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## AN EFFECTS EVALUATION OF ERP APS SYSTEM IMPLEMENTATION IN THE UNCERTAIN TERMS WITH USING FUZZY MODELING AND INFERENCE

### Abstract

*In the paper the approach to forecasting of selected manufacturing company indexes from ERP APS system implementation that makes the element of efficiency evaluation procedure of planned ERP APS system implementation undertaking in a SME is presented. The approach proposed takes into account the present state of enterprise preparation for implementation with existing implementation constraints and uses data from the earlier implementation of the given system with adoption of fuzzy modeling and inference.*

### 1. INTRODUCTION

Offered on the market the Advanced Planning and Scheduling (APS) as applications combined with Enterprise Resources Planning (ERP) systems using the most of data with ERP system enable planning and scheduling in the on-line mode (Gunther, Tempelmeier 2003, Kluge, Kuźdowicz, Andracki 2005, Kluge, Kuźdowicz, Orzeszko 2005, Maciejec 2005, Rutkowski 2002). The main difference between classic MRP planning in the ERP system and APS concept is a change of successive planning of materials demand and usage of resources into one integrated simultaneous planning of many various resources with optimization of using of the resources according to the operational goals of the manufacturing company. Simultaneous consideration of all the crucial resources makes possible achieving of real planning outcomes (Gunther, Tempelmeier 2003, Kluge, Kuźdowicz, Andracki 2005, Kluge, Kuźdowicz, Orzeszko 2005). Producers who offer ERP APS systems for medium-sized manufacturing companies search for methods that make possible to evaluate the efficiency of planned implementation of a given application. The process of implementation of ERP APS system is long and expensive, so it requires a lot of preparations of the enterprise, without that it becomes a very risky investment (Adamczewski 2000, Grudzewski, Hejduk 2004, Kluge, Kuźdowicz, Orzeszko 2005). Therefore, there is a need of elaboration of such a method of an efficiency evaluation of the planned implementation undertaking that takes into account the

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present state of enterprise preparation for implementation of system with implementation constraints.

The purpose of this work is the presentation of the concept of forecasting of selected manufacturing company indexes from ERP APS system implementation that makes the element of efficiency evaluation procedure of planned ERP APS system implementation undertaking in a medium-sized manufacturing company. Proposed approach takes into account the present state of enterprise preparation for implementation with existing implementation constraints and uses data from the earlier implementation of the given system with adoption of fuzzy modeling and inference.

## 2. PROBLEM DESCRIPTION

Proposed in this work the conception makes the element of the performed research that regard the following decision problem. Given a medium-sized manufacturing company specified by quantitative and qualitative indexes as well as the known state of preparation for implementation of ERP APS system. Given ERP APS system with the functional capability and technical requirements. The answer to the following question is searched: Does the given enterprise preparation for implementation, realizing of implementation and exploitation of given ERP APS system allow to obtain selected company indexes in the required time and the required budget with known implementation constraints? In particular: Given a state of enterprise preparation for ERP APS system implementation and its indexes in the moment  $T_0$  as well as a planned state of preparation and implementation in the next moments  $T_1$ ,  $T_2$ , ...,  $T_n$  (see the table 1). The forecasting of enterprise indexes in these moments is searched.

Tab. 1. Data determined a state of a company

Time		$T_0$	$T_1$	$T_2$	$T_3$
Present and planed state of preparation and implementation	Preparing of data	Sp1_0	Sp1_1	Sp1_2	Sp1_3
	Documents flow	Sp2_0	Sp2_1	Sp2_2	Sp2_3
	Purchase of the server	Sp3_0	Sp3_1	Sp3_2	Sp3_3
	...				
Enterprise indexes	Number of orders realized in the time	W1_0	W1_1=?	W1_2=?	W1_3=?
	Using of resources	W2_0	W2_1=?	W2_2=?	W2_3=?
	Number of overtime	W3_0	W3_1=?	W3_2=?	W3_3=?
	...				

