QUANTITATIVE METHODS IN ECONOMICS
Vol. XIV, No. 1, 2013, pp. 105 – 116

ANP APPLICATION: RISK MANAGEMENT IN PRODUCTION OPERATIONS

Anna Florek–Paszkowska[1]
Quality Assurance Department, Academy of Economics in Cracow
e-mail: anna.greda@uek.krakow.pl
Piotr Cymanow
Department of Economics and Agriculture Organization
Agricultural University of Cracow
e-mail: pcymanow@ar.krakow.pl

Abstract: This academic paper presents results of research conducted in 2012 in a production business in south Poland where the Analytic Network Process (ANP) method was applied. The objective of the research was to establish the level of risk for selected factors resulting from higher production output of the business in focus. Moreover, selection of the decision-making variant burdened by the lowest risk priority for the achievement of goals set comprised an important research criterion. The application of ANP facilitated a comprehensive approach to the issue in focus. The overriding goal was to demonstrate the efficacy of the method in solving multi-criteria decision problems, especially those which require risk analysis.

Keywords: risk, company, decision-making, Analytic Network Process, ANP

INTRODUCTION

Risk management should comprise a component of an integrated company management system. As much as managing pure risk refers to operational risk and to marginal degree to tactical management level, managing speculative risk constitutes a domain of strategic management. This allocation may result from the fact that risk factors identified at the lowest level (i.e. operational level)

[1] Surname at birth: Gręda.

of management for the most part refer to pure risk (insured risk, which is a result of random events,) and to a minor degree, to speculative risk (risk in action.) The readiness to accept risk must result from the calculation of potential benefits and losses related to actions taken [Cymanow 2010].

An increased insecurity accompanying decision-making process and the corresponding increase in the level of risk for actions taken comes to be an important management feature in the post-industrial era. Market dynamics – which refers to both domestic and international markets – hence the growing number of variable factors in the environment, forces companies to identify underlying risk. Managerial staff should be aware and skilled enough to recognize dangers related to business operations and by the same to introduce procedures which facilitate effective actions, in turn leading to taking the right decisions. Identification of risk allows to eliminate or at least partially effectively limit its adverse implications, and by the same to increase the likelihood of achieving goals set for the organization [Jedynak, Szydło 1997].

A thorough study and assessment of risks areas identified should trigger actions aimed to ensure proper management of risks faced by the business. Hence, actions which may be taken to eliminate or neutralize risk and / or its implications should be defined. The following risk response methods are identified [Tarczyński, Mojsiewicz 2001]:

- Risk acceptance (risk monitoring only)
- Risk minimization (specific preventive actions are required)
- Risk avoidance (discontinuation of actions which may be causing risk)
- Risk transfer or diversification (reduction or elimination at source.)

Managers of the organization should focus on areas which facilitate maintaining or increasing existing competitive advantages at a specified acceptable risk level.

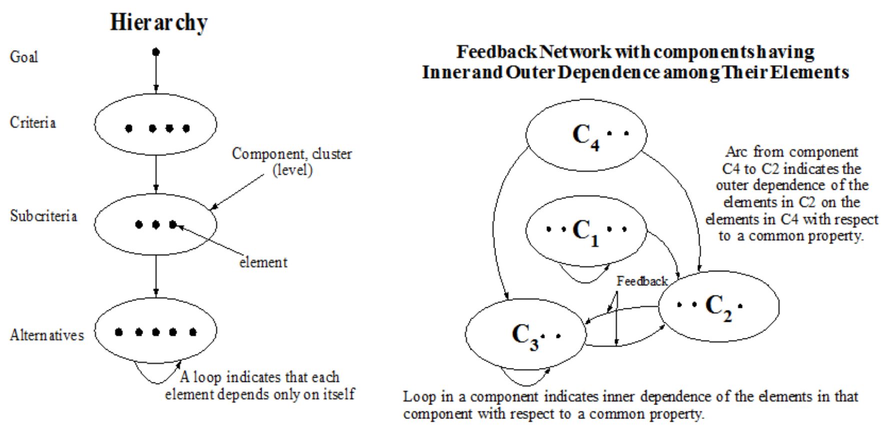
The primary objective of research conducted is to assess the level of risk while implementing specific decision-making variants related to increasing production output in the business discussed and to ensure that the optimum decision is taken in line with criteria assumed. The optimization is to consist in selecting an alternative which is marked by the lowest risk level from among factors determining enhanced scale of operations. The application of ANP facilitated a comprehensive presentation of the stage in the decision-making process related to risk management and by the same allowed to demonstrate a significant efficacy of the tool in focus while solving multi-criteria problems.

