APPLICATION OF THE AHP/ANP IN FOOD QUALITY MANAGEMENT

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ABSTRACT

The objective of the present study is to demonstrate the application of multicriteria decision making methods in selecting the most efficient option of quality management system in food industry. Most studies concentrate on single aspects of quality management, instead of looking at the problem more holistically by analysing all factors and often complex relations between them. In response to this shortage, the present study proposes a more holistic model of successful quality management of food products. The Analytic Hierarchy/Network Process (AHP/ANP) were applied to build and analyse the problem. The successful quality management has been defined here as a goal of *improving the quality of food products and increasing the company management effectiveness*. The overall model comprises Benefits, Opportunities, Costs and Risks and consider a range of various factors influencing the decision problem. The AHP/ANP results are based on empirical survey (questionnaire interviews) carried out with managers in three leading food enterprises in Poland. The problem presented in this paper is very important not only in Poland. B,O,C,R models of *improving the quality of food products and increasing the company management effectiveness* can be successfully applied by food enterprises to choose the most appropriate quality management systems. Other methods applied to solve this problem would likely fail to analyse these dependencies so thoroughly. Last but not least, the rules of building the B,O,C,R models to select the best option of quality management system in food industry can also be applied in other than food companies.

Keywords: quality management, food products, BOCR analysis, AHP/ANP

1. Introduction

Nowadays, the concept of "quality" is very important in any branch of production and services. Since the beginning of the 90's a great deal of attention in Poland has been devoted to "quality management". Yet, our theoretical and practical experiences in this area are not as advanced as those in the USA, Japan or Western Europe, where the notion of "quality" has begun to develop from the 50's.

Over the past decades, food quality and safety has become a very sensitive subject (Kolozyn-Krajewska and Sikora, 2004). The recent food scandals, such as BSE, dioxins, melamine in baby formula, heavy metals in food, methanol in alcoholic beverages, bacterias in food (e.g. Salmonella, Campylobacter, E. coli) have greatly undermined the consumer confidence in food industry. For that reason, safety and wholesomeness of food products are adjudge as the most important cases. These features are invisible and consumer has to believe in producer's declaration. Therefore food producers', to satisfy consumer and gain his confidence to quality and safety on firm's products, implementing and certifying quality management systems and standards. Besides, producers put effort to get certificates for implementing systems, also to gain quality prizes and signs for their products (Greda, 2005).

The present study puts emphasis on quality and its importance in food production. Thus, it is nessesary to define the terms "quality" and "quality management". In general context, "quality" can be defined in many ways and has a lot of meanings. The most universal definition states that "quality" is a *capability to satisfying and sometimes exceed the consumers' needs and expectations"*, while "quality

management" is understood as "*co-ordinated actions of managing the organization and its supervising with respect to the quality*".

Nowadays, if Polish food companies want to succeed at the EU and the global market, they have to offer high-quality, cheaper, innovative and ecological products, as demanded by the consumer. Products with such features increase the consumer satisfaction, which is the crucial aspect of being successful in a highly competitive setting. Hence, the companies has turned their attention to all aspects related to product quality and its management (Greda, 2008 a).

A relatively large number of publications in this field deal only with costs and benefits of quality management, while only a few consider opportunities and risks thereof. Besides, most studies concentrate on individual aspects of quality management, instead of looking at the problem more holistically by analysing all factors and often complex relations between them (Lisiecka, 2000; Luning, et al, 2005; Wysokinska – Senkus, 2007; Zymonik, 2003).

The objective of the present study is to demonstrate the application of multicriteria decision making methods in selecting the most efficient option of quality management system in food industry. The Analytic Hierarchy/Network Process (AHP/ANP) were applied to build and analyse the problem.

2. Methodology – Analytic Network Process (ANP)

The Analytic Network Process (ANP) is a new theory that extends the Analytic Hierarchy Process (AHP). Its basic structures are networks, which undergo interactions and feedbacks within and between the clusters. So, it can be applied for solving more sophisticated decision problems (Saaty, 2001).

To remind shortly the steps in choosing the best alternative with using the Analytic Network Process (ANP) are as follows (Saaty, 2004 a; Adamus and Greda, 2005):

1. Define a decision-making problem and present it in form of a general goal to be achieved.
2. Decompose the problem into a network with four sub-networks, namely: Benefits (B), Opportunities (O), Costs (C) and Risks (R) (BOCR). In each of them, we distinguished: goal (defined under the *Step 1)*, criteria, sub-criteria (...) and alternatives.
3. Define clusters of elements and their mutual connections, according to their internal and external dependencies and influences, considering each control criterion and sub-criterion under B,O,C,R.
4. Pairwise comparisons of connected elements inside the clusters (*internal dependence*) and between them (*external dependence*) using the Saaty's fundamental scale (1 – 9) in each B,O,C,R network. We have to answer four kinds of questions in the ANP. In Benefits (B) subnet: *given a criterion, which of two elements are more benefticial with respect to that criterion*? Similar questions are asked in Opportunities (O) subnet. The best alternative has the highest priorities for Benefits and Opportunities. In Costs (C) or Risks (R) decision subnet we have to answer: *which element is more costly or risky*? The worst alternative has the highest priorities for Costs and Risks.
5. Pairwise comparisons of clusters of elements with respect to their influence on the control criterion in each of the B,O,C,R decision subnets. These weights are used to evaluate elements of respective blocks of supermatrix columns.
6. Synthesize results for each alternative in the B,O,C,R subnets. We choose the best alternative by using *multiplicative formula* (BO/CR) and *additive – negative formula* (bB+oO-cC-rR). In the latter formula the importance of each subnet e.i. Benefits (B), Opportunities (O), Costs (C), Risks (R) must be estimated by creating *strategic criteria* ratings model and prioritize the B,O,C,R.
7. Perform sensitivity analysis of the final result. The analysis concerns „what-if" questions.

3. ANP Model

The AHP/ANP method was used to structure a decision making problem concerning selection of the best combination of quality management systems in food companies. The AHP/ANP model was created following a review of the existing studies regarding the application and functioning of quality management systems (particularly in food industry), and as such of a combination of various evidence and theories (Adamus and Greda, 2004; Bednarczyk, 2005; Bieganowski and Bartnik, 2003; Ciechan – Kujawa, 2003; Gieryń, 2006; Greda, 2008 b; Horubała, 1995; ISO 15161; Kijowski and Sikora, 2003; Owczarek and Bieganowski, 2003).

3.1 Respondents

The AHP/ANP results are based on empirical survey (questionnaire interviews) carried out with managers in three leading food enterprises in Poland. These companies were large international corporations, their products are known globally. Each company has also been rewarded for the quality of the products as well as for the overall activity (i.e. research, charity). The aim was to ask about the improvement of the quality management systems since these companies are known to have a great experience in implementation and certification of the quality management systems at the market. In each of them, quality systems were presented in integrated form (mostly by documents and common policy of quality management). Overall, 86 respondents were interviewed.

3.2 AHP/ANP models

Application of the Analytic Network Process allows more explorative and thorough analysis of factors contributing to select the optimal alternative, which represents a combination of the quality management systems used in food industry.

In the constructed ANP model, the main goal is "*improving the quality of food products and increasing the company management effectiveness"*, in terms of four networks: Benefits, Opportunities, Costs and Risks. The B,O,C,R analysis of this interdisciplinary problem extends the analogous analysis solved by the AHP hierarchies of Costs and Benefits. The outcomes are more reliable and accurate than in the Analytic Hierarchy Process, because the ANP models consist of the networks of mutual influences and feedbacks between the most important factors in decision making process.

The ANP decision networks of Benefits and Costs have been derived based on the AHP analysis of this problem, and supplemented by additional influences between elements, inside and outside of the clusters. These models were broadened by including additional decision networks of Opportunities and Risks that were not included in the AHP analysis.