To estimate the searched forecasting, using this kind of indexes data from the earlier implementation of the given system in companies the same kind is proposed. The indexes data can be the basis for establishing the rules existing between the data from the previous and the next period in order to build up the model of the input/ output mapping that is realized by a real system and not know in mathematical form. The obtained model approximating the modeled real system can be used for finding output values for new input values.

The exemplary data making the basis for the searched forecasting of indexes W1 and W2 are presented in the table 2. The data were then prepared for establishing existing rules of the modeled system (with inputs x and outputs y), what is presented in the table 3. The modeled system is in the analyzed case a system with five inputs ( $x_1, x_2, x_3, x_4, x_5$ ) and two outputs ( $y_1, y_2$ ).

Tab. 2. Data from ERP APS system implementation – an example

	Enterprise A						Enterprise B					
	T1	T2	T3	T4	T5	T6	T1	T2	T3	T4	T5	T6
T	1	2	3	4	5	6	1	2	3	4	5	6
Sp1	0	0	1	1	1	1	0	1	1	1	1	1
W1	2	5	8	4	6	12	2	4	7	18	35	61
W2	3	2	2	3	4	8	9	5	5	7	13	31
W3	2	3	2	4	3	4	4	5	5	6	6	3

Tab. 3. The data from the table 2 prepared for modeling of the system

	Enterprise A						Enterprise B					
	T1	T2	T3	T4	T5	T6	T1	T2	T3	T4	T5	T6
$x_1$	1	2	3	4	5	6	1	2	3	4	5	6
$x_2$	0	0	1	1	1	1	0	1	1	1	1	1
$x_3$	2	5	8	4	6	12	2	4	7	18	35	61
$x_4$	3	2	2	3	4	8	9	5	5	7	13	31
$x_5$	2	3	2	4	3	4	4	5	5	6	6	3
$y_1$	5	8	4	6	12	2	4	7	18	35	61	
$y_2$	2	2	3	4	8	9	5	5	7	13	31	

### 3. FORECASTING OF ENTERPRISE SELECTED INDEXES FROM ERP APS SYSTEM IMPLEMENTATION WITH THE AID OF ECONOMETRIC MODELING

The indexes data from the earlier implementation of the given system in companies the same kind can be the basis for establishing the econometric model of the input/ output mapping that is realized by a real system and not know in mathematical form. The stages of the econometric model building are following:

- designation of the dependent and explanatory/ endogenous and exogenous variables;
- definition of the econometric model (linear);
- estimation of parameters of the defined model;

- estimate and verification of the established model;
- modifications and repeated verifications up to acceptance.

The obtained model can be used for simulation and forecasting purposes. The example of using the econometric modeling for modeling of a system with two inputs and single output as well as using the obtained model for simulation of forecasted values was presented below.

### 3.1 The example of using the econometric modeling in the case of a system with two inputs and single output

The exemplary measurement samples of a real system after determination of significant and insignificant inputs of the modeled system are presented in the table 4.

Tab. 4. The exemplary measurement data of the real system  $y_1 = -x_1^2 - x_2^2$

x1	-1	0	1	-1	-1	-0,5	-0,5	0	0	0,5	0,5	1	1
x2	0	0	0	1	-1	0,5	-0,5	1	-1	0,5	-0,5	-1	1
y1	-1	0	-1	-2	-2	-0,5	-0,5	-1	-1	-0,5	-0,5	-2	-2

The approximating model was defined as the Ivakhnienko's polynomial function by the formula (1).

$$y_1 = A + Bx_1 + Cx_2 + Dx_1^2 + Ex_2^2 + Fx_1x_2 \quad (1)$$

The defined model was transformed to the linear form by substitution:  $x_1^2 = z_1$ ,  $x_2^2 = z_2$ ,  $x_1x_2 = z_3$ . The parameters of the model were estimated with the aid of the method of least squares. As results the model of the analyzed mapping was obtained in mathematical form. The established function by the formula (2) describes very well the searched dependence.

$$y_1 = -2,2 \cdot 10^{-16} - 1x_1^2 - 1x_2^2 \quad (2)$$

However in the case of the problem analyzed in this work and formulated in the chapter 2, a modeled system is the multi-input and multi-output system and searches of the system model with econometric modeling can be complicated, long and not ended with a success. The alternative can be the conception of using of fuzzy modeling and inference that is presented in the chapter 4.

