	31
7	-1	1	1	-1	44
8	1	1	1	1	30
9	-1	-1	-1	-1	45
10	1	-1	-1	1	31
11	-1	1	-1	1	43
12	1	1	-1	-1	31
13	-1	-1	1	1	49
14	1	-1	1	-1	30
15	-1	1	1	-1	44
16	1	1	1	1	30

Figure 1. Table containing fractional factorial design and obtained results of measurements

From such a perspective, the object of research studies has a universal character and is mainly characterized by:

- input parameters that may acquire different values of the selected intervals

- output parameter that depends on the input parameters and creates the so called function of the research object; it is the function of research object that constitutes the main scientific information.

Once the data have been entered and the analysis by means of the STATISTICA program commenced, the issue – Conclusion: Evaluation of effects need to be considered.

evaluate the effects ; Variable.:variable output.; R^2= ,96439;Correct:,95144 (sweet1) 2**(4-1) plan (scheme) , Residue MS=2,977273 variable output.

	effect	standard error	t(11)	p	(-95%) - confidence limits	(+95%) - confidence limits	factor, coefficient.	standard error - factor.	(-95%) - confidence limits	(+95%) - confidence limits
average/constant	38,1250	0,431369	88,3813	0,000000	37,1756	39,0744	38,12500	0,431369	37,17556	39,07444
(1)variable 1	-14,7500	0,862739	-17,0967	0,000000	-16,6489	-12,8511	-7,37500	0,431369	-8,32444	-6,42556
(2)variable 2	-1,7500	0,862739	-2,0284	0,067433	-3,6489	0,1489	-0,87500	0,431369	-1,82444	0,07444
(3)variable 3	0,7500	0,862739	0,8693	0,403240	-1,1489	2,6489	0,37500	0,431369	-0,57444	1,32444
(4)variable 4	0,7500	0,862739	0,8693	0,403240	-1,1489	2,6489	0,37500	0,431369	-0,57444	1,32444

Figure 2. Table containing the evaluation of effects

Figure 2. contains the evaluation of effects. The displayed effects are statistically significant at the accepted significance level of 5%. Accepting the assumption of the linear model, applied by a two-level fractional factorial design, the first variable has a significant influence on efficiency. The increase in the value of the first factor will

significantly lower the efficiency. The other effects are not statistically significant. The chart – Pareto of standardized effects presents it graphically (Figure 3.). Pareto chart is used to identify and evaluate the significance of analysed issues by marking on the chart columns that correspond to the frequency of the particular categories.

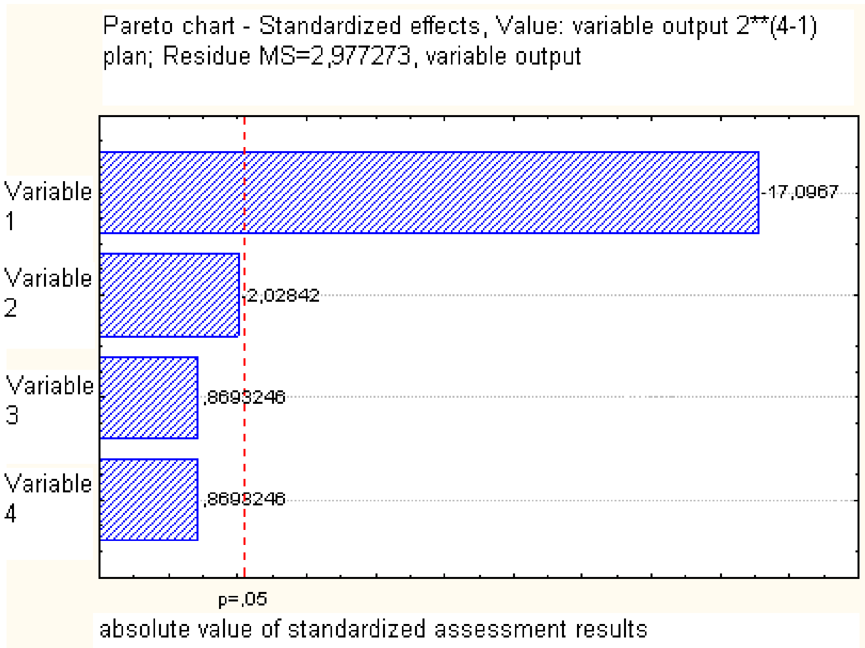

Figure 3. Pareto chart

Analysis of variance (ANOVA) is a group of statistical methods used to compare a few populations. In general, this is a technique of studying results (experiments, observations) that depend on one or a few factors that are activated simultaneously.

The statistically significant effects are clearly separated from the insignificant ones. It correspond to the chosen significance level of 5%. The ANOVA (Figure 4.). table displays qualitative information about the influence of the particular effects on the complete response variation of the research object.

ANOVA; Variable.:Variable output.; R^2= ,96439;Correct:,95144 (sweet1) 2**(4-1) plan (scheme); residue MS=2,977273 Variable output					
	SS	**df**	**MS**	**F**	**p**
(1)variable 1	870,25	1	870,25	292,2977	0
(2)variable 2	12,25	1	12,25	4,1145	0,067433
(3)variable 3	2,25	1	2,25	0,7557	0,40324
(4)variable 4	2,25	1	2,25	0,7557	0,40324
error	32,75	11	2,9773		
total SS	919,75	15			

Figure 4. Table including ANOVA analysis

In figure 5. is describe normality diagram. Diagnostic normality diagram has on the horizontal axis the remainder values and on the vertical axis the normal values calculated for the ordered sequence of remainder values. The lines refer to the arrangement of an ideal normal distribution.

