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MODEL FOR ESTIMATION OF ENTERPRISE MANAGEMENT SYSTEM POTENTIAL BASED ON FUZZY LOGIC INFERENCE

The approaches to management system potential estimation are analyzed. Enterprise management system potential is considered as a function of potentials of its constituent units. The expediency of fuzzy logic application for estimating of the enterprise management system potential is grounded. The sequence of actions in Mamdani-type fuzzy inference is considered. A model of enterprise management system potential estimation based on the Mamdani-type fuzzy inference is proposed.

Keywords: *enterprise management system; fuzzy logic inference; linguistic variable.*

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МОДЕЛЬ ОЦІНЮВАННЯ ПОТЕНЦІАЛУ СИСТЕМИ УПРАВЛІННЯ ПІДПРИЄМСТВОМ НА ОСНОВІ АПАРАТУ НЕЧІТКОГО ЛОГІЧНОГО ВИСНОВКУ

У статті проаналізовано підходи до оцінювання потенціалу системи управління підприємством. Розглянуто потенціал системи управління підприємством як функцію потенціалів його складових блоків. Обґрунтовано доцільність застосування апарату нечіткої логіки для оцінювання потенціалу системи управління підприємством. Розглянуто послідовність дій в системі нечіткого логічного висновку І. Мамдані. Запропоновано математичну модель потенціалу системи управління підприємством на основі системи нечіткого логічного висновку І. Мамдані.

Ключові слова: *система управління підприємством; лінгвістична змінна; нечіткий логічний висновок.*

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МОДЕЛЬ ОЦЕНИВАНИЯ ПОТЕНЦИАЛА СИСТЕМЫ УПРАВЛЕНИЯ ПРЕДПРИЯТИЕМ НА ОСНОВЕ АППАРАТА НЕЧЕТКОГО ЛОГИЧЕСКОГО ВЫВОДА

В статье проанализированы подходы к оценке потенциала системы управления предприятием. Рассмотрен потенциал системы управления предприятием как функция потенциалов его составляющих блоков. Обоснована целесообразность применения аппарата нечеткой логики для оценивания потенциала системы управления предприятием. Рассмотрена последовательность действий в системе нечеткого логического вывода И. Мамдани. Предложена модель оценивания потенциала системы управления предприятием на основе системы нечеткого логического вывода И. Мамдани.

Ключевые слова: *система управления предприятием; лингвистическая переменная; нечеткий логический вывод.*

Problem setting. Management system potential is the strategic basis for the formation of the total enterprise potential. Its primary role is explained by the fact that it is the management system, its quality and competitiveness that defines the possibility of enterprise functioning and development. In this context, the solving of problem of the management system potential quantitative estimation attains paramount importance.

Recent research and publications analysis. In our view, the closest to solving the task of management system potential quantitative estimation are the approaches to

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estimating both subjective and objective components of management processes. The choice of indicators to estimate these components must correspond to the concept of efficiency of using management potential in the narrow sense reflecting management performance solely rather than the overall enterprise functioning.

In this context, A.S. Zienina-Bilichenko (2009) notes that the definition of management potential should begin with management resource, which, according to its place and role in management system, significantly influences, provides and makes conditions for other resources, their optimal structure and effective combination. According to Zienina-Bilichenko's approach, management potential should be subdivided into administrative work potential and resources (qualifications, professional, age, organizational, time and economic) and the potential and resources of particular elements of management system (management processes quality, management methods, their innovativeness etc.). This corresponds to understanding the notion of management system potential as a combination of subjective and objective components of management process.

S.V. Knyaz (2013) emphasized that it is appropriate to mark out in the structure of management system potential not only objective and subjective (in the author's interpretation – regulatory, administrative and psychological) components, but also synthesized ones, which are the synthesis of subjective and objective components of the potential equally depending on both.

In addition to emphasizing the need for marking out both subjective and objective components of management system potential, it is also worth noting that the definition of management system potential components should begin with defining enterprise management system elements. It is the summary potential of these elements that will form the total management system potential.

The nature and the structure of enterprise management system potential was investigated by I. Ansoff (1989), A.S. Zienina-Bilichenko (2009), E.V. Lapin (2004; 2007), I.P. Otenko (2004). It should be noted that quite a clear thesis about the need of correlation between management system potential components and management system elements is not implemented in any of the studied approaches to determination of the structure of enterprise management system potential. This fact can be primarily explained by the interpretation of management potential (also managerial potential, potential of company's general management) mainly as a combination of subjective management activities. This approach significantly restricts the possibility of potential structuring and establishes a correspondence between its components and elements of the enterprise management system, which is obviously defined by both subjective (personnel management) and objective (management system structure, facilities management, methods of management etc.) factors.