## 4. THE CONCEPTION OF FORECASTING OF ENTERPRISE SELECTED INDEXES FROM ERP APS SYSTEM IMPLEMENTATION WITH THE AID OF FUZZY MODELING AND INFERENCE

The indexes measurement data can be the basis for build up the fuzzy model of the input/output mapping that is realized by a real system and not know in mathematical form. The obtained fuzzy model approximating the modeled real system can be used for finding output values for new input values. The founded output values of the fuzzy model and the output values of the real system are more or less similar, depending on the accuracy of the fuzzy

model. The in this way established output values are obtained by carry out of the fuzzy inference.

The first step of creation of fuzzy model based on input/ output measurement data is determination of significant and insignificant inputs of the modeled system. The mean fuzzy curve method developed by Lin and Cunningham can be used for this purpose (Piegat 1999, Piegat 2001). Then, the fundamental elements of a fuzzy model structure are searched - the rule base and the number of fuzzy sets assigned to the particular inputs and the output of the model. One of the existing methods of self-organization and tuning of fuzzy model parameters is for determining these elements proposed. It is the geometric method of the maximum absolute error point (Piegat 1999, Piegat 2001) that was presented in the next part of this work.

#### **4.1. The self-organization and tuning of fuzzy model parameters with the geometric method of the maximum absolute error point**

The geometric method of the maximum absolute error point is one of the method for determination of fundamental elements of a fuzzy model structure on the basis of a real system measurement data (Piegat 1999, Piegat 2001). It is assumed in this method that the significant inputs of the model are known. A simplified version of a modeling algorithm with the geometric method of the maximum absolute error point (MAEP) can be presented the following (Piegat 1999, Piegat 2001):

A) Definition of a hyper-tetrahedral base model  $M_0$  of the system with the method of extension of the universe of discourse of the model beyond the universe of discourse of the modeled system.

B) Tuning of the base model based on the measurement samples of the system using of neuro-fuzzy network.

C) Determination of the base model error  $E_0$  and checking the precision of the base model. If its precision is adequate – termination the modeling, otherwise – continuation the modeling (step D).

D) Positioning 2 rules in the points of the maximum and minimum error of the base model  $E_0$  – the error model  $E_{0M}$ .

E) Tuning the membership function parameters of the error model  $E_{0M}$  on the basis of error samples of the base model  $E_0$ .

F) Creating a new model  $M_1$  with addition of the base model and the error model  $E_{0M}$  and checking the model precision. If it is adequate – termination the modeling, otherwise – calculation an error residuum  $E_1$  and continuation the modeling until satisfactory precision is reached.

The MAEP modeling method is based on locating the rules in points of model error extreme. It is the method of positioning of the fuzzy model rules in “important” points of the surface of system mapping that are the extreme in contradistinction to clustering-based methods that can be called frequency methods and consider the points of maximum density of measurement samples as the “important” points of the system.

In the MAEP method, a global model is partitioned into a base model and error residuum models, so it is a set of parallel fuzzy models where each model has a simple structure and contains a small number of rules and fuzzy sets. The base model is the most approximate generalization of the modeled system and covers the entire universe of discourse. The rules of the base model describe the general tendencies encountered in the system. For determination a base model of a multi-inputs system, application of the method of the expansion beyond universe of discourse of the system allows us to reduce a rapidly increase in the number of

rules that is specific to locating the base model rules in the corners of the output universe of discourse. Error residuum models are local models modeling exclusively the individual extreme of error residua. This method of modeling allows us to avoid an extensive increase in the number of rules too.

