Decision-making under environmental uncertainty

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Abstract: Goal of the paper: proposal of a model for decision-making enhancement that includes qualitative and quantitative elements influencing managerial decision-making processes under geopolitical uncertainty. **Methods:** primary: Analytic Hierarchy Process – for assessment of individual and collective utility of indexes describing the functioning of enterprises; secondary: Delphi questionnaires, Pareto-Lorenz diagram, stratified random sampling; AHP evaluations came from six professional managers **Results:** a mixed qualitative and quantitative instrument bringing geopolitical occurrences into managerial decision-making under turbulent environmental conditions; **Practical implications:** increased efficiency of managerial decision-making processes, with managerial decisions closer to the possible optimum, under given environmental conditions. **Added value:** the application of multicriteria models for enhancement of managerial decision-making provides a larger perspective on environmental threats and lowers the decision-making uncertainty.

Key-words: decision-making; management, Analytic Hierarchy Process; geopolitical environment, uncertainty.

Podejmowanie decyzji w warunkach niepewności otoczenia

Streszczenie: Cel: celem artykułu jest zaprezentowanie modelu decyzyjnego, ujmującego jakościowe i ilościowe wyznaczniki zarządczych procesów decyzyjnych w warunkach niepewności geopolitycznej. **Metody:** podstawowa: Analityczny Proces Hierarchiczny – do oceny indywidualnej i kolektywnej użyteczności wskaźników funkcjonowania przedsiębiorstw; pomocnicze: kwestionariusze Delfickie, diagram Pareto-Lorenza, dobór warstwowy losowy; Oceny istotności AHP pozyskano od sześciu praktyków zarządzania. **Wyniki:** zaproponowano ilościowo-jakościowy model decyzyjny w warunkach burzliwości otoczenia decyzyjnego, ujmujący czynniki geopolityczne. **Implikacje praktyczne:** wzrost efektywności procesu decyzyjnego, podejmowane decyzje zarządcze w przedsiębiorstwach stają się bliższe możliwie optymalnym w danych warunkach otoczenia. **Wartość dodana:** stosowanie wielokryterialnych modeli wspierania procesów decyzyjnych poszerza spojrzenie badacza na zagrożenia płynące z otoczenia decyzyjnego oraz obniża niepewność procesów decyzyjnych.

Słowa kluczowe: podejmowanie decyzji; zarządzanie; Analityczny Proces Hierarchiczny; otoczenie geopolityczne; niepewność.

Introduction

International companies are conditioned by two types of determinants – measurable and immeasurable. To the first group belong quantitative indexes (e.g.: capitalization, equity price, earnings before interest and taxes – EBIT, floating assets level, general level of income, investment to income ratio, level of cash on bank account, number of clients, level of employment, operating profit, Parts Per Million (PPM), return on capital). To the second, qualitative ones (e.g.: flexibility, geographical range of activity, innovativeness, product diversification, product life cycle, structure of backlog of orders, survival ratio). They are

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difficult to compare, however necessary for strategic planning. Therefore nor quantitative, nor qualitative determinants should be omitted in business decision-making. A question about the extent and mode of their inclusion into managerial practice arises.

Even if some authors have postulated rationalization of decision-making processes through structuring (e.g. [Peleckis 2015]), management literature shows a relatively little number of instruments, framing quantitative and qualitative indexes inside one model. Managers have even a smaller choice, when geopolitical factors come into question. The reasons of this fact most probably come from a general preference of researchers in the field of economics and management for quantitative models and statistical data analysis. Nevertheless, the nature of managerial decision-making reaches beyond numbers, incorporating a range of qualitative factors into the process. This paper is an attempt of filling this gap of knowledge by proposing a practically applicable Analytic Hierarchy Process (AHP) solution to this problem.

Theoretical framework for designing decision-making models

Decision Theory is a dynamically developing field of science. It's founding fathers are: Ramsey [1931], de Finetti [1937], von Neumann & Morgenstern [1944], Savage [1954], Pratt, Raiffa & Schlaifer [1965] and Howard [1966]. A meta-analysis of contributors to this sub-discipline of Management science can be found in Okasha [2016] or Salo, Keisler & Morton [2011]. A Web of Science search (TOPIC: decision-making AND theory AND models) returns 7.869 results in past 5 years only, out of which 897 in the field of Management science, which proves the actuality of the research problem for this discipline.

Decision-making models can be divided into following groups:

- verbal (descriptive and iconic) – they present features and interrelations inside the model, sometimes graphically (iconic verbal models), although without scaling;
- analogue (physical, graphical) – most focus is put on possibly accurate representation of the original phenomenon (scaling included), which limits their utility in praxis;
- symbolic (formal or mathematical) – some aspects of the object are transcribed into a formal notation, with use of abstract symbols and relations; static mathematical models do not consider time, whereas dynamic ones do and are also multidimensional; stochastic mathematical models deal with uncertain data and aim at managing the risk resulting from taken decisions; deterministic mathematical models leave uncertainty outside their scope and provide determined values as results.

This paper discusses symbolic models. The work of Szarucki [2016] proves that linking a correct model type with a decision problem can be a complicated research task. E.g. although the complexity of static models is lower than in case of dynamic ones, their credibility for enhancement of managerial decision-making in relation to the time coverage of resulting decisions varies. This is also the case of deterministic models, which can be used in stable decision environments, whereas only stochastic models include enough decision criteria to lower the decision-making uncertainty – at the cost of higher complication of the tool.