The research objective. Thus, the development of an approach to the estimation of management system potential should include defining its elements and establishing a quantitative relationship between the total management system potential and the potentials of its components. It is necessary to build a mathematical model that establishes quantitative correlation between the set of input variables (management system components potential) and output variable (enterprise management system potential).

Key research findings. In accordance to the author's results establishing the general scientific and philosophical nature of the concept "potential", it is proposed to

understand enterprise management system potential (EMSP) as the capabilities for the effective management of enterprise functioning and development provided by management resources as well as individual, social and psychological abilities of managerial staff (Kalyuzhna, 2013: 246). Enterprise management system potential depends on the potential of its constituent units. Enterprise management system potential as a function of the potentials of its components has the form

$$P_{EMSP} = F(P_{IT}, P_{MP}, P_{SF}, P_{MD}), \quad (1)$$

where P_{EMSP} is the enterprise management system potential; P_{IT} is the informative and technical potential of the enterprise management system; P_{MP} is the management personnel potential of the enterprise management system; P_{SF} is the structural and functional potential of the enterprise management system; P_{MD} is the potential of preparing, adoption and implementation of management decisions of the enterprise management system.

The task is stated as follows: enterprise management system potential is to be identified provided known values of its unit potentials. It is necessary to construct a mathematical model that associates a set of input variables, which are the unit potentials, with the output one – the total enterprise management system potential. As management system potential is not a quantitative variable and it is difficult to express it in the form of an analytical expression, it is reasonable to build its linguistic model. This model works with linguistic input and output variables which are the results of the EMSP evaluation, such as "low potential", "average potential", "high potential". In this model, some rules can be formulated that bind linguistic variables for management system potential with those for the potentials of its constituent units.

Models of this type are a subject of fuzzy logic, in which a linguistic model can be transformed into a numerical one. It means that based on the rules defined for linguistic variables, one can put each set of numerical values of input variables in correspondence with one output value. Such a transformation technique is called a fuzzy inference system. For quantitative determination of the EMSP as a function of the potentials of its constituent units, it is proposed to use the Mamdani-type fuzzy inference (Mamdani and Assilian, 1975), which is one of the most common fuzzy logic methods and is also described by S.D. Shtovba (2007).

The Mamdani-type fuzzy logic inference is presented by the following knowledge base:

$$(x_1 = \bar{a}_{1j}\ \Theta_j\ x_2 = \bar{a}_{2j}\ \Theta_j \ldots \Theta_j\ x_n = \bar{a}_{nj}\ weight\ w_j) \Rightarrow y = d_j, j = \overline{1,m}, \quad (2)$$

where $\bar{a}_{1j}$ is a fuzzy term, a measured variable x_j in the j-th rule, $j = \overline{1,m}$; d_j is the inference of the j-th rule; m is the number of rules in the knowledge base; Θ_j is a logical operation linking fragments of antecedent of the j-th rule (it can be logical operation AND or OR); $\Rightarrow$ is a fuzzy implication; $w_j \in [0,1]$ is the weight of the j-th rule witch reflects the extent of expert's confidence in the adequacy rules linking inputs $X = (x_1, x_2, \ldots, x_n)$ with output y.

The process of the Mamdani-type fuzzy logic inference consists of the following steps:

1. Fuzzification. Input variables are a set of distinct integers bounded by their domain of definition. Input variables fuzzification provides a transition from these

numerical values to linguistic variables using them for the compilation of membership functions.

2. Formation of fuzzy knowledge base. Fuzzy knowledge base is a set of fuzzy rules of <If – then> type that define the relationship between input and output variables in the studied system. The rule sense (or antecedent) is the claim of "low x", where "low" is a term specified by a fuzzy set on a universal set of linguistic variables x. The rule inference (or consequent) is a fact of "y is d" type, in which the value of the output variable is set by a fuzzy term ("y is high"). Thus, the formation of fuzzy knowledge base involves the establishment of a set of rules that describe the system behavior depending on input linguistic variables.

3. Using fuzzy logic operators to evaluate system rules. Evaluation is carried out in parallel to all the rules and its result is a numerical value for each rule that evaluates the degree of its implementation.

4. Implication. Implication is the process of changing a membership function output variable depending on the degree of compliance with rules. The input variable for the implication process is a numerical value (one for each rule), while the output one is a fuzzy set for the output linguistic variable. Its membership function must reflect the outcome of the evaluation of antecedents of knowledge base rules on the ground of general fuzzy logic rules.