A neuro-fuzzy network representing a model created with the MAEP method is trained in small fragments, one by one. The base model is trained first. Then, depending on the results the individual error models is trained. Since only a fragment of the network is trained at a time, the training is simpler and easier than in the case of entire network training. The latter situation may cause individual neurons to complete with one another and restrain the adaptation process.

The MAEP method can be applied mainly for modeling the system represented by noise-free or slightly noise- affected measurement data. To increase effectiveness of the method in conditions of stronger noise, filtration should be performed. The weighted mean method can be applied for that purpose.

The example of using the MAEP method for modeling of a single input and single output system was presented in the work (Ważna, Kuźdowicz 2006). The run and the results of determination of the rule base and the number of fuzzy sets assigned to the particular inputs and the output of the model with the MAEP method is presented below for a system with two inputs and single output.

#### 4.1.1 The example of using the MAEP method in the case of a system with two inputs and single output

The exemplary measurement samples of a real system after determination of significant and insignificant inputs of the modeled system are presented in the table 4 in the example 3.1. The run of modeling can be in the following way presented:

A) In the case of a system with two inputs it is presumed, that the universe of discourse for the model is triangular. Three first rules are located in the triangle corners with the coordinates  $P1(a11, a21, b1)$ ,  $P2(a12, a21, b2)$ ,  $P3(a11, a23, b3)$  with this way, that the universe of discourse for the model includes the measurement samples of the modeled real system. For analyzed example the rules were placed in the points  $P1 = (2, -1, 8)$ ,  $P2 = (-1, 8, 8)$ ,  $P3 = (-1, -1, 8)$ . The points determine simultaneous the parameters  $a11, a12, a21, a22, b1, b2, b3$  of membership functions, that present the Fig. 1a), b), c).

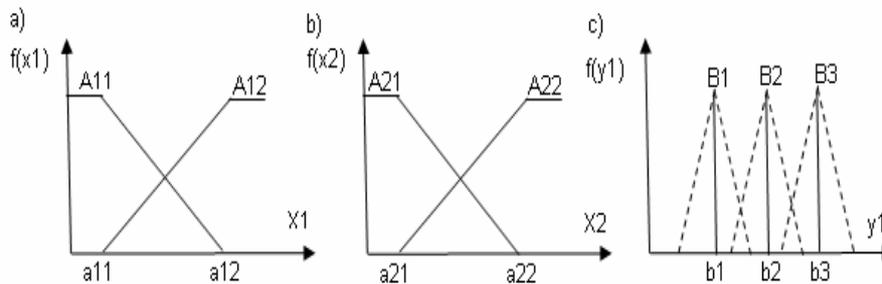


Fig. 1. Membership functions of fuzzy model (based on Piegat 1999)