Figure 3 presents the ANP model for Benefits. Four areas of the company activities (organisational, production, technological and economic) have been considered as control criteria with respect to three alternative quality management systems:

A. *The system of food safety assurance* (GMP/GHP, HACCP);
B. *The system of quality management of food products* (GMP/GHP, HACCP, ISO 9001);
C. *The integrated system of quality management of food products* (GMP/GHP, HACCP, ISO 9001, ISO 14001, PN-N/OHSAS 18001).

Alternative A is a combination of Good Manufacture Practice (GMP), Good Hygienic Practice (GHP) and Hazard Analysis and Critical Control Point (HACCP). They are obligatory in all food companies, and GMP/GHP are prerequisite programs of HACCP.

Alternative B comprises the same obligatory systems as A (GMP/GHP and HACCP), but additionally includes ISO 9001 norms. This alternative is the most common solution in the majority of food enterprises.

The third alternative (C) embraces all the above GMP/GHP, HACCP and ISO 9001, with additional systems ISO 14001 and PN-N/OHSAS 18001. This option includes the Environmental Management

norm ISO 14001 because food production is also connected with waste production and pollution of the environment. Finally, safe work conditions should be an integral component of each industrial activity, thus occupational health and safety standards (PN-N/OHSAS 18001) were also added to this model.

Process approach to quality management in ISO 9001 norms helps to integrate this system with ISO 14001 and PN-N/OHSAS 18001 (Skrzypek and Hofman, 2006). This approach can be supported by guidelines PAS 99:2006 (Publicly Available Specification) published by BSI in 2006, containing basic requirements that help in systems integration (Kleniewski, 2007).

Quality management systems can be integrated in three ways: (1) building integrated system from the beginning, (2) gradual incorporation of new systems into the existing ones, or (3) implementation of each quality system separately and managing them individually. The second option is the most frequently applied and perhaps the optimal way, because enterprise's knows the system's work and it's easier to accept demanding of a new implementing quality system (Tabor and Raczka, 2004).

In a similar way, the ANP models were prepared for Costs (Figure 2), Opportunities (Figure 3) and Risks (Figure 4). Each network includes organisational, production, technological and economic criteria (areas of company activities), corresponding subcriteria and decision alternatives explained above (A, B, C). Chapter 4 describes steps in analysis of the whole model and summarizes the results.

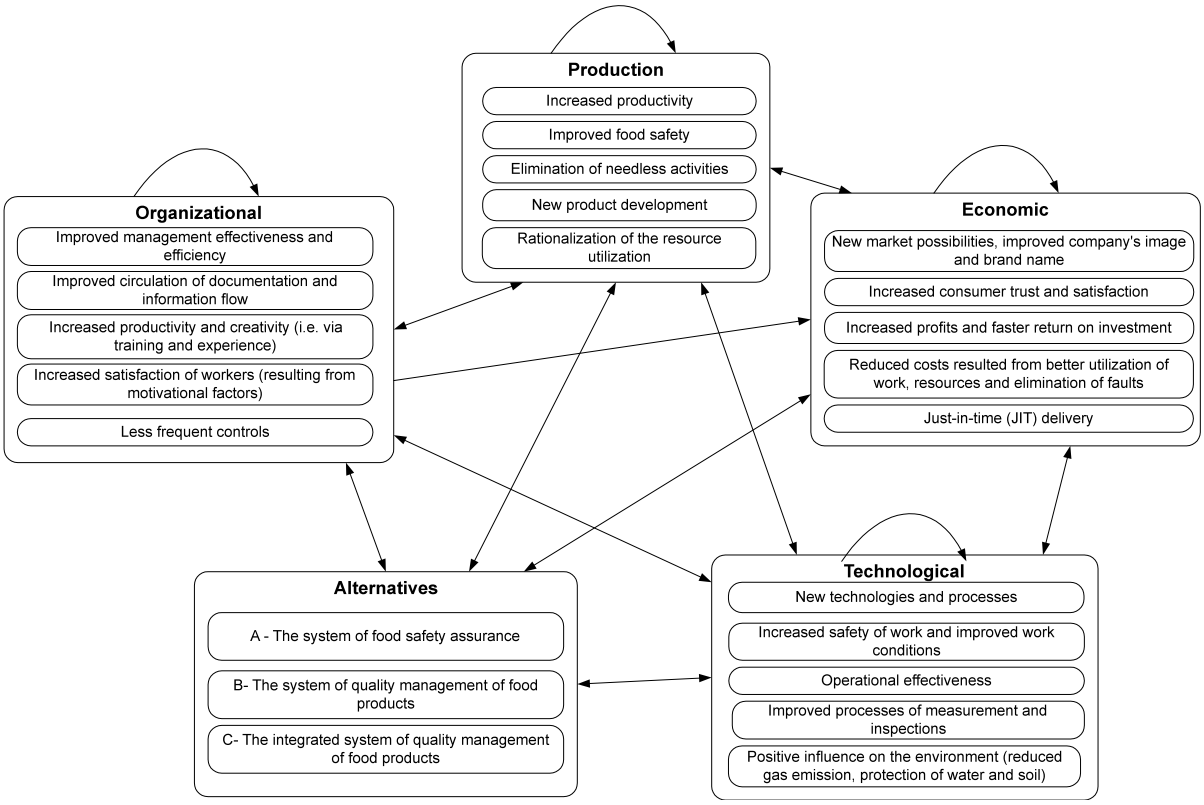

Figure 1. ANP model for Benefits of „*improving the quality of food products and increasing the company management effectiveness*"

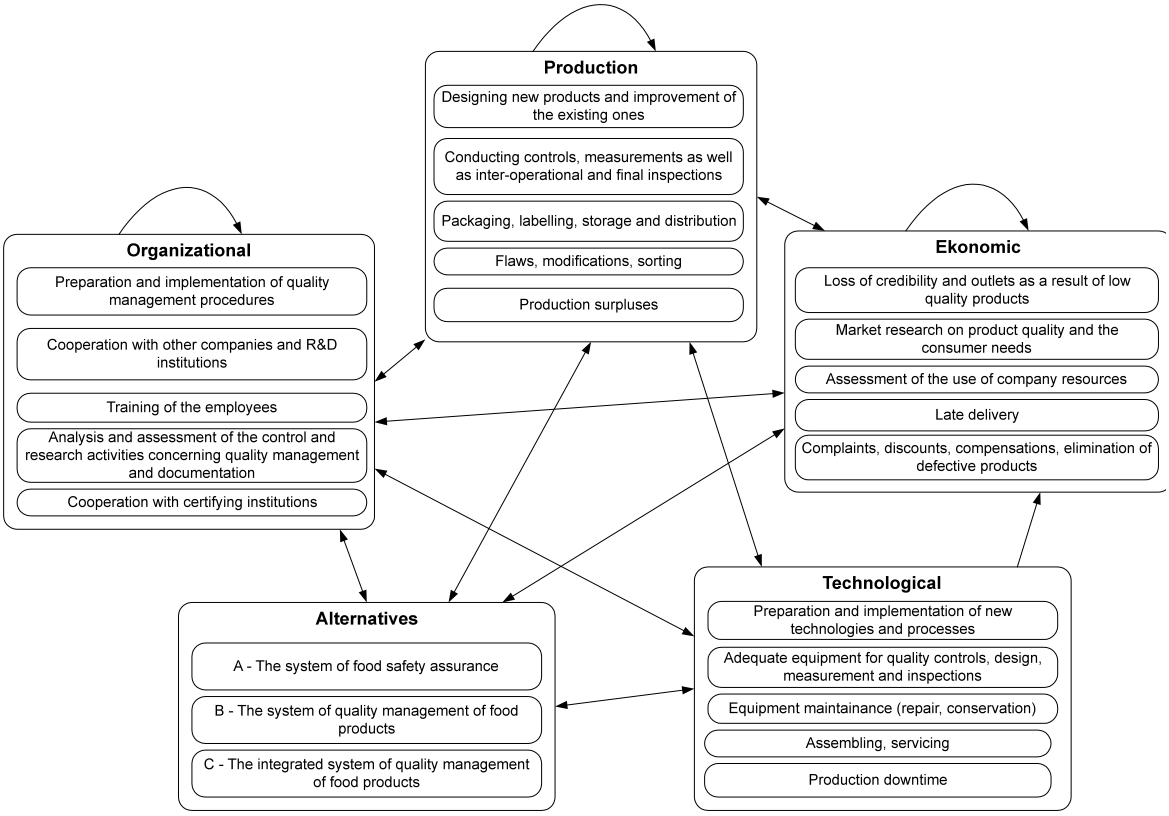

Figure 2. ANP model for Costs of „*improving the quality of food products and increasing the company management effectiveness*"