As a result of inference for the j-th rule knowledge base obtained following fuzzy output y:

$$\bar{d}_j^* = imp(\bar{d}_j, \mu_j(X^*)), \quad j = \overline{1,m}, \tag{3}$$

where imp is an implication that in fuzzy logic is usually realized by minimum transaction meaning the "cut" membership function $\mu_{d_j}(y)$ at $\mu_j(X^*)$:

$$\bar{d}_j^* = \int_{y \in [\underline{y}, \bar{y}]} \min(\mu_j(X^*), \mu_{d_j}(y))/y. \tag{4}$$

5. Aggregation of all output fuzzy sets in a fuzzy set. Aggregation is the process of unification of all membership functions obtained for each rule into a single fuzzy set. Resulting inference knowledge base for all take a new aggregation of fuzzy sets:

$$\bar{y}^* = agg(\bar{d}_1^*, \bar{d}_2^*, \ldots, \bar{d}_m^*), \tag{5}$$

where agg is an aggregation of fuzzy sets, usually realized by maximum operation.

6. Defuzzification of fuzzy set. Defuzzification is a receipt from defined by the aggregation fuzzy set a variable, which is a numerical output. The numerical value of the vector y, corresponding with the input vector X^*, is defined through defuzzification fuzzy set $\bar{y}$.

Thus, using the Mamdani-type fuzzy inference involves a transition from quantitative input variables to the linguistic variables with membership functions assembly (fuzzification) and the use of fuzzy set of rules that define the relationship between the input and output variables in the studied system. The result of the use of the Mamdani-type fuzzy inference is receiving from the aggregated fuzzy set membership functions of output variable numbers corresponding to the set of input variables (defuzzification). Procedure of the enterprise management system potential estimation based on the Mamdani-type fuzzy inference is shown in Figure 1.

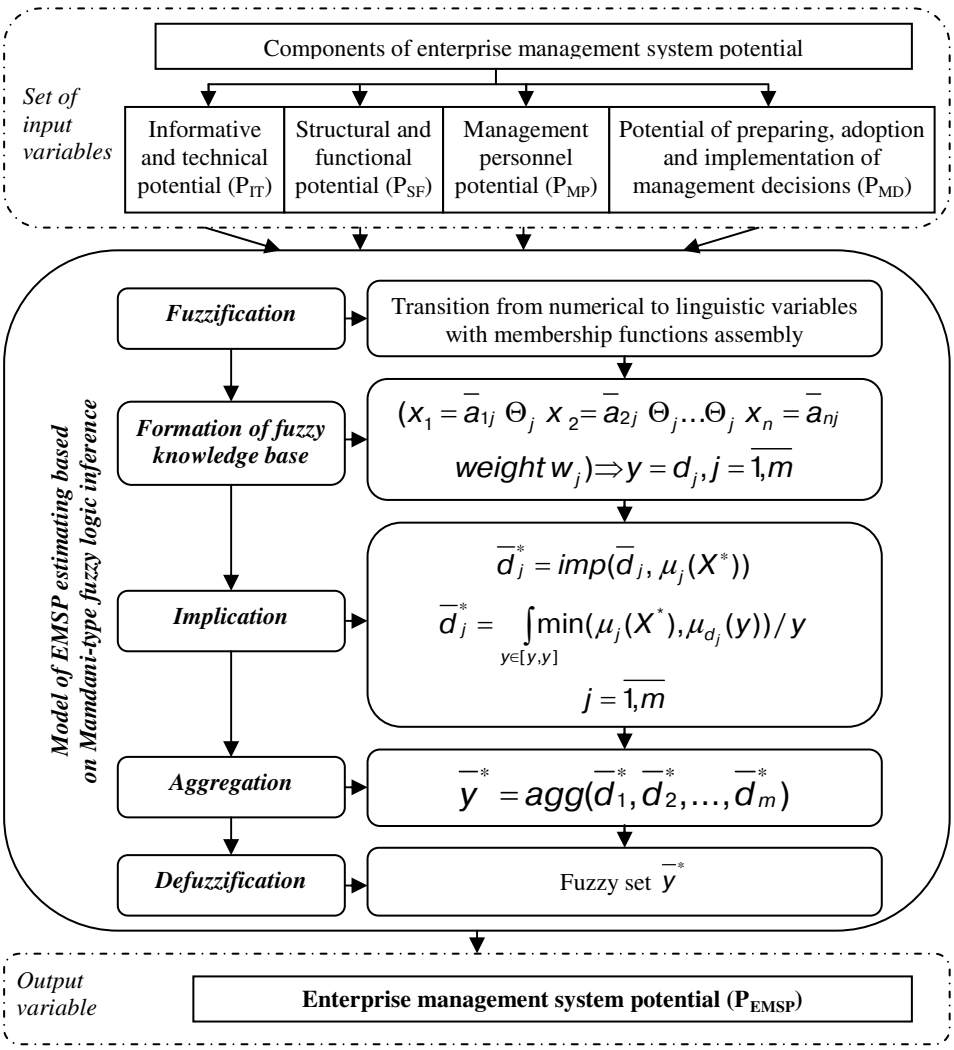

Figure 1. **The procedure of the enterprise management system potential estimation based on the Mamdani-type fuzzy logic inference,** *author's development*

