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MULTI-CRITERIA ASSESSMENT OF RISK IN THE MANAGEMENT OF A FOOD INDUSTRY ENTERPRISE WITH THE APPLICATION OF THE ANALYTIC NETWORK PROCESS

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ABSTRACT

This paper presents the possibility of applying a multicriteria method – Analytic Network Process (ANP) in taking decisions pertaining to strategic management in the food industry. Important advantages of the ANP method have been described with reference to the related Analytic Hierarchy Process indicating the possibility of creating models reflecting issues such as benefits, costs, opportunities, and risks, which are key in decision making processes. The paper includes a risk management model for implementing an innovative quality management tool – the ISO 22000 norm. The impact of the main criteria – economic, organizational, manufacturing, technological areas together with their respective subcriteria, which influence the final decision – within the constructed subnets with respect to risk – have been presented in a comprehensive way. In the course of analysis it has been indicated that there are more arguments in favour of implementing the described solution in business practice.

Keywords: ***Quality Management, Decision-Making Risk, Multi-Criteria Analysis, Analytic Network Process, ANP***

I. INTRODUCTION

Quality management is now becoming one of the important elements of gaining competitive advantage. It has primary significance with reference to effective execution of corporate strategy in food industry enterprises, which results in the need to change previous assumptions as regards the tools and methods used in the abovementioned area of wielding managerial power. Managing innovativeness as regards quality improvement and control makes the managers take up actions aimed at using the existing forms of certifying food products, which in turn requires making considerable financial expenditures and a great organizational effort in order to modify the current strategy. Decision-making problems related to this issue are a subject o a continuous search for optimum tools for evaluating the risk related to the changes introduced by the managers. A universal group of methods applicable in multi-criteria decision-making processes has recently been the Analytic Hierarchy Process (AHP) and its extension, the Analytic Network Process (ANP). The main objective of the conducted research is to evaluate the risk level in the execution of particular decision-making variants related to the implementation of the ISO 22 000 norm in a selected enterprise and to make an optimum decision from the

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point of view of the assumption made beforehand. Thanks to the use of the Analytic Network Process, it is now possible to offer a comprehensive presentation of the decision-making process phase related to risk assessment along with the evidence of considerable usefulness of the discussed tools as regards solving decision-making problems, not only in the area of production management, but also in other fields of organizational operation which have a complex multi-criteria structure.

II. SUBJECT MATTER OF THE RESEARCH AND GENERAL OUTLINE OF THE APPLIED RESEARCH METHOD

The ISO 22000 norm "Food safety management systems – Requirements for any organization in the food chain", which is an alternative basis for the implementation of the HACCP, focuses on the issue of identifiability and prevention as regards the production of raw materials and finished foodstuff [1]. Having such a certificate is a source of significant competitive advantage, although it involves considerable expenditures and significant risk related to the implementation. Comprehensive research on the benefits, costs, opportunities and risk inherent in the possibility to introduce certification under ISO 22000 was done in 2014 through an interview with a questionnaire, conducted among the managerial staff of a company manufacturing finished foodstuffs – deep frozen and dealing with fruit and vegetable processing. Due to high cost triggered by the certification process, the decision was based on the empirical ANP model, where the managers of particular departments tried to create rational reasons for and against the ISO 22 000 system. In this paper, part of the results of the research has been presented regarding the analysis of the risk related to the discussed problem, elaborated with the use of the Analytic Network Process. The structure of the ANP risk model has the form of a decision-making network with mutual dependencies and links between the key factors, as seen by the Author and considered in the decision-making process. In the discussed model, the following structure has been adopted (figure 1): level I is the main objective – "improvement of product quality and safety", level II includes the main criteria: economic, organizational, production and technological. Under each criterion, sub-criteria were adopted, which in turn constitute level III of the ANP decision-making model[2] – they make it possible to understand a given problem more precisely. Another level of this model are the sub-networks developed for the crucial sub-criteria whose global priority is equal or greater than 0,03 (3%). They have the greatest influence on the choice of an optimum alternative (variant), which in the discussed model is tantamount to the decision with the lowest risk priority.