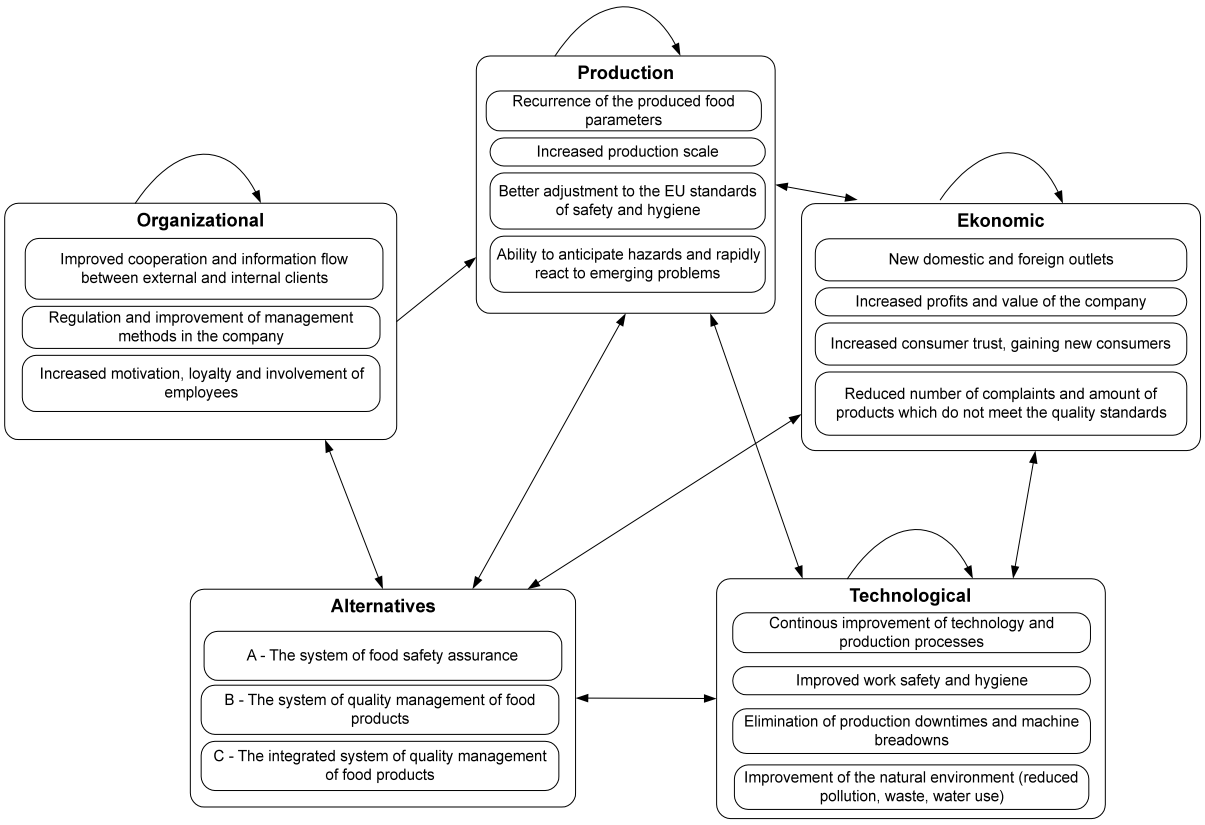

Figure 3. ANP model for Opportunities of „*improving the quality of food products and increasing the company management effectiveness*"

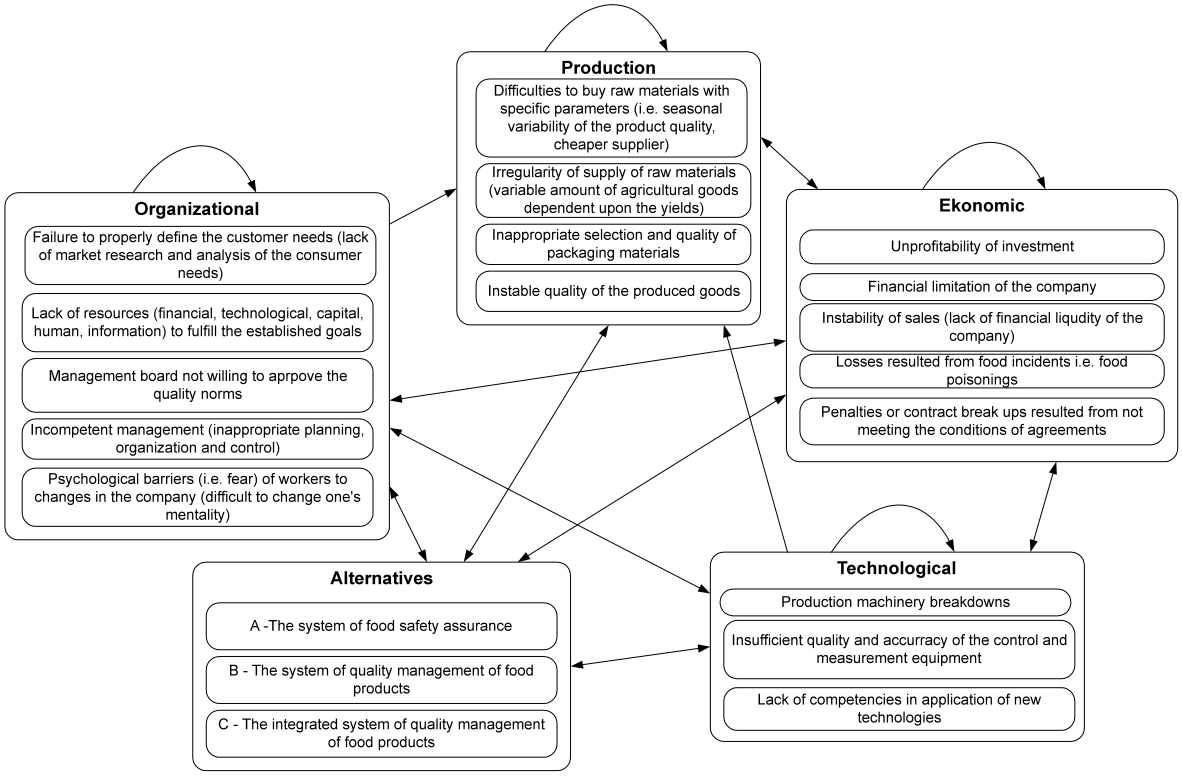

Figure 4. ANP model for Risks of „*improving the quality of food products and increasing the company management effectiveness*"

4. Analysis and Results

The ANP analysis comprises seven steps as described in Chapter 2. Construction of the BOCR model (Chapter 3) was followed by its analysis using pairwise comparisons of the elements according to the Saaty's 9-point scale. Pairwise comparisons have been performed within and between each group of decision factors. To make the final decision, which is choosing the best alternative *to improve the quality of food products and increase the company management effectiveness*, all factors from the B,O,C,R models were analyzed using *Super Decisions* software. The objective is to find the alternative that is most beneficial and offers most opportunities while at the same time representing the lowest risk and the lowest costs variant.