As shown in Figure 1, the development of the model of enterprise management system potential estimating based on the Mamdani-type fuzzy logic inference needs the development of fuzzy logic inference for each of the EMSP unit potential. These are informative and technical potential (P_{IT}), management personnel potential (P_{MP}), structural and functional potential (P_{SF}), potential of preparing, adoption and implementation of management decisions (P_{MD}). These potentials according to the statement of the problem determine the total enterprise management system potential (P_{EMSP}).

Quantitative input variables for the model of the enterprise management system potential estimation have been received by forming the system of indicators assessing the EMSP (Kalyuzhna, 2013: 294–297). The system of indicators characterizes the potentials of each particular EMSP unit.

The system of indicators assessing EMSP is obtained by grouping quantitative and qualitative management characteristics in accordance with the determined units of the enterprise management system potential. The formed system of indicators assessing EMSP allows building the Mamdani-type fuzzy inference, which will provide the quantitative estimation of the enterprise management system potential for each unit and will be the basis for assessing the total management system potential.

Building a Mamdani-type fuzzy inference involves the formation of a set of rules describing the system behavior depending on input linguistic variables. To optimize the set of rules for estimating the enterprise management system potential, each of the indicators characterizing EMSP units is characterized by a rank of importance. This importance rank of the indicators takes a value between 1 (the lowest rank, i.e. the least impact of an indicator on EMSP) to 3 (the highest rank, i.e. the most impact of an indicator on EMSP).

Table 1. **The set of rules for estimating the enterprise management system potential,** *author's development*

Input variables				**Output variable**
P_{IT}	**P_{SF}**	**P_{MP}**	**P_{MD}**	**P_{EMSP}**
Rule 1. ($P_{IT} = P_{SF} = P_{MP} = P_{MD}$)				
high	*high*	*High*	*high*	*high*
average	*average*	*Average*	*average*	*average*
low		*Low*		*low*
Rule 2. (P_{IT} = "low") or (P_{SF} = "low") or (P_{MP} = "low") or (P_{MD} = "low")				
low				*low*
	low			*low*
		low		*low*
			Low	*low*
Rule 3. (P_{IT} <> "low") and (P_{SF} <> "low") and (P_{MP} <> "low") and (P_{MD} <> "low")				
high (average)	*high (average)*	*high (average)*	*not low*	*high (average)*
high (average)	*high (average)*	*not low*	*high (average)*	*high (average)*
high (average)	*not low*	*high (average)*	*high (average)*	*high (average)*
not low	*high (average)*	*high (average)*	*high (average)*	*high (average)*
Rule 4. ($P_{IT} = P_{SF}$ <> "low") or ($P_{MP} = P_{MD}$ <> "low") or ($P_{IT} = P_{MP}$ <> "low") or ($P_{IT} = P_{MD}$ <> "low") or ($P_{SF} = P_{MD}$ <> "low")				
high	*high*	*average*	*average*	*average*
average	*average*	*high*	*high*	*average*
high	*average*	*high*	*average*	*average*
average	*high*	*average*	*high*	*average*

It should be noted that the approach to defining a set of rules for EMSP determination as a function of input variables (unit potentials such as P_{IT}, P_{MP}, P_{SF}, P_{MD}) has some differences as compared to the approach to defining a set of rules for the determination of unit potential. Namely, it is inappropriate to assign certain significance ranks to unit potentials as all of them equally determine the total enterprise management system potential. In addition, if at least one of unit potentials is esti-