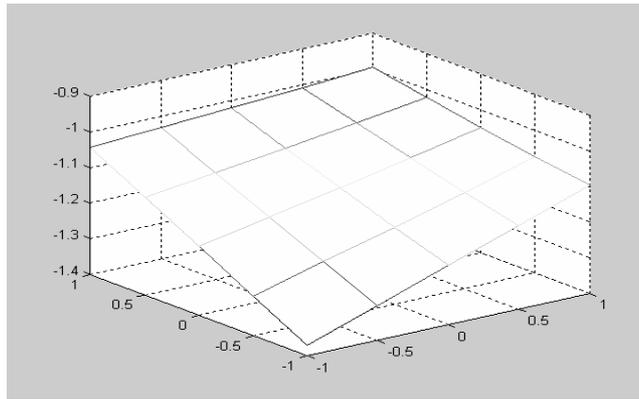


Fig. 2. The base model M0

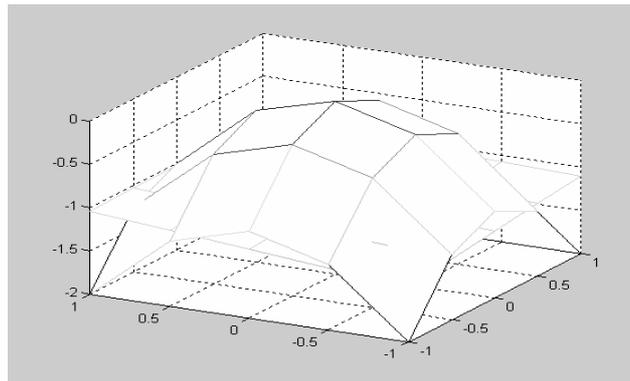


Fig. 3. The precision of the base model M0 (the model M0 and the values of the real system)  
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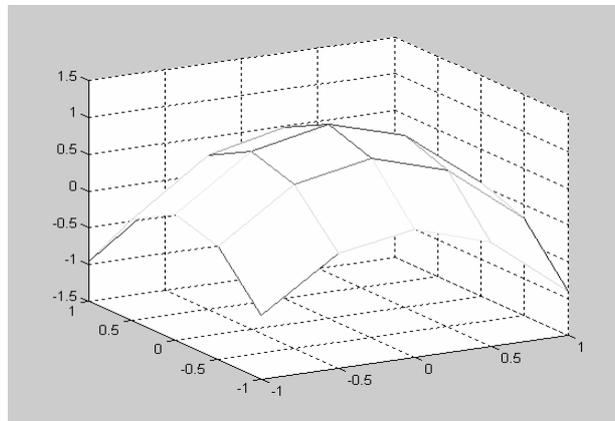


Fig. 4. The base model error E0

B) The in the step A) determined base model M0 is optimized. For that purpose the model is converted into a neuro-fuzzy network and tuned on the basis of measurement samples of the modeled system. A subject to tuning is the parameters  $b_1$ ,  $b_2$ ,  $b_3$ . The parameter tuning is performed following the principle of the method of error back-propagation and using the gradient methods. After tuning, the following results were obtained:  $b_1=-0,96$   $b_2=0,1$   $b_3=-1,37$ . The surface of the obtained base model M0 is presented by the Fig. 2.

C) The precision of the base model M0 is checked by comparing of the output values of the fuzzy model and the outputs values of the measurement samples of the modeled system. The surface of the base model M0 before tuning and the surface of the base model after tuning are presented by the Fig. 3. The base model error E0 surface is presented by the Fig. 4. The mean value of the absolute error of the base model M0 after tuning equals 0,592.

D) Points of the maximum and minimum error of the base model E0 are the points:  $P_4=(0; 0; 1,13077)$  and  $P_5=(1; 1; -1,0074)$ . New rules are located in the points for the purpose determination of a model of the error E0 that is called the error model E0M.

E) For modeling of the error surface E0 the following membership functions were used: the functions from the Fig. 5 with the parameters adequate to the points  $P_4$  and  $P_5$  from the step D) then  $m_1=0$ ,  $m_2=0$  and  $m_3=1$ ,  $m_4=1$  as well as the functions from the figure 1c) with parameters  $b_{12e}=1,13077$  and  $b_{34e}=-1,0074$  that are too adequate to the values of the points  $P_4$  and  $P_5$ . The membership functions from the Fig. 5 constitute the projection of multi-dimensional membership functions  $f_{Aij}(x_1,x_2)=f_{Ai}(x_1)*f_{Aj}(x_2)$  on the planes  $(m, x_1)$  and  $(m, x_2)$ . The in this way determined multi-dimensional membership functions were applied to modeling of the error surface E0. The membership function parameters of the error surface model after tuning equal:  $d_1=0,72$ ,  $l_1=3,4$ ,  $d_2=0,74$ ,  $l_2=2,5$  and  $d_3=0,37$ ,  $l_3=3$ ,  $d_4=0,45$ ,  $l_4=1,9$ . The obtained model of the error surface E0 is presented by the Fig. 6 and is the tuned model E0M.