SUBJECT AND METHOD OF RESEARCH

Subject of Research and General Structure of Analytic Network Process

A comprehensive research of benefits, costs, opportunities, and risks related to the generation of "higher production output[2]" was conducted in 2012 based on a survey interview with managerial staff of the production business located in south Poland. This paper reviews a collection of survey interviews conducted about risk analysis for the problem in focus, developed in line with Analytic Network Process. The structure of the ANP risk model is a decision-making network marked by interdependencies and links between key elements (selected as key elements by the Authors) included in the decision-making process. The following structure is assumed under the model discussed (Figure 1): level 1 is the key goal, i.e. 'higher production output,' level 2 includes key organizational, production, economic, and technological criteria. As part of every criterion, sub-criteria are assumed, comprising level 3 of the ANP decision-making model[3] and facilitating a better understanding of the problem at hand. The next level of the model comprises sub-networks developed for key sub-criteria, with the value of their global priority higher or equivalent to 0.03 (3%). They have the biggest impact on the selection of the optimum decision-making alternative (variant,) which is interpreted as the decision marked by the lowest risk priority under the model discussed.

Figure 1. Comparison between general hierarchy structure and decision-making network



Source: Based on [Saaty 2004]

Three decision-making alternatives are posited under the model: (1) an upgrade of the existing production line, (2) an acquisition of a new technological

---

[2] Key objective of ANP.

[3] Up to this level, the model follows the pattern of controlled hierarchy.

line as well as (3) a two-shift operation. An upgrade of the existing technological line refers to an increase of the output generated by the present drawing machine from the level of 2.5 tons per hour to 3.6 tons per hour. The cost of the refurbishment will come up to PLN150 thousand whereas the number of staff will increase by 4 people (up to 24.) If the decision to purchase a new line is made, the drawing machine with the output of 5 tons per hour will apply. An estimated cost of purchase will come up to PLN 350 thousand whereas due to an automation of the line, the number of staff will decrease by 4, i.e. down to 24 people. On the other hand, reengineering will lengthen the working time up to 16 hours per day (2 shifts.) An introduction of this solution will not generate costs related to the purchase or upgrades, however, the machine will be utilized more intensively. Moreover, the number of staff will increase to 30 people.

As part of the risk network model for 'higher production output' of the business in focus, sub-networks were developed so that elements could be grouped in general feedback system clusters as part of which connections in line with their external and internal dependencies and impacts were made. This is indicated by arrows which connect clusters marked by common links between elements.

The importance of decision-making elements in ANP and risks were identified by way of comparing pairs of elements as follows: key criteria, sub criteria, and clusters (in decision-making sub-networks developed) against their impact on every element in the subsequent cluster with which they are connected (the so-called external dependency) or in elements within the same cluster (the so-called internal dependency.)

When benchmarking, the criteria/sub-criteria against which items are benchmarked are taken into account. Items are benchmarked in line with how a certain element impacts on an element to a larger degree and how this extent is larger from that for a different element from the controlled hierarchy sub criterion. While conducting benchmarking in the risk model, the following question is posed: which element is marked by higher risk (is more risky)? The fundamental scale for pair-wise comparisons by Saaty was applied in the exercise (1-9). Opinions were presented in the form of the so-called unweighted supermatrix which was then recalculated and presented in the form of the weighted and limited supermatrix. Examples of such matrices can be found in the following studies: [Saaty 2001], [Saaty, Ozdemir 2005], [Saaty, Cillo 2008], and [Gręda 2009]. When seeking a solution to the problem posited, Super Decisions computer software was used. When calculating variants, the software automatically processes only these criteria and sub-criteria which are accompanied by networks or sub-networks.