In the ANP model of Benefits 214 pairwise comparisons have been performed (Figure 1), in case of Opportunities (Figure 2) – 148 pairwise comparisons, in Costs (Figure 3) – 257, while in Risks (Figure 4) – 188. The overall amount of pairwise comparisons in the whole ANP model was 807. The CR index was lower than 10% in all pairwise comparisons matrices of B,O,C,R models. Table 1 presents local and global priorities for 72 subcriteria in the ANP model of Benefits, Opportunities, Costs and Risks. These results were integrated for all experts calculated as geometric means of the outcomes.

Table 1. Prioritization of ANP control criteria and subcriteria of Benefits (B), Opportunities (O), Costs (C) and Risks (R)

Merits	**Criteria**	**Subcriteria**	**Local priorities**	**Global priorities**
	Organizational	Improved management effectiveness and efficiency	0,2334	0,0174
		Improved circulation of documentation and information flow	0,1033	0,0077
		Increased productivity and creativity (i.e. via training and experience)	0,1950	0,0146

Benefis (B)		Increased satisfaction of workers (resulting from motivational factors)	0,1614	0,0120
		Less frequent controls	0,3069	0,0229
	Production	Increased productivity	0,1268	0,0393
		Improved food safety	0,3958	**0,1225**
		Elimination of needless activities	0,1005	0,0311
		New product development	0,2145	**0,0664**
		Rationalization of the resource utilization	0,1624	**0,0503**
	Technological	New technologies and processes	0,1786	0,0298
		Increased safety of work and improved work conditions	0,2414	**0,0403**
		Operational effectiveness	0,3504	**0,0585**
		Improved processes of measurement and inspections	0,0886	0,0148
		Positive influence on the environment (reduced gas emission, protection of water and soil)	0,1410	0,0235
	Economic	New market possibilities, improved company's image and brand name	0,2195	0,0183
		Increased consumer trust and satisfaction	0,1377	0,0115
		Increased profits and faster return on investment	0,2299	0,0192
		Reduced costs resulted from better utilization of work, resources and elimination of faults	0,2124	0,0177
		Just-in-time (JIT) delivery	0,2003	0,0167
	Alternatives	A	0,1621	0,0593
		B	0,2313	0,0845
		C	0,6066	0,2217
Costs (C)	Organisational	Preparation and implementation of quality management procedures	0,0541	0,0090
		Cooperation with other companies and R&D institutions	0,0189	0,0032
		Training of the employees	0,5637	**0,0940**
		Analysis and assessment of the control and research activities concerning quality management and documentation	0,2147	0,0358
		Cooperation with certifying institutions	0,1486	0,0248
	Production	Designing new products and improvement of the existing ones	0,1386	0,0389
		Conducting controls, measurements as well as inter-operational and final inspections	0,3897	**0,1092**
		Packaging, labelling, storage and distribution	0,4006	**0,1123**
		Flaws, modifications, sorting	0,0301	0,0084
		Production surpluses	0,0410	0,0115
	Technological	Preparation and implementation of new technologies and processes	0,1663	0,0297
		Adequate equipment for quality controls, design, measurement and inspections	0,5010	**0,0895**
		Equipment maintainance (repair, conservation)	0,2076	0,0371
		Assembling, servicing	0,0838	0,0150
		Production downtime	0,0413	0,0074
	Economic	Loss of credibility and outlets as a result of low quality products	0,1773	0,0197
		Market research on product quality and the consumer needs	0,1708	0,0197
		Assessment of the use of company resources	0,1659	0,0185
		Late delivery	0,0734	0,0082
		Complaints, discounts, compensations, elimination of defective products	0,4125	**0,0459**
	Alternatives	A	0,1866	0,1997
		B	0,2474	0,1913
		C	0,5659	0,1489
	Organisational	Improved cooperation and information flow between external and internal clients	0,6686	0,0221
		Regulation and improvement of management methods in the company	0,1919	0,0063

Opportunities (O)		Increased motivation, loyalty and involvement of employees	0,1394	0,0046
	Production	Recurrence of the produced food parameters	0,1907	**0,0428**
		Increased production scale	0,0770	0,0173
		Better adjustment to the EU standards of safety and hygiene	0,3453	**0,0775**
		Ability to anticipate hazards and rapidly react to emerging problems	0,3869	**0,0868**
	Technological	Continous improvement of technology and production processes	0,2626	**0,0523**
		Improved work safety and hygiene	0,3650	**0,0727**
		Elimination of production downtimes and machine breadowns	0,3005	**0,0598**
		Improvement of the natural environment (reduced pollution, waste, water use)	0,0719	0,0143
	Economic	New domestic and foreign outlets	0,3046	**0,0342**
		Increased profits and value of the company	0,2219	0,0249
		Increased consumer trust, gaining new consumers	0,2078	0,0233
		Reduced number of complaints and amount of products which do not meet the quality standards	0,2657	0,0298
	Alternatives	A	0,1619	0,0698
		B	0,2018	0,0870
		C	0,6363	0,2744
Risks (R)	Organizational	Failure to properly define the customer needs (lack of market research and analysis of the consumer needs)	0,3331	**0,1388**
		Lack of resources (financial, technological, capital, human, information) to fulfill the established goals	0,5159	**0,2150**
		Management board not willing to aprove the quality norms	0,0486	0,0203
		Incompetent management (inappropriate planning, organization and control)	0,0494	0,0206
		Psychological barriers (i.e. fear) of workers to changes in the company (difficult to change one's mentality)	0,0529	0,0220
	Production	Difficulties to buy raw materials with specific parameters (i.e. seasonal variability of the product quality, cheaper supplier)	0,1516	0,0194
		Irregularity of supply of raw materials (variable amount of agricultural goods dependent upon the yields)	0,0343	0,0044
		Inappropriate selection and quality of packaging materials	0,1400	0,0179
		Instable quality of the produced goods	0,6741	**0,0861**
	Technological	Production machinery breakdowns	0,6656	**0,0316**
		Insufficient quality and accurracy of the control and measurement equipment	0,1465	0,0069
		Lack of competencies in application of new technologies	0,1879	0,0089
	Economic	Unprofitability of investment	0,2261	**0,0664**
		Financial limitation of the company	0,1698	0,0499
		Instability of sales (lack of financial liqudity of the company)	0,4827	**0,1418**
		Losses resulted from food incidents i.e. food poisonings	0,0526	0,0155
		Penalties or contract break ups resulted from not meeting the conditions of agreements	0,0687	0,0220
	Alternatives	A	0,3008	0,0412
		B	0,2887	0,0330
		C	0,3506	0,0401

According to the experts, the most beneficial elements are (Table 1): improved food safety (0,1225), new product development (0,0664), operational effectiveness (0,0583). The highest priorities were received by decision elements concerning production and technological control criteria.

In the Cost model, elements with the highest priorities were: packaging, labelling, storage and distribution (0,1123), conducting controls, measurements as well as inter-operational and final inspections (0,1092), training of the employees (0,0940).

Improving the quality of food products may also bring opportunities such as ability to anticipate hazards and rapidly react to emerging problems (0,0858), better adjustment to the EU standards of safety and hygiene (0,0775), improved work safety and hygiene (0,0727).