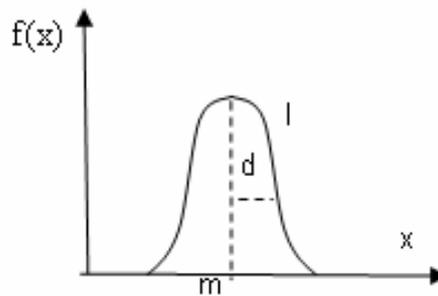


Fig. 5. Membership function for modeling of the error surface E0 (based on Piegat 1999)

F) The mean value of the absolute error of the model  $M_1=M=E_0M$  after tuning equals 0,268. The error residuum E1 is presented by the Fig. 7. Modeling was continued three times obtaining the model M with the mean value of the absolute error 0,0043.

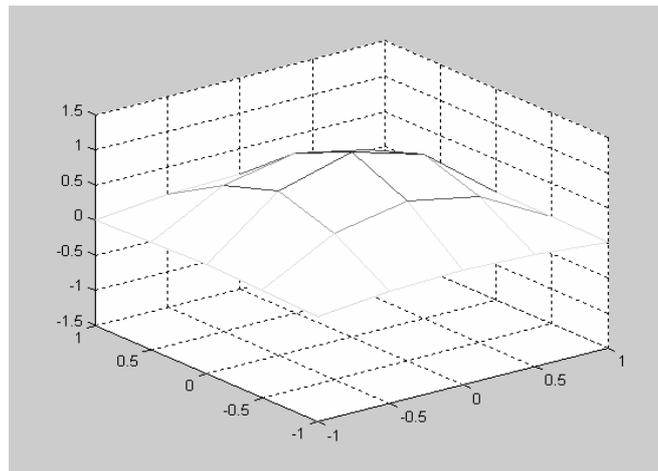


Fig. 6. The model of the error surface E0

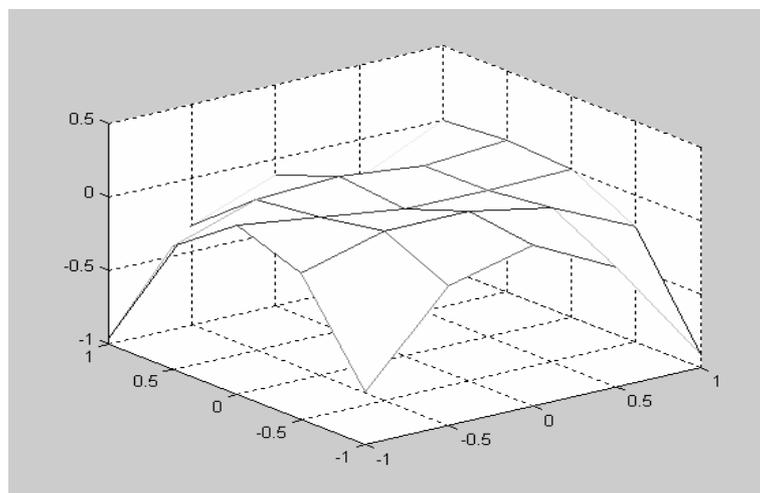


Fig. 7. The error residuum E1

#### 4.2. The fuzzy inference

The fuzzy model of the input/ output mapping that is realized by a real system and not know in mathematical form can be used for establishing of similar output values of the real system for input data with unknown output values. The searched output values obtained in this way are estimated by carry out of fuzzy inference. The results of the fuzzy inference for the system analyzed in the example 4.1.1 are presented below.

#### 4.2.1 The example of fuzzy inference effects

The fuzzy model established in the example 4.1.1 on the basis of the measurement data was used to fuzzy inference for the purpose of obtaining of the forecasted values  $y_1$  based on the exemplary selected elements  $x_1$  from the interval  $[-1, 1]$  and  $x_2$  from the interval  $[-1, 1]$ . The results of the fuzzy inference are presented by the Fig. 8. The Fig. 9 presents the values of the real system for the purpose of comparison.