General Framework of Research Method Applied: Analytic Network Process

In order to solve the problem posited concerning the selection of an optimum solution marked by the lowest level of risk to ensure a higher production output, the Analytic Network Process method was applied. ANP is an extension of the Analytic Hierarchy Process (AHP) and AHP has a particular place within ANP.

Hence, references frequently cite AHP/ANP methods. AHP/ANP is one of the most widely recognized methods globally as well as one of the fastest growing mathematical methods in recent years, applied to solve multicriteria decision problems. Both these theories have revolutionized the way complex mathematical problems are solved. Thomas L. Saaty from the University of Pittsburgh (USA) developed the methods.

The difference in the ANP consists in dependencies (interdependencies) occurring between groups of elements and within the groups, feedback, as well as in the presentation of the problem's structure not as hierarchy as is the case with AHP but as a network which comprises the system of interlinked components.
The ANP method allows to demonstrate the complexity of the problem at hand and facilitates comprehensive assessment of diverse links and interdependencies as well as assigning importance to quantitative and qualitative decision-making factors. The prioritization takes place through the pair-wise comparison against a given objective, criterion, or sub-criterion, in line with the 9-degree fundamental preference scale of Saaty [Gręda 2010]. The scale is presented in Table 1.

Table 1. Fundamental scale for pair-wise comparisons by T. L. Saaty

Intensity of importance	Definition	Explanation
1	Equal meaning	Equivalence of both of the elements benchmarked (two factors contribute equally to the objective)
3	Moderate importance	Weak (moderate) importance or preference of one factor over the other (one activity is slightly more important than the other)
5	Strong importance	Strong preference (importance) of one factor over the other
7	Very strong or demonstrated importance	Dominant importance or very strong preference of one factor over the other
9	Extreme importance	Absolutely higher importance (preference) of one factor over the other (advantage of one factor over the other is at the highest possible level of affirmation)
2, 4, 6, 8	For compromise between the above values	At times, numerical interpolation is required when a compromising opinions occur (central values from the above scale are applied in such instances)
1.1 – 1.9	For closely connected factors	If the meanings of factors are close and almost impossible to tell apart, the average equivalent to 1.3 is adopted while the extreme = 1.9
Reciprocals of above	Reciprocal values	If factor I has one of the above non-zero numbers assigned to it when compared with factor j, then j has the reciprocal value when compared with I When X and Y are compared and 'a' value is allocated, it must be automatically assumed that '1/a' must be the result of the Y and X comparison.

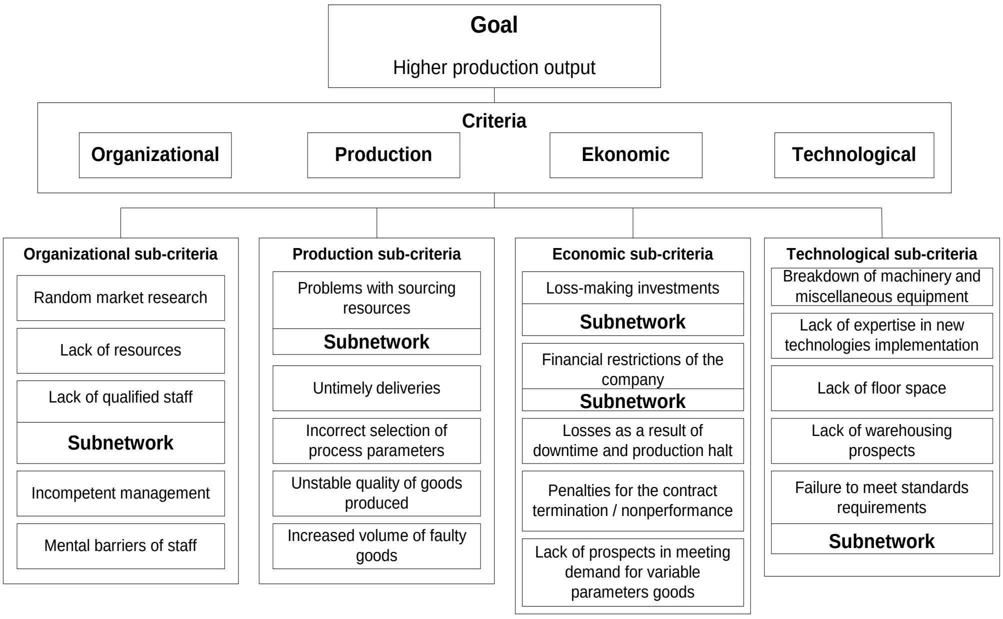
Source: [Saaty 2001]