Fig. 1: Comparison between General Hierarchy Structure and Decision-Making Network

[2] To this level disscussed model presents a hierarchy structure.

Source: Based on [2]

In order to solve the problem related to the choice of an optimum solution as regards the „improvement of product quality and safety", an attempt was made to use the Analytic Network Process method in practice, which is an extension of the Analytic Hierarchy Process. AHP has a special place in the ANP methodology. This is why in the literature on the subject one can find numerous references to the AHP/ANP method. AHP/ANP are among the most recognised and quickly growing mathematical methods in the global scale in the recent years, used to solve multi-criteria decision-making problems. The originator of these methods is Thomas L. Saaty from the University of Pittsburgh (USA), who has recently been awarded the title of an Honorary Doctor by the Jagiellonian University in Krakow. The ANP method makes it possible to observe the complexity of the solved problem and to perform a comprehensive estimate of various interdependencies and links as well as to assign meaning to qualitative and quantitative decision-making factors. Differences in the ANP method consist in the introduced links (interdependencies) between the groups of elements and within such groups, feedbacks and in the presentation of the problem structure not in a hierarchic way, as in AHP, but as a network constituting a system of interconnected components. Prioritisation is made by comparing the elements in pairs with reference to the given objective, criterion or sub-criterion, using a 9-grade Saaty fundamental preference scale. The scale is presented in table 1.

Table 1 The Saaty Fundamental Pairwise Comparison Scale

Significance	Definition	Explanation
1	Equal significance	Equivalence of both compared elements (both elements contribute to the achievement of the goal to a similar extent)
3	Slight or moderate advantage	Slight (moderate) significance or preference of one element over the other (one element has slightly more significance than the other)
5	Strong advantage	Strong preference (significance) of one element over the other
7	Very strong (powerful) advantage	Dominant significance or very strong preference of one element over the other
9	Extreme or absolute	Absolutely greater significance (preference) of one element over the other (advantage of one element over the other is on the greatest definable level)
2, 4, 6, 8	For compromise comparisons between the above values	Sometimes there is a need for numerical interpolation of compromise opinions (in this case you use the middle values from the above scale)
1,1 – 1,9	For elements with similar significance (related)	If the significance of the elements is so close that it is hard to distinguish between them, then we adopt the average value equal 1,3 while the extreme value is = 1,9
Reverse of the above scale	Transition of grades	If the element "I" has one of the above values different from zero standing for the result of the comparison with the element "j", then "j" has the reverse value when compared to the element "i". If the comparison of X to Y is assigned the value "a", then we must automatically assume that the result of comparing Y to X will be "1/a"

Source: On the basis of [3]

Using multi-criteria decision-making techniques will make it possible to answer the question: which of the adopted decision-making variants (alternatives) will be encumbered with the lowest risk through the execution of sensitive factors, or what will be the consequences of making or not making a particular decision – as presented in the discussed research problem. In the model, two decision-making alternatives have been presented: (1) implementing ISO 22000 with all its implications in the four areas mentioned before: economic, organizational, production and technological, (2) withholding from the implementation of ISO 22000 – considering the abovementioned implications of such decision.

The total multi-criteria analysis focuses on 4 key elements that can be presented as 4 distinct models. These will be:

a. The benefit model
b. The opportunity model
c. The cost model
d. The risk model

This paper focuses on presenting the results of the analysis in the risk area as a factor that has the crucial impact on the effectiveness of the selected alternative in the conditions of high decision-making insecurity.

III. GENERAL STRUCTURE OF THE ELABORATED NETWORK RISK MODEL

Using the Analytic Network Process at work makes it possible to obtain the results based on interdependencies and mutual feedback between the elements in various, disordered directions and on various levels of the network structure of the analysed risk model. Whereas in the AHP method, which is the prototype of the ANP, pairwise comparisons are made on each level of the hierarchic structure towards decreasing significance or severity (they are ordered), in the ANP method the direction of the comparison is not defined. It follows from the links between compared elements and their interdependencies. In figure 2, a general scheme of the risk model is presented, as related to the choice of an alternative regarding the implementation of or resignation from ISO 22000, with sub-criteria specified by the managerial staff under main criteria.