The comparison of the obtained results shows that the established fuzzy model allow to identify the analyzed dependence though the input/ output mapping is not know in mathematical form. The smaller precision of approximation for some regions of the universe of discourse is caused by the lack of possibilities of formulating any rules for the regions not

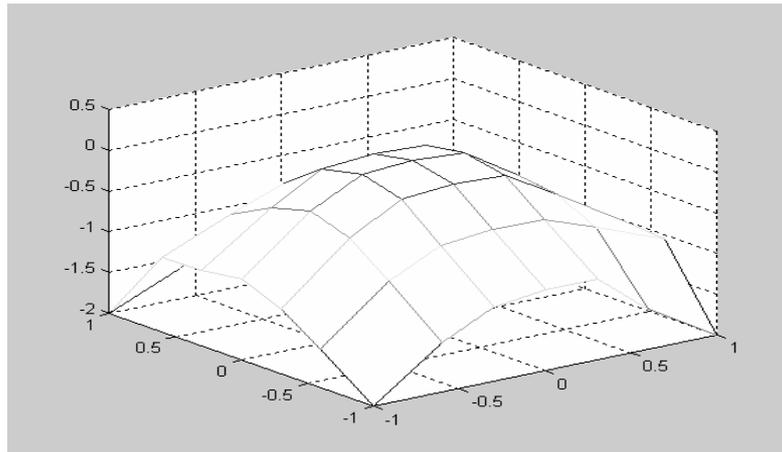


Fig. 8. Results of the fuzzy inference with the model M

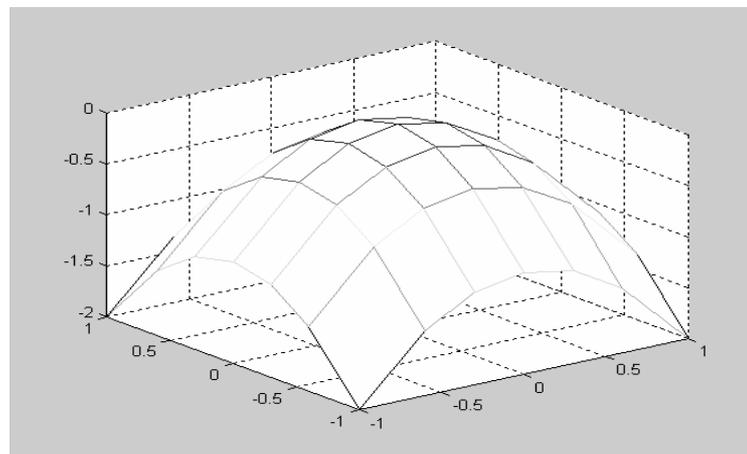


Fig. 9. The values of the by the model M modeled real system

covered with samples. However in the case of real systems, if the system never operates in the neighborhood of the mentioned regions, the model surface should be sufficient for practical purpose. In addition with weighted mean method artificial measurement "samples" in the regions of the universe where no measurements are provided can be generated (remembering however, that the significance and reliability of artificial samples is lower than of real samples) ([8], [9]). In practice the obtained estimates can be sufficient for make good decision relating a forecasted future that never guarantees precise decisions. Therefore, using of the proposed regular procedure PMBB can be alternative for searches of the input/ output real mapping in mathematical form with the aid of econometric modeling.

## 5. CONCLUSIONS

The presented in this work conception is the proposition of using of fuzzy modeling and inference for the efficiency evaluation of planned implementation undertaking in the scope of forecasting of selected manufacture company indexes with ERP APS system implementation. The experiences from the earlier implementation of the ERP APS system in companies the same kind are the basis of the searched forecast.

The presented fuzzy modeling of the input/ output real mapping with the aid of the existing geometric method of the maximum absolute error point (the MAEP method) makes the regular procedure that does not depend on the kind of the modeled system. In addition, the fuzzy approach that serves to description of imprecise designated phenomena enables modeling of uncertainty in the natural way and gives results allowing to make good decision by the lack of precise estimates in the forecasting of a future. The proposed in this work approach is the subject of the continued research.

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