Application of multicriteria decision techniques allows to answer the following question: which of the decision-making variants assumed (alternatives) will be burdened by the lowest risk if sensitive factors are introduced as well as which will allow to increase production output in the production business? The ANP method will also facilitate the sensitivity analysis for models developed, which will help answer the question of replacement alternatives. The AHP/ANP method facilitates the selection of the most beneficial decision from a range of alternatives.

RESULTS OF RESEARCH AND DISCUSSION

Application of ANP at work facilitates risk analysis and decision-making concerning the selection of a relevant decision-making variant for higher production output for the business in question. In comparison to the AHP method, results produced by way of ANP are more precise. They are based on interdependencies and feedback of elements in various random directions and at various levels of the network structure of the risk model analyzed. The AHP model compares pairs at every level of the hierarchy structure towards a decreasing priority (they are ordered.) In the ANP method, the direction of comparisons is not defined. It results from links between comparable elements and their interdependencies.

Figure 2. ANP risk model for 'higher production output' of the business



Source: own study

Figure 2 depicts the ANP 'higher production output' risk model. Selection of the variant which carries the lowest risk priority value was made by way of benchmarking all components of the decision model (criteria, sub-criteria, and items as part of sub-networks under development.) For each element of the risk model, local and global priorities were calculated. Global priorities indicate the importance of each and every network component in the process to ensure that the main goal is achieved whereas local components indicate the significance of those components within each sub-system cluster. Values of local and global priorities for specific components of the risk model are presented in Table 2.