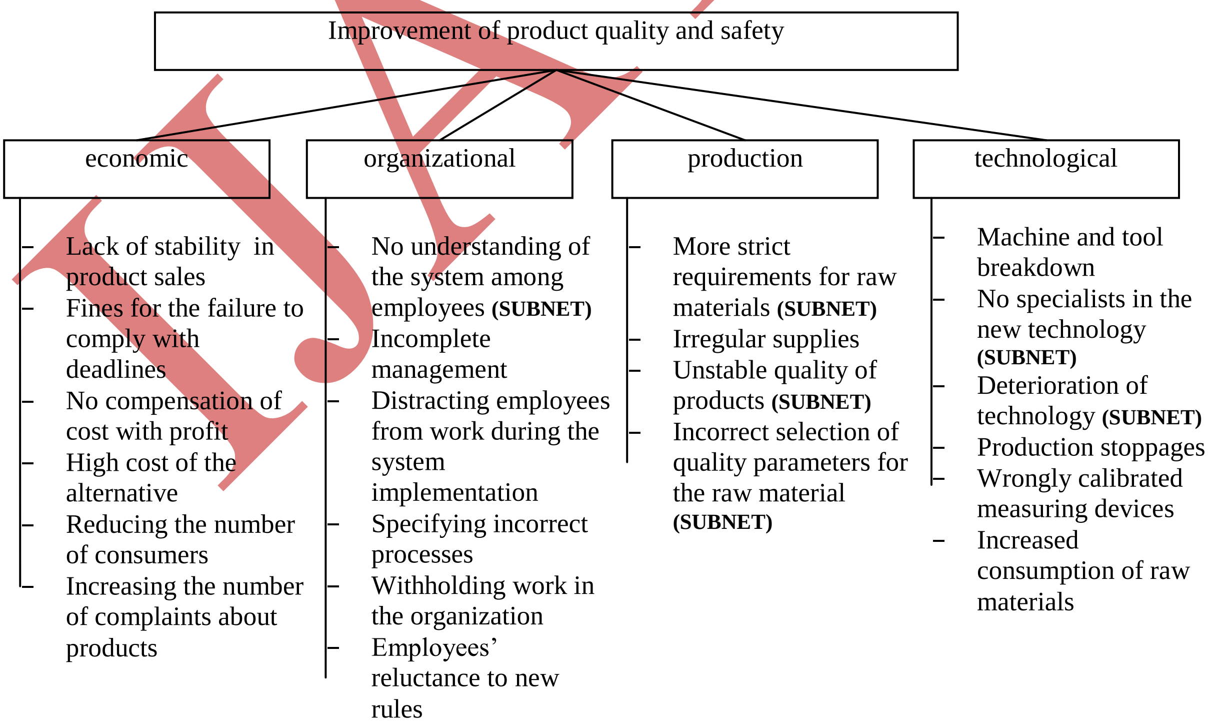

Fig. 2 General Shape of the Risk Model

Source: Own work

In the network risk model related to the "improvement of product quality and safety in the analysed enterprise, sub-networks were developed in such a way that the elements were grouped in clusters of the general feedback system within which connections were made in accordance with their internal and external dependencies and influences. This is indicated by arrows connecting the clusters that display links between their elements. The significance of decision-making elements in the ANP risk model was defined through pairwise comparisons of elements under: main criteria, sub-criteria and clusters (in the developed decision-making sub-networks) according to their impact on each element in the next cluster with which they are connected (the so-called external dependency) or on the elements inside the same cluster (the so-called internal dependency). When making the comparisons, one must bear in mind the criterion/sub-criterion with reference to which the comparisons are made. The comparisons between elements are made on the basis of which element impacts which element to a greater extent and how much greater that extent would be, as compared to another element from the sub-criterion of the control hierarchy. When making a comparison within the risk model, one has to ask the question: which of the elements has a greater risk (is more risky)? For the comparisons, the Saaty fundamental pairwise comparison scale was used (1-9). The opinions were presented in the form of a so-called non-weighted supermatrix and then converted and presented as a weighted and limited supermatrix. Examples of such supermatrices can be found in the papers by: Saaty, Ozdemir [4], Saaty, Cillo [5], Florek – Paszkowska, Cymanow [6]. To solve the discussed problem, a computer programme called Super Decisions was used, which in the calculation of variants automatically processes only those criteria and sub-criteria which have sub-networks under them.