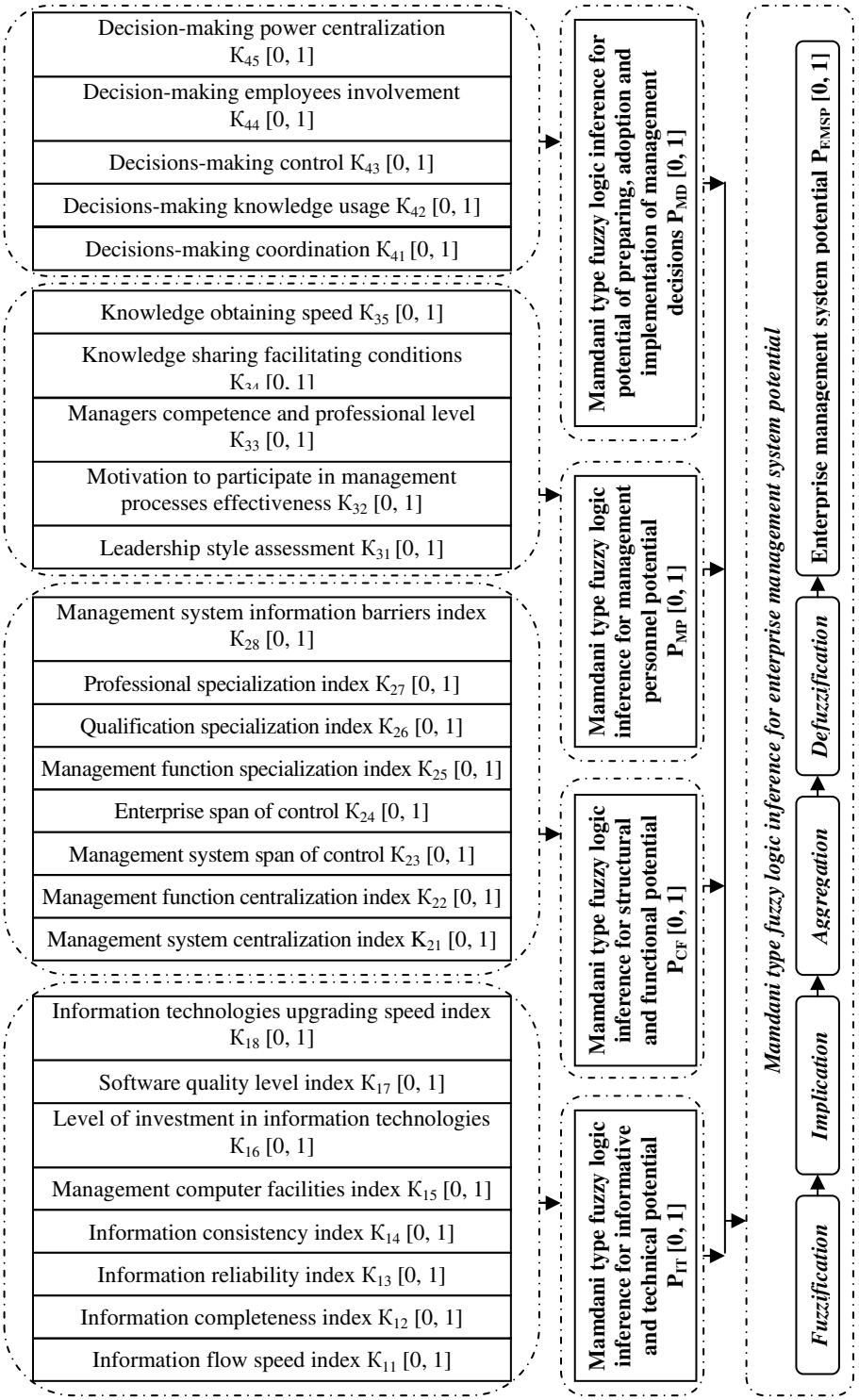

Figure 2. **The model for estimation of enterprise management system potential based on the Mamdani-type fuzzy logic inference,** *authors' development*

mated by the "low" linguistic variable, the total EMSP can not be assessed as "high", even if potentials of all other units are described by the same linguistic variable. It is due to the fact that the unit potential described by "low" linguistic variable is equal to zero in the extreme case. This means that the state of the corresponding EMSP unit is totally inadequate and the corresponding management tasks and functions are not implemented at all.

With regard for these considerations, the set of rules describing the enterprise management system potential will be as follows (Table 1).

The system of indicators assessing the enterprise management system potential and the set of rules for its estimating is the basis for building a model of the enterprise management system potential estimating based on the Mamdani-type fuzzy logic inference for each unit. In turn, output variables of these systems (i.e. the values of EMSP unit potentials) are the input variables for the Mamdani-type fuzzy logic inference, which makes it possible to determine the total enterprise management system potential (Figure 2).

Conclusions. The Mamdani-type fuzzy logic inference developed for the enterprise management system potential allows setting a quantitative relationship between management system potential and the potentials of its constituent units. This provides an opportunity to estimate the state of enterprise management system potential and to determine the direction for its further development. The determination of these directions must take into account the unit structure of the enterprise management system potential presented and the set of rules developed for estimating the enterprise management system potential.

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