Table 2. Significance of decision elements in risk model

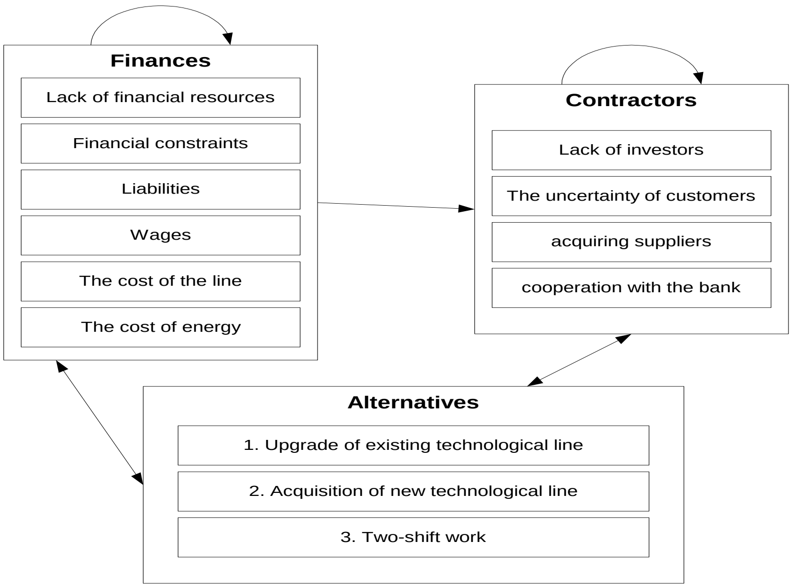
Criterion	Sub-criterion	Local Priorities	Global Priorities
Organizational criterion (0.1409)	Random market research	0.1080	0.0076
	Lack of resources	0.1753	0.0123
	Lack of qualified staff	0.5465	0.0385
	Incompetent management	0.1105	0.0078
	Mental barriers of staff	0.0597	0.0042
Production criterion (0.2628)	Problems with sourcing resources	0.5235	0.0688
	Untimely deliveries	0.1150	0.0151
	Incorrect selection of process parameters	0.1011	0.0133
	Unstable quality of goods produced	0.1202	0.0158
	Increased volume of faulty goods	0.1402	0.0184
Economic criterion (0.4554)	Loss-making investments	0.2901	0.0661
	Financial restrictions of the company	0.5213	0.1187
	Losses as a result of downtime and production halt	0.0418	0.0095
	Penalties for the contract termination / nonperformance	0.0758	0.0173
	Lack of prospects in meeting demand for variable parameters goods	0.0710	0.0162
Technological criterion (0.1409)	Breakdown of machinery and miscellaneous equipment	0.2446	0.0172
	Lack of expertise in new technologies implementation	0.1116	0.0079
	Lack of floor space	0.0856	0.0060
	Lack of warehousing prospects	0.0673	0.0047
	Failure to meet standards requirements	0.4909	0.0346

Source: own study

The risk network model stipulates 5 decision-making sub-networks for the following factors: (a) financial restrictions of the company (0.1187), (b) problems with ensuring resources (0.0688), (c) lack of return on investment (0.0661), (d) lack of qualified staff (0.0385), (e) failure to meet standards (quality) requirements (0.0345).

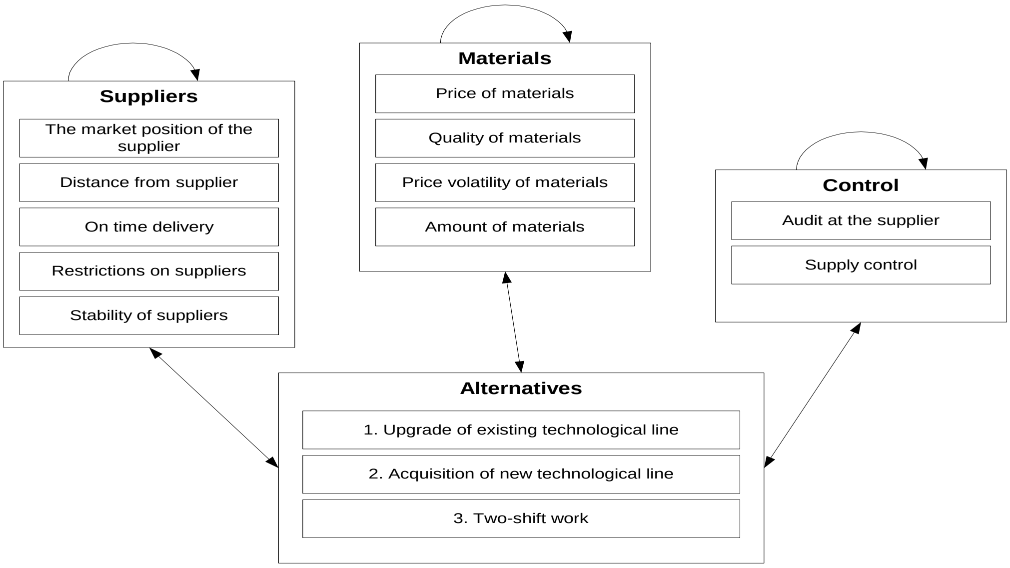
Due to editing restrictions, Figure 3 provides an example of a sub-network for the following sub-criterion: financial restriction of the business whereas Figure 4 provides an example of the following sub criterion: problems with ensuring resources.