IV. RISK ASSESSMENT RELATED TO MAKING A DECISION ON THE IMPLEMENTATION OF THE ISO 22000 NORM

The possibility to estimate the risk related to the discussed research problem must be preceded by a choice of a variant with the lowest risk priority. To this end, one should compare all factors of a decision-making model (criteria, sub-criteria and elements within the developed sub-networks). For each element of the "risk" model, the calculation of local and global priorities was performed. Global priorities for all network elements indicate the significance of each of them in the achievement of the main objective, whereas local priorities indicate the significance of these factors within each cluster of the sub-system. The sizes of local and global priorities for particular elements of the risk model have been presented in table 2.

Table 2 Significance of Decision-Making Elements in the Risk Model

Criterion	Sub-criterion	Local priorities	Global priorities
Economic (0,0721)	No stability in product sales	0,2604	0,0094
	Penalties for the failure to keep the deadlines	0,0735	0,0027
	No compensation of expenses with profits	0,0962	0,0035
	High alternative cost	0,0589	0,0021
	Reducing the number of consumers	0,2721	0,0098
	Increasing the number of product complaints	0,2389	0,0086
Organizational (0,1685)	**No understanding of the system among employees**	**0,4423**	**0,0373**
	Incomplete management	0,0421	0,0036

	Distracting employees from work during the system implementation	0,2164	0,0182
	Specifying incorrect processes	0,0917	0,0077
	Withholding work in the organization	0,0993	0,0084
	Employees' reluctance to new rules	0,1082	0,0091
Production (0,4435)	**More strict requirements for raw materials**	**0,1591**	**0,0353**
	Irregular supplies	0,0865	0,0192
	Unstable quality of products	**0,4310**	**0,0956**
	Incorrect selection of quality parameters for the raw material	**0,3234**	**0,0717**
Technological (0,3159)	Machine and tool breakdown	0,1289	0,0204
	No specialists in the new technology	**0,2264**	**0,0358**
	Deterioration of technology	**0,3364**	**0,0531**
	Production stoppages	0,0784	0,0124
	Wrongly calibrated measuring devices	0,1709	0,0270
	Increased consumption of raw materials	0,0590	0,0091

Source: Own work

If the value of the global priority after the rounding is equal to or greater than 3%, this means that it would be necessary to perform the analysis considering the feedback and interdependencies and to create separate risk sub-networks. In the examined network risk model, 6 decision making sub-networks were developed for the following factors: (a) no understanding of the system among employees (0,0373), (b) more strict requirements for raw materials (0,0353), (c) unstable quality of products (0,0956), (d) incorrect selection of quality parameters for the raw material (0,0717), (e) no specialists in the new technology (0,0358), (f) deterioration of technology (0,0531). Due to editorial restrictions, in fig. 3 a sample sub-network has been shown for the sub-criterion "unstable quality of products" – as the element with the highest value of the global priority.