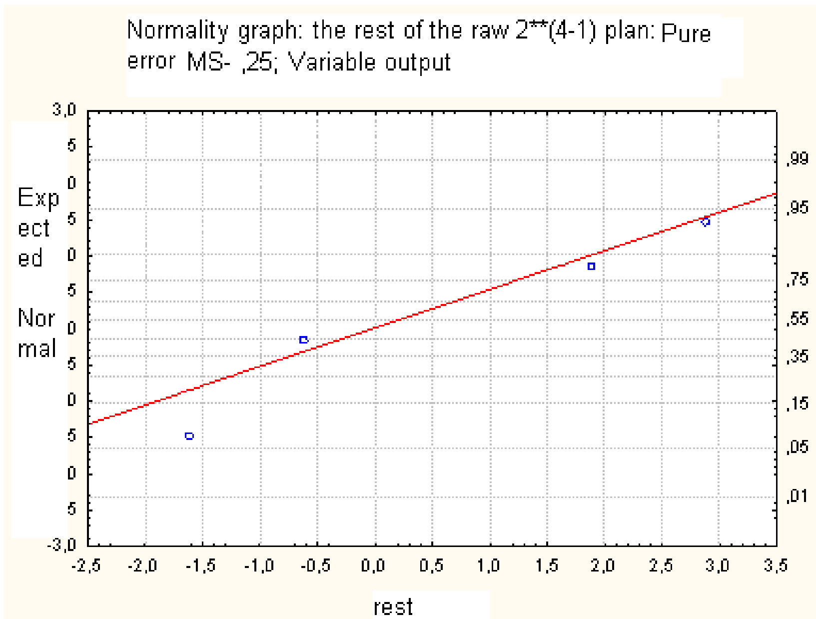

Figure 5. Normality diagram

To conclude, a scheme of a cube with calculated forecast values (Figure 6.) for the particular vertexes need to be illustrated. Due to the type of the task – maximization of efficiency – the vertex with the highest forecast value need to be found. The presented below diagram refers to the first three variables.

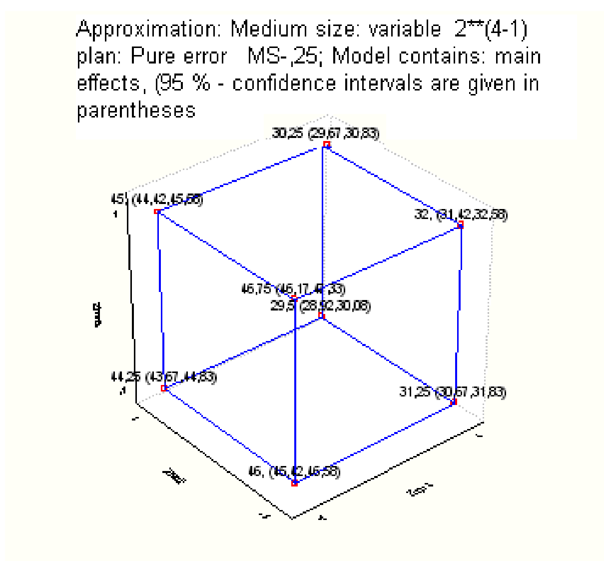

Figure 6. Scheme of a cube with calculated forecast values

The analysis covers a sequence of undertakings connected with the qualitative and quantitative analysis of the problem and aims to specify – from the standpoint of formulated aims – the best variants of enterprise development, including the improvement of the efficiency of a technological process.

Conclusion

The growing competition on the market requires frequent, even worked out on the spot, decisions connected with the course of the technological process. The growing requirements in reference to shortening the time of calculations that are indispensable to design a production plan result in the need for applying new methods and devices that enable to work out a production planning. Methods and models are mainly created by the use of simulation modelling. The possibility to test and evaluate alternative decisions, strategies and policies before they are applied in the existing enterprises is the main reason for making use of computer simulation [Witkowski, 2000].

Technical innovations belong to the main responsibilities of knowledge-based economy. The presented process of computer-aided design of experiments enables to single out input variables that significantly influence the investigated process. It allows to build an appropriate and reliable mathematical model in a short time. A significant purpose of the presented plan is also to specify the influence of variance of the particular input parameters on the variance of the entire process. It allows to identify sensitive points of the studied process.

In further analysis, experimental data taken from a technological process of an enterprise that functions in the sector of glass-making industry will be used.

Bibliography

[Euwe, 1997] Euwe M.J. Wortmann H., Planning Systems in the Next Century, „Computers in Industry", 1997, Vol 34.

[Knosala, 2007] Knosala R. i zespół, Komputerowe wspomaganie zarządzania przedsiębiorstwem, Polskie Wydawnictwo Ekonomiczne, Warszawa 2007

[Pietraszek, 2004] J. Pietraszek, Planowanie doświadczeń – możliwość czy konieczność, http://www.statsoft.pl/czytelnia/jakosc/wprowjak.html

[Polański, 1984] Z. Polański, Planowanie doświadczeń w technice, PWN,1984

[Witkowski, 2000] Witkowski T., Decyzje w zarządzaniu przedsiębiorstwem, WNT, Warszawa, 2000.

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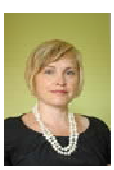

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