Figure 3. Sub-network for the sub-criterion of 'financial restrictions of the business' in ANP risk model for 'higher production output'



Source: own study

Figure 4. Sub-network for the sub-criterion of 'issues with ensuring resources' in ANP risk model for 'higher production output'



Source: own study

Values of priorities presented in Table 3 for specific variants in the risk model were determined as a result of a pair-wise comparison of their significance in the achievement of each sub-criterion in the organizational, production, technological, and economic sphere as part of sub-networks under development as well as related impact factors (this is indicated by incoming and outgoing arrows around the decision-making variants cluster.)

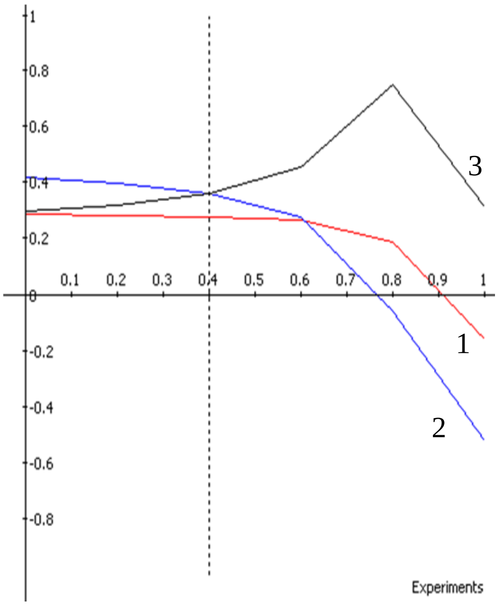
Table 3. End results for decision variants

Criterion	Organizational criterion (0.1409)	Produ-ction criterion (0.2628)	Economic criterion (0.4554)		Technologi-cal criterion (0.1409)	Total	Norma-lized value
Sub-criterion / Variant	Lack of qualified staff (0.5465)	Problems with ensuring resources (0.5235)	No return on invest-ment (0.2801)	Financial restrict-ions of the company (0.5213)	Failure to meet standards require-ments (0.4909)		
Variant 1	0.1333	0.0418	0.0671	0.0568	0,1126	0.0369	0.2072
Variant 2	0.1395	0.0931	0.1387	0.1470	0,1441	0.0867	0.4870
Variant 3	0.0804	0.0818	0.0738	0.0862	0,0985	0.0545	0.3058

Variant 1: Upgrade of existing technological line
Variant 2: Acquisition of new technological line
Variant 3: Two-shift work

In order to confirm the stability of solutions arrived at, the sensitivity analysis was conducted. Based on this, it can be verified how the solution suggested will change once the risk value has been modified (upwards or downwards) in the presented network model for the higher production output. Thanks to this analysis, the stability of solutions assumed may be verified if any criterion or sub-criterion assumed in the model is modified.

Figure 5. demonstrates the sensitivity analysis



1. Upgrade of existing technological line.
2. Acquisition of new technological line.
3. Two – shift work.

Source: own study based on Super Decisions software calculations

When conducting the sensitivity analysis for the risk model, it is noted that up to the risk priority value of 0.6, the best solution (burdened by minimum risk) consists in upgrading the existing technological line. The second-best solution consists in selecting two-shift work, whereas the solution to acquire a new technological line bears the highest risk (linked to high costs of investment.) From the risk priority value of 0.4 onwards, the risk level for the 'acquisition of a new technological line' option decreases and becomes the least risky solution above the value of 0.6.

Taking into account the risk analysis performed, it is concluded that the decision concerning an acquisition of the new technological line in a longer-term perspective seems the most beneficial solution from the point of view of the business discussed due to an increased stability of parameters of goods produced, smaller number of staff needed to service the new equipment, equipment's higher output and lower risk of breakdown, which is linked to timely deliveries as well as facilitating the prospect of new orders (which would not have been possible to ensure by the old machine.) In order to acquire the new technological line, the business can apply for Technology Loan and once granted, use EU subsidies to write off a percentage of the loan – as part of Technology Bonus from EU funds for entrepreneurs under 4.3. Innovative Economy Operational Program.