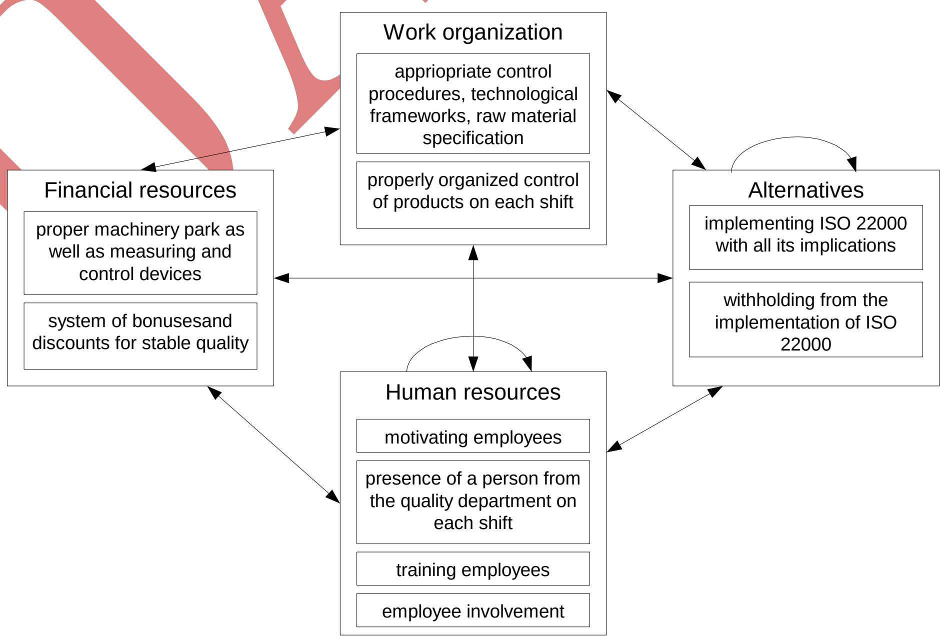

Fig. 3. Decision Making Sub-Network for the Sub-Criterion "Unstable Quality of Products" In the Risk Model

Source: Own work

The value of priorities were calculated for particular variants in the risk model (table 3). This was done by pairwise comparison of their significance in the execution of each sub-criterion from the economic, organizational, production and technological area and within the developed sub-networks, as well as of the factors that impact them (which is indicated by arrows pointing from and towards the cluster of decision making variants).

Tab. 3 Final Results for Decision Making Variants – Implementation or Resignation from ISO 22000

Criterion	**Organizational criterion** (0.1685)	**Production criterion** (0.1591)			**Technological criterion** (0,3159)		**Norma-lized value**
Sub-criterion / Variant	**No understanding of the system among employees** (0.4423)	**More strict requirements for raw materials** (0.1591)	**Unstable quality of products** (0.4310)	**Incorrect selection of quality parameters for the raw material** (0.3234)	**No specialists in the new technology** (0.2264)	**Deterioration of technology** (0,3364)	
implementing ISO 22000	0.1555	0.0418	0.0671	0.0568	0,1126	0,2125	0.4529
withholding from the implementation of ISO 22000	0.1555	0.0931	0.1387	0.1470	0,1441	0,2875	0.5471

Source: Own work with the application of the Superdecisions programme

It follows from the above data that in the risk model, the arguments for implementing the ISO 22000 system in order to improve product quality and safety outweigh the risk following from the resignation from any actions in this respect. In order to check the stability of obtained solutions, sensitivity analysis was conducted in the final phase of the research. The analysis responds to the question as to whether and to what extent the profitability of the decision will change when the most significant factor changes in the model of benefits, opportunities, costs and risk. In the case of the analysed risk model, a change in the parameters for the selected production factor (having the highest priority value) caused a slight change of the curves – which proves the high stability of the decision made as regards risk management and shows that the decision to implement the quality management system ISO 22000 was right.

V. CONCLUSION

Developing a risk model as regards the implementation of a system for food safety management is an important element in supporting strategic actions taken by the analysed enterprise. The ANP network risk model presents a dynamic approach to managing decision making uncertainty in four key areas – economic, organizational, production and technological. A comprehensive analysis of the rationality of the decision to implement should also take into consideration three remaining elements of the model ANP structure, i.e. the area of benefits, opportunities and costs. The presented solution with the application of the Analytic Network Process makes it possible to recognise network modelling as a useful and practical tool, which can also be used for solving other multi-criteria decision making problems.

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