The analysis of local and global priorities for all factors from the ANP model of Risks showed that the most risky elements are those from organisational and economic activities. The highest priorities of risks were obtained by the lack of resources (financial, technological, capital, human, information) to fulfill the established goals (0,2150), instability of sales (lack of financial liqudity of the company) – 0,1418, failure to properly define the customer needs (lack of market research and analysis of the consumer needs) – 0,1388.

Results for global priorities for all factors included in the ANP model of Benefits are presented in Figure 5, Opportunities in Figure 6, Costs in Figure 7 and Risks in Figure 8.

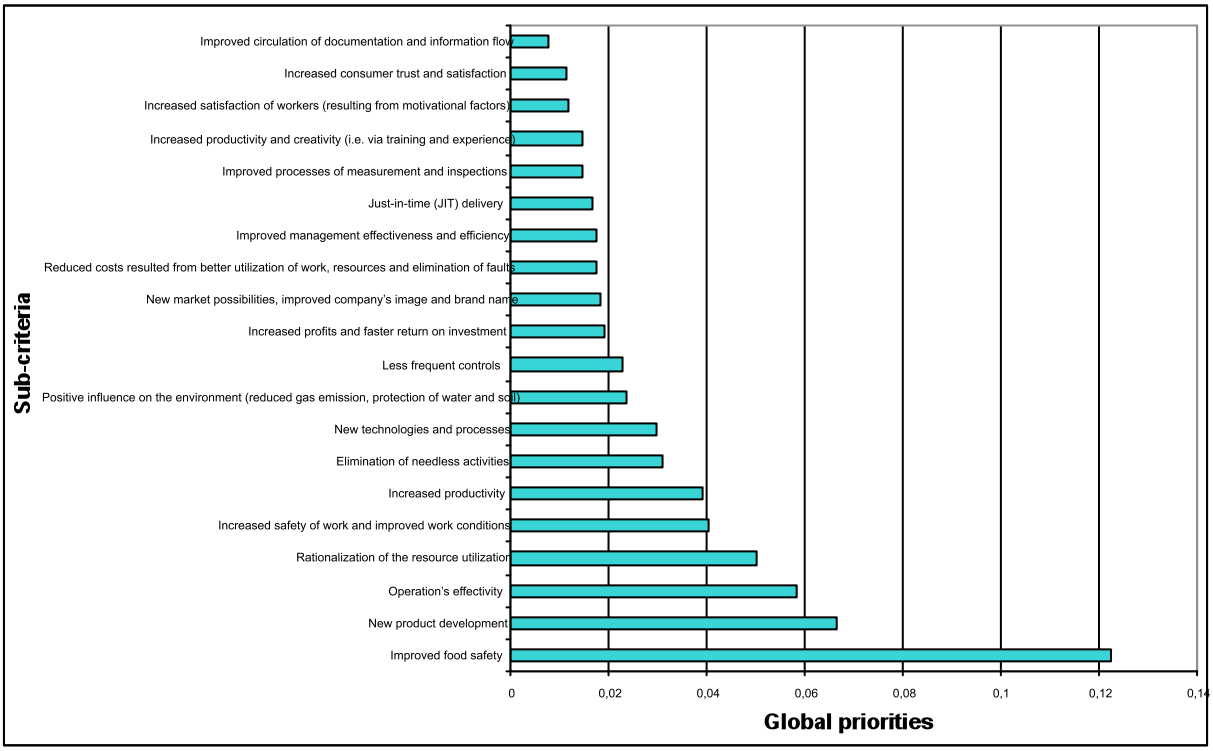

Figure 5. Global priorities of subcriteria in the ANP model of Benefits

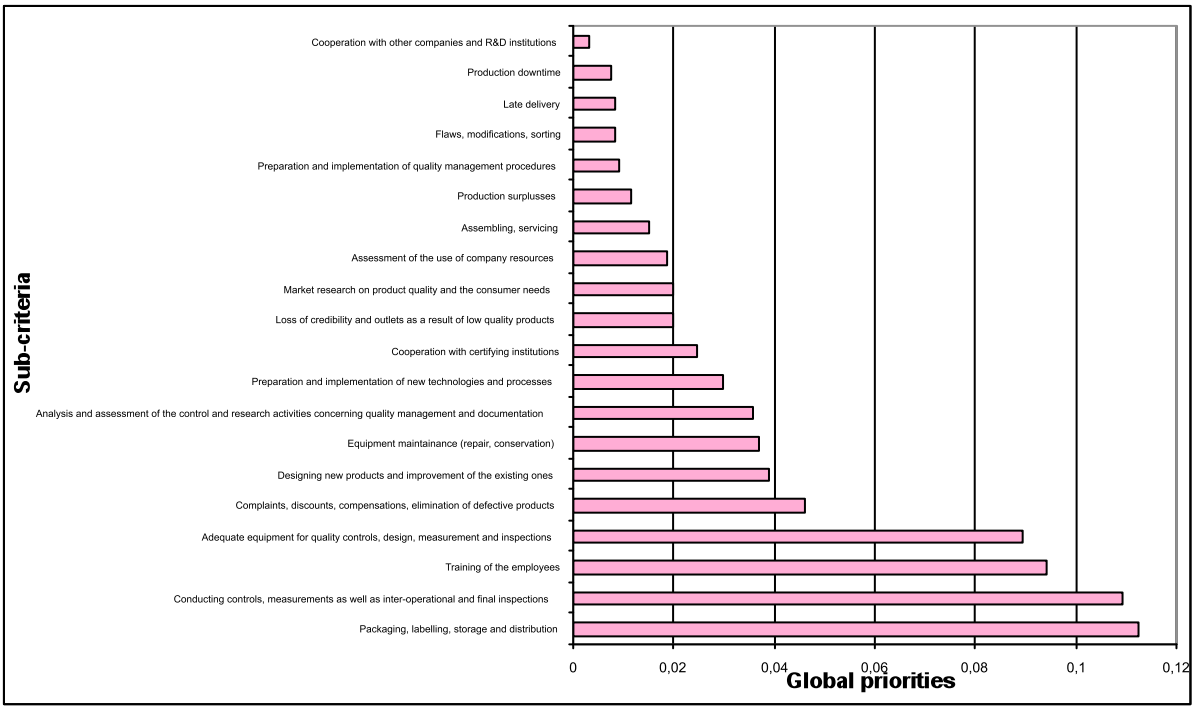

Figure 6. Global priorities of subcriteria in the ANP model of Costs

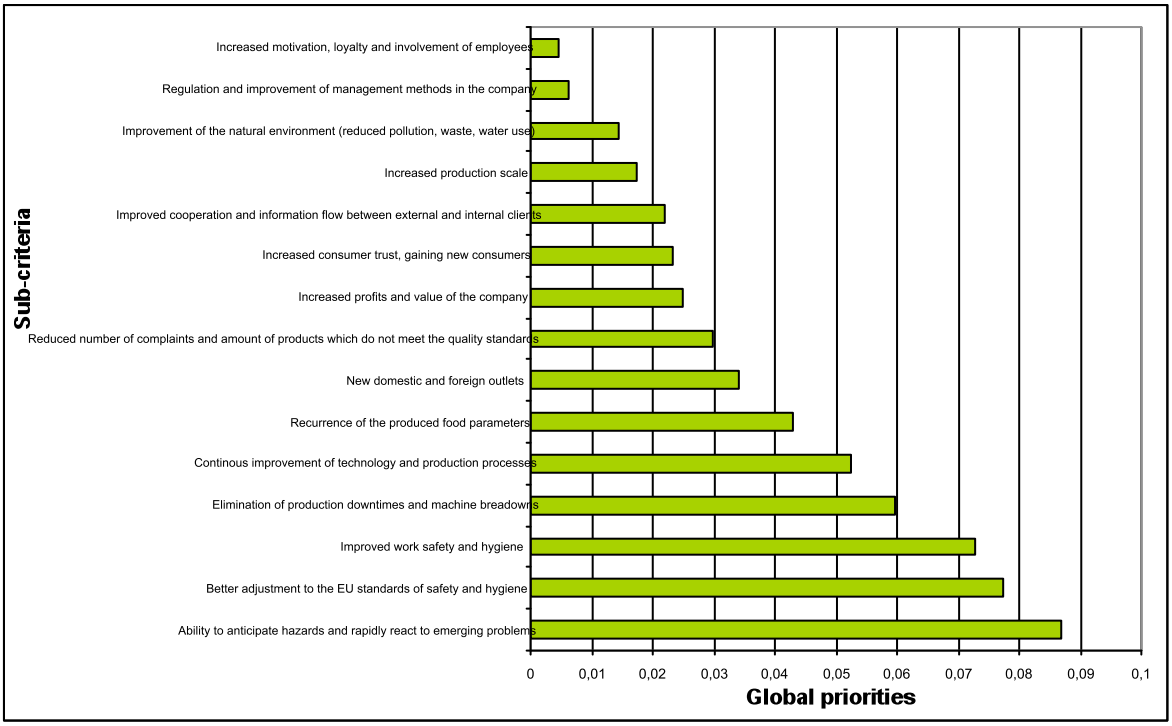

Figure 7. Global priorities of subcriteria in the ANP model of Opportunities

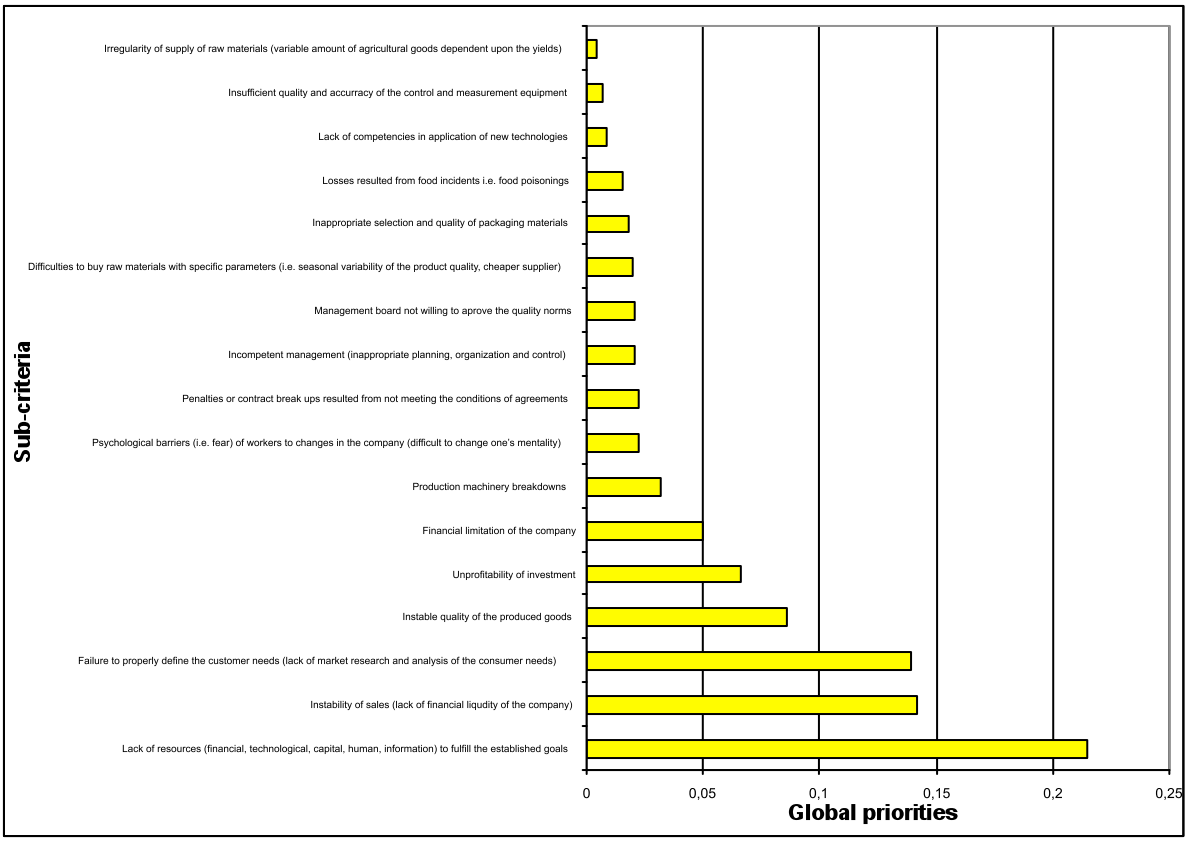

Figure 8. Global priorities of subcriteria in the ANP model of Risks

Subcriteria with global priorities higher than 0,03 (3%) were the most important in decision process and had the biggest influence on choosing the best alternative of *improving the quality of food products and increasing the company management effectiveness*. To make the final decision, it was necessary to consider all factors and combine their results. It was possible by using two mathematical formulae of ANP: *multiplicative* (BO/CR) and *additive – negative* (bB+oO-cC-rR). As regards the multiplicative formula, priorities of alternatives in Benefits and Opportunities models are divided by the respective priorities derived from Costs and Risks. The best alternative is the one with the highest value. However, this formula is used only if Benefits, Opportunities, Costs and Risks are considered equally important. Otherwise, additive-negative formula should be employed. Prior to do so, we need to define the importance of BOCR sub-systems (merits) by deriving strategic criteria (Saaty, 2004 b). The strategic criteria are invariant criteria or objectives of an individual or organization that always need to be satisfied and are external to the actual decision model. Such representation let us look at the problem from more general perspective, including economic-production, social, political, image and educational criteria. The importance of merits was estimated by ranking of Benefits, Opportunities, Costs and Risks. The rating was made for top alternative from each BOCR network with respect to the strategic criteria. The strategic criteria model is presented in Figure 9.