SUMMARY

The development of the risk model for higher production output results from multiple threats which may be noted in the course of business operations. These threats may result in the lack of desired business performance, and be accompanied by unintended losses or higher outlays against those anticipated. Hence, risk is involved[4]. The ANP risk network model demonstrates a dynamic approach to risk management[5]. It is focused on the future of the business and consists in anticipating dangers (and their neutralization and elimination,) lateral thinking, and prevention. To ensure this, relevant decision variants were assumed, and the sensitivity analysis was conducted to assess the stability of solutions suggested if internal or external factors of business operations changed.

The business should be managed so that any new foreseeable risks and accompanying responses can be accounted for[6]. It is recommended that the management and the staff are aware of the risks which may be encountered in various areas of business operations. Hence, the risk analysis for 'higher production output' considers the following four areas: organizational, production, technological, and economic – all of which were adopted to facilitate this study of the ANP model.

To recapitulate, the risk study concerning higher production output and the solution proposed in line the Analytic Network Process deems it a useful and practical tool, which may be applied to solve other multi-criteria decision problems as well[7].

---

[4] Technical literature defines the concept of *risk* in a variety of ways. Economics and decision science references interpret risk as a nondeterministic concept whereby the probability of various scenarios – both positive and negative - are determined [Findeisen 1985].

[5] K. Lisiecka [2000] also distinguishes a passive approach to risk management. It is past-oriented and is focused on the discovery and identification of threats, as well as on the analysis and action. In line with this approach, risk is treated as a negative concept and the source of losses which should be taken into account when operating a business.

[6] Ibid.

[7] Examples of such problems are discussed in e.g. books by [Saaty, Ozdemir 2005], and [Saaty, Cillo 2008].

REFERENCES

Cymanow P. (2010) Proces zarządzania ryzykiem w strategii organizacji, Wieś i Doradztwo, 1-2 (61-62), str. 68-74.

Findeisen W. (red.) (1985) Analiza Systemowa – Podstawy i Metodologia, PWN, Warszawa, str. 571.

Gręda A. (2009) Zarządzanie jakością produktów żywnościowych, Praca doktorska realizowana na Wydziale Zarządzania Uniwersytetu Warszawskiego.

Gręda A. (2010) Wybór efektywnego systemu zarządzania jakością w przedsiębiorstwach branży spożywczej z wykorzystaniem Analitycznego Procesu Sieciowego, Problemy Jakości, 7, str. 16-28.

Jedynak P., Szydło S. (1997) Zarządzanie ryzykiem, Zakład Narodowy im. Ossolińskich, Wrocław.

Lisiecka K. (2000) Zagrożenia w działalności gospodarczej przedsiębiorstw a zintegrowane systemy zarządzania, [w:] Zintegrowane Systemy Zarządzania Jakością, Materiały II konferencji naukowej z cyklu „Jakość wyrobów w gospodarce rynkowej", Wyd. AE w Krakowie, str. 67-74.

Saaty T. L. (2004) Fundamentals of the Analytic Network Process. Dependence and Feedback in Decision-Making with a Single Network, Journal of Systems Science and Systems Engineering, published at Tsinghua University, Beijing, Vol. 13, No. 2, June.

Saaty T. L. (2001) Decision Making with Dependence and Feedback. The Analytic Network Process, RWS Publications, Pittsburgh PA.

Saaty T. L., Ozdemir M. (2005) The Encyclicon. RWS Publications, Pittsburgh, PA.

Saaty T. L., Cillo B. (2008) The Encyclicon. A Dictionary of Complex Decisions Using the Analytic Network Process, Vol. 2, RWS Publications, Pittsburgh. PA.

Tarczyński W., Mojsiewicz M. (2001) Zarządzanie ryzykiem, PWE, Warszawa.