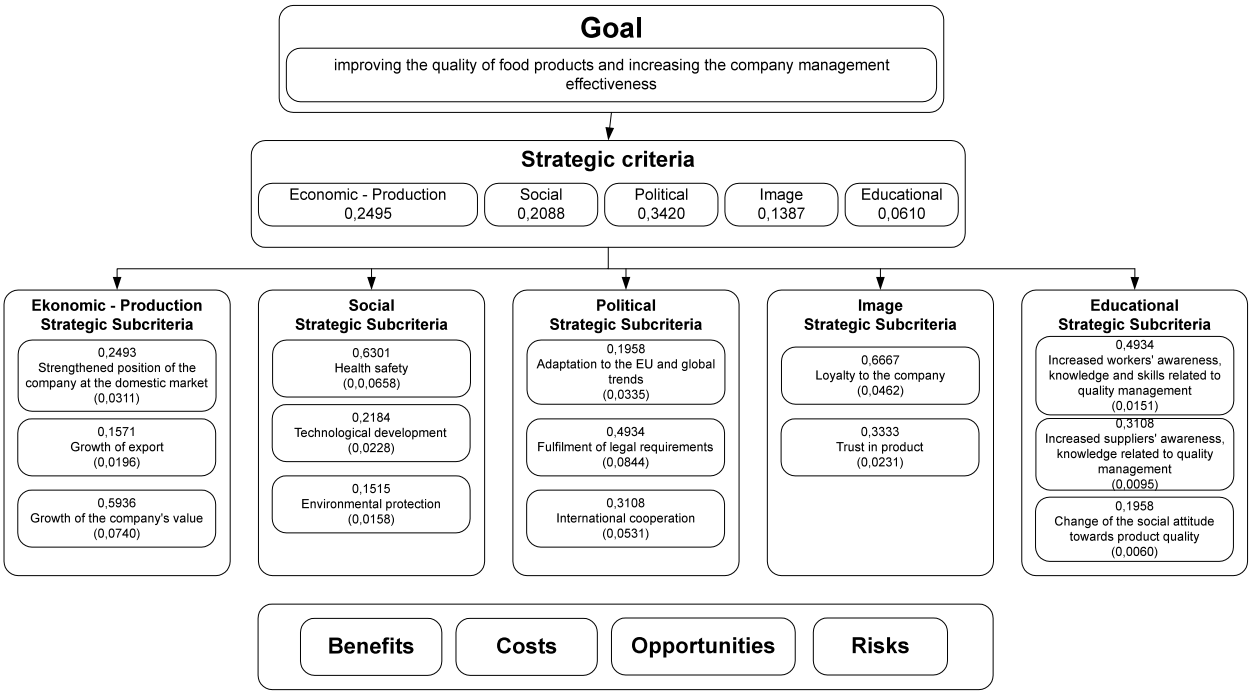

Figure 9. Strategic criteria model for "*improving the quality of food products and increasing the company management effectiveness"*

To perform the ranking, personal criteria were created (see the top of Table 2). Priorities for each sub-system (merit) were estimated though matching a given personal criterion to every strategic subcriterion and then summing up their weights. The ranking prepared for the merits (B,O,C,R) shows that Benefits and Opportunities are the most significant in choosing the best (optimum) alternative *of improving the quality of food products and increasing the company management effectiveness*. They received the highest priorities: 0,3200 and 0,3161, respectively.

Table 2. Priority estimation for merits: Benefits (B), Opportunities (O), Costs (C), Risks (R)

Very big (0,3909); big (0,2798); medium (0,2041); small (0,0753); very small (0,0499)
Very high (0,4734); high (0,2628); medium (0,1442); low (0,0716); very low (0,0479)

Criteria	**Subcriteria**	**Benefis (B)**	**Costs (C)**	**Opportunities (O)**	**Risks (R)**
Economic-Production (0,2495)	Strengthened position of the company at the domestic market (0,0311)	Very big	Medium	Very big	Very big
	Growth of export (0,0196)	Very big	Medium	Very big	Big
	Growth of the company's value (0,0740)	Very big	Big	Big	Big
Social (0,2088)	Health safety (0,0658)	Very big	Big	Very big	Small
	Technological development (0,0228)	Very high	High	Very high	Medium
	Environmental protection (0,0158)	Very big	Big	Very big	Very big
Political (0,3420)	Fulfilment of legal requirements (0,0844)	Very big	Małe	Very big	Małe
	International cooperation (0,0531)	Big	Medium	Very big	Big
	Adaptation to the EU and global trends (0,0335)	Very big	Big	Very big	Big
Portrait (0,1387)	Trust in product (0,0231)	Very high	High	Very high	High
	Loyalty to the company (0,0462)	Very high	Very high	Very high	Medium
Educational (0,0610)	Increased workers' awareness, knowledge and skills related to quality management (0,0151)	Very big	Big	Very big	Big
	Increased suppliers' awareness, knowledge related to quality	Very big	Medium	Very big	Medium

	management (0,0095)				
	Change of the social attitude towards product quality (0,0060)	Big	Medium	Big	Big
	Priorities	**0,3200**	**0,1925**	**0,3161**	**0,1714**

As a result of the BOCR analysis, the best is alternative C (*the integrated system of quality management of food products*). The choice of the best alternative was confirmed by two mathematical formulae. However, additive-negative formula gives negative results for alternative A. It means that it is not advisable for a food company to stay only with obligatory systems of quality management. A company should develop in order to meet the growing needs of the customers. Priorities for other alternatives were positive. Benefits and Opportunities surpass Costs and Risks in terms of implementation of the above alternatives. Final results are presented in Table 3.

Table 3. Final results of the ANP analysis

Alternatives	**Benefits** (0,3200)	**Costs** (0,1925)	**Opportunities** (0,3161)	**Risks** (0,1714)	**Formula** BO/CR	**Formula** bB+oO-cC-rR
A	0,2672	0,3297	0,2544	1,0000	0,2062	-0,0689
B	0,3813	0,4372	0,3171	0,8002	0,3456	0,0009
C	1,0000	1,0000	1,0000	0,9718	1,0290	0,2770

To check stability of the proposed solution, sensitivity analysis was performed for the ANP models of Benefits, Opportunities, Costs and Risks. It allows checking how the ultimate priorities solution would change if the values of BOCR increase or decrease.

From Figure 10 we can see that priorities of Benefits subnets do not have a big influence on the final results. Even if the priority for Benefits is lower than 0,32, alternative C is still the best solution. All lines in the sensitivity analysis graph for Benefits subnet displays a growing trend with the growing priority of Benefits. However, for the priority higher than 0,4, this tendency starts changing for *the integrated system of quality management of food products*. The priority for this alternative is still optimal compared with other alternatives, but starts falling down. Sensitivity analysis for alternatives in Opportunities' model shows similar situation (insensitive to the changes) - Figure 11.

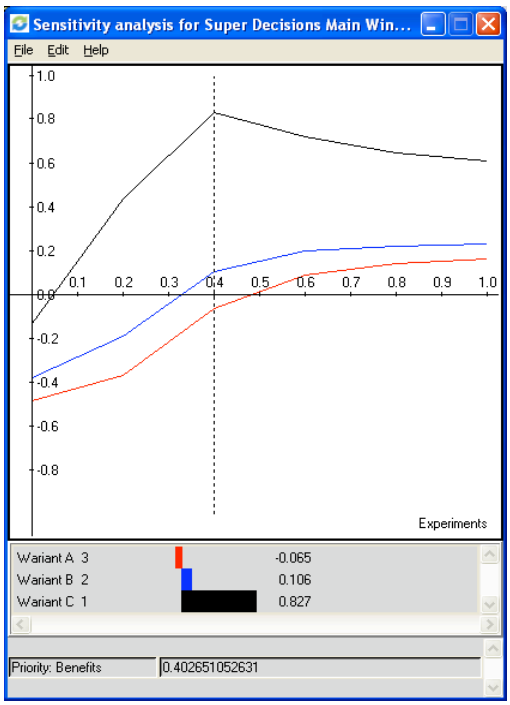

Figure 10. Sensitivity analysis for Benefits

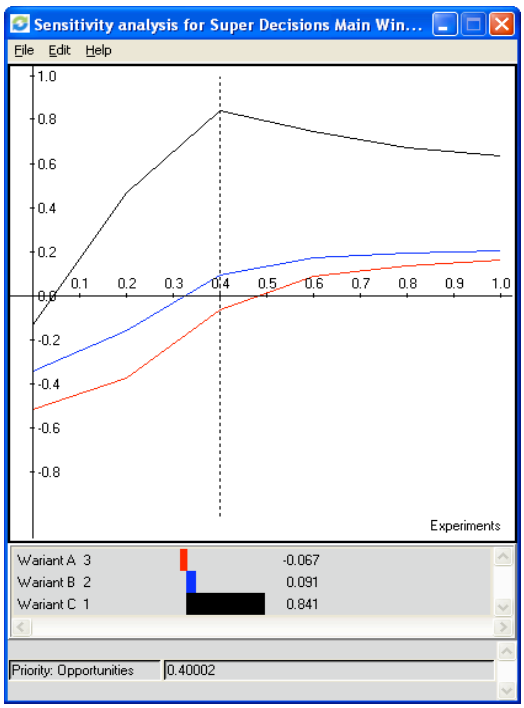

Figure 11. Sensitivity analysis for Opportunities

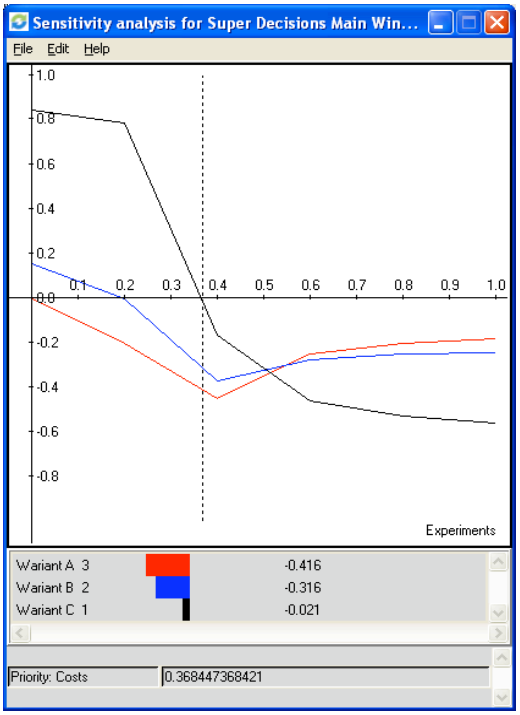

Figure 12. Sensitivity analysis for Costs

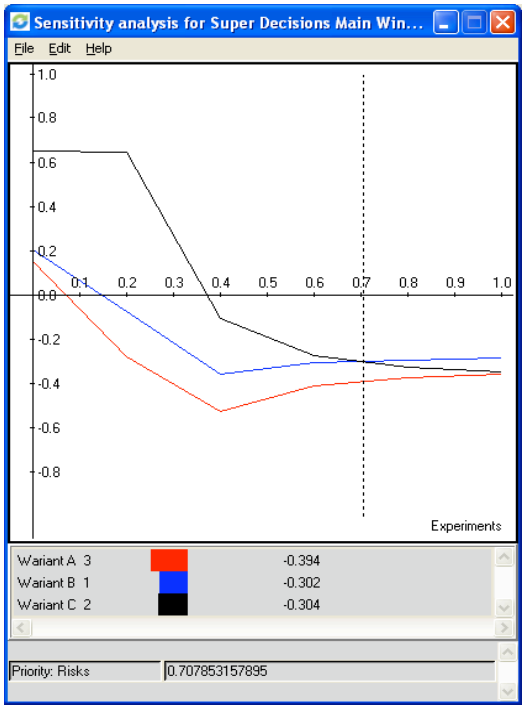

Figure 13. Sensitivity analysis for Risks

Graphs for alternatives in Costs' sensitivity analysis (Figure 12) show decreasing trend for all of them. It means that for the higher priority of the Costs subnets priorities for alternatives are lower. Alternative C is the best till the priority of Costs subnets equals 0,5. Above that value, this solution starts to be the worst. And then the best solution is alternative A.

In the sensitivity analysis for Risks (Figure 13), as in case of the Costs' sensitivity analysis, all graphs show downward tendency. The worst situation can be observed for alternative A. For the priority of Risks higher than 0,17 alternative C starts falling down. This alternative (C) is the best till the priority equals 0,7. Above that value, this alternative occupies the second location (after the alternative B).

Overall, sensitivity analysis shows that priorities for all three alternatives (A, B and C) are more sensitive to changes of priorities for Costs and Risks subnets than for Benefits and Opportunities.

5. Conclusions

Polish food is perceived on the European market as high quality [Jendroszczyk, 2009]. However, to compete with products of other EU member states more efficiently, it is necessary to create mechanisms and technical conditions for producing safe food with high quality standards. At present, a company has to prove the consumer that the products are safe and high quality. Food safety is in fact the most important for the consumer and essential in food trade. The recent food incidents in various places of the globe forced Poland and many other countries to introduce restrictions on imported food. For that reason, from 1 May 2004, implementation of systems and standards of food hygiene and safety is mandatory for Polish food companies. The obligatory systems of food safety assurance are: Good Manufacture Practice (GMP), Good Hygienic Practice (GHP) and Hazard Analysis and Critical Control Point (HACCP).

Food safety is the subject of legal controls (the most recent Act of 25 August 2006), while other quality features are up to the consumer acceptance. Hence, food companies have to guarantee a certain level of quality of their products not only by implementing systems of food safety assurance, but also systems of quality management, e.g. norms ISO 9001. Moreover, food companies should extend their activity to environmental management (ISO 14001) and proceed to enlarge hygiene and safety of work

e.g. by initiating the system PN-N/OHSAS 18001 (Urbaniak, 2007). Implementation of these systems cause gradual movement of food industry towards the concept of Total Quality Management (TQM).

It is advisable for the implemented systems to be integrated in a maximum way. They should form one united system realizing a common goal. In this case, it is reflected in the continuous improvement of the quality of food products. It should increase the consumer confidence in producers in local and global scale. Besides, this approach to the quality management, by involvement of all workers and "cells" in organization, helps to achieve high quality in all spheres of the company's activity. For many years, this type of management methods and production techniques have been used by leading organizations in the world.

To conclude, the problem presented in this paper is very important not only in Poland. The B,O,C,R models of *improving the quality of food products and increasing the company management effectiveness* can be successfully applied by food enterprises to choose the best quality management systems. The ANP models include every kind of dependencies and feedbacks between decision elements. Therefore, they reflect complexity of the problem and actual connections between factors inside and outside the firm. Other methods applied to solve this problem would likely fail to analyse these dependencies so thoroughly.

The final conclusions are as follows:

1. The AHP/ANP models accounts 72 (organisational, production, technological and economic) factors determing „*improving the quality of food products and increasing the company management effectiveness*" in order to provide a more explorative view on this interdisciplinary problem.
2. The applied method (Analytic Network Process) enables observation of the complexity of the problem being solved, with its numerous internal and external interdependencies between factors in the B,O,C,R models. Besides, it let us answer the question: *which alternative by realization of the most important factors contribute to improving the quality of food products and increasing the company management effectiveness?*
3. The most costly factors of *improving the quality of food products and increasing the company management effectiveness* are:
    a) packaging, labelling, storage and distribution (0,1123);
    b) conducting controls, measurements as well as inter-operational and final inspections (0,1092);
    c) training of the employees (0,0940).
4. The largest benefits, which result from *improving the quality of food products and increasing the company management effectiveness* are:
    a) improved food safety (0,1225);
    b) new product development (0,0664);
    c) operational effectiveness (0,0583).
5. Analysis of decision elements in the ANP model of opportunities shows that they mostly refer to:
    a) ability to anticipate hazards and rapidly react to emerging problems (0,0858);
    b) better adjustment to the EU standards of safety and hygiene (0,0775);
    c) improved work safety and hygiene (0,0727).
6. Among the factors with the highest priority of risk are the following:
    a) lack of resources (financial, technological, capital, human, information) to fulfill the established goals (0,2150);
    b) instability of sales (lack of financial liqudity of the company) – 0,1418;
    c) failure to properly define the customer needs (lack of market research and analysis of the consumer needs) – 0,1388.
7. As a result of prioritization, two mathematical formulae (*multiplicative* and *additive – negative*) give the same results for *integrated system of quality management of food products* as the best alternative.

8. Sensitivity analysis may slightly change the priorities of alternatives, but would require extreme conditions for B,O,C,R prioritization and their control criteria.
9. The AHP/ANP were used to solve the most significant problems in all fields of science and practice. The author's intention was to show the usefulness of this method in addressing the problem of food quality management.
10. The principles of building the B,O,C,R models to select the best option of quality management system in food industry can also be applied in other than food companies.

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