Mathematical models also have their limitations, coming mainly from a multitude of decision criteria, low level of problem structuring and time of application. Managers expect quick and effective instruments for enhancement of their decision tasks, but they also need them to be simple. This contradiction results in a trade-off between the ease of applicability and quality of final decision – a balance, that is difficult to find.

Ogryczak & Śliwiński [2009, p. 5] point at the difficulty of modelling decision-maker's preferences in uncertain decision environment by stating, that in decision problems under uncertainty the decision arises from the maximization of a real valued outcome (scalar). This implies that the occurrence scenarios resulting from the decision process is uncertain and therefore the chosen decision alternative is the possibly best only under assumptions internal to the model. Also the choice of a decision alternatives has externalities, as in most cases they are difficult to compare (which is the main limitation of descriptive models).

To sum up, the choice of a proper type of model for decision-making enhancement require a compromise between simplicity and complexity, as a result of trade-off between applicability and precision of projection of a complex decision environment. The application of decision-making tools that combine quantitative and qualitative decision criteria (such as the AHP) could partially solve this problem.

Research methodology

The impact of geopolitical determinants on decision-making processes of international companies will be discussed on basis of the Open Systems Model [Deresky 2013, pp. 13-25]. The model divides the business environment of international companies into operating-, host-country- and global environment. Because of its vulnerability to external shocks and therefore resulting non-predictability, the global environment is perceived as constant and therefore will be omitted in further analysis.

Multidimensional decision-making problems, as the one treated here, require a systematic approach and are analysed in four main stages [Ogryczak 2006]:

- problem definition – problem observation, recognizing the necessity of changes, formulation of expectations about the result of decision-making; here it is the need for inclusion of geopolitical occurrences into managerial decision-making;
- problem formulation – in this phase main details of decision hierarchy are being defined, e.g. the decision-makers, available decision alternatives together with their limitations as well as external parameters; in presented research the group of decision-makers is composed of 6 experts extracted in course of preliminary factor selection phase and AHP evaluation phase out of 31 people; 7 factors describing the functioning of international enterprises are the decision alternatives, whereas the determinants of operating- and host-country environments compose the set of external parameters and decision limitations;
- making the final decision – formalization of the decision-making process that allows to choose a rational decision; the aim of proposed tool is to offer a possibility of choosing the possibly optimal decision alternative and minimize the costs of wrong decision;
- implementation & control – the link between the entire decision process and business reality; this stage provides also valuable feedback for the decision-maker about decision optimization needs and possibilities and the direction of future decision-making tasks.

Adopted methodology of the research process encompasses three phases: (i) initial factor selection; (ii) preliminary factor selection; (iii) AHP evaluation.

Initial factor selection consisted of direct semi-structured interviews with randomly chosen strategic and tactical level managers of international companies. The respondents were questioned about their decision-making habits, percentage of faulty decisions and willingness of using decision-making enhancement tools. The interviews resulted in reducing the initial number of 100 indexes describing the functioning of international enterprises to 18 critical.

Preliminary factor selection aimed at further lowering the number of analysed indexes and resulted in extracting seven most useful ones via a paper questionnaire, which has been answered by 31 active managers of Polish and international enterprises. The questionnaire included questions about: education, employment structure (size of employment, income from local, regional, international and global markets, language skills, legal form of operation, number of employees, levels of profit or loss in past time periods, percentage of foreign capital involvement in ownership, region of operation of analysed companies, territorial coverage (regional, national, international, global), type of contract, willingness of using consulting services and years of experience on the market. Additional questions focused on grading the above indexes in times of prosperity and recession. The interviews resulted in a final set of seven indexes, i.e.: flexibility, level of income, number of clients, operating profit, product diversification structure of backlog of orders and survival ratio.

Delphi questioning was employed for gathering data in the preliminary factor selection phase. Ziglio [1996, p. 21] understands Delphi as “a structured process for collecting and distilling knowledge from a group of experts by means of a series of questionnaires interspersed with controlled opinion feedback”. Duval, Fontela & Gabus [1975, p. 211] suggest that decision-makers should ask for opinions of experts when complete and reliable information on the decision problem is not available. Helmer [1977, p. 18] points at Delphi being a communication channel for experts, especially useful to formulate group judgments.

Gathered data will be presented on a modified version of Pareto-Lorenz diagram. Hamrol [1998, p. 220] writes, that this tool has been built on an empirically stated regularity, that in nature, technics, human activity, etc. usually 20-30% of causes decides on around 70-80% of results. Grudowski [1996, p. 92] adds that the 80-20% ratio makes the diagram a useful instrument for grading the relevance of particular determinants of complex decision problems.

Here the 80-20% ratio results in a suggestion to managers to concentrate on the 20% of indexes describing the economic condition of their companies that will provide at least 80% of probability of making the best managerial decision. Analysing a wider set of factors will only lower the decision-making efficiency, without raising the quality of final decision.

AHP evaluation consisted of attribution of weights to the final set of seven indexes by six experts – active managers, resulting from stratified random sampling of the group of 31 respondents in the second phase of research. Bartlett, Kotrlik, Higgins [2001, p. 49] state that in the stratified random sampling method the stratification requires each element of the population to belong to one strata only and to one of them at least. Strata need to be uniform and at the same time bear significant differences in between. With use of this method, the sample population has been divided into layers. Division criteria arise from Ackoff’s levels of management [Ackoff 1970, pp. 5-42]: (i) strategic (e.g. managerial board) – making and controlling strategic decisions; (ii) tactical (e.g. division managers) – making and supervising operational decisions; (iii) operational (e.g. operational directors) – their decisions have a functional character and cover usually one specialized function only.

Experts obtained via stratified random sampling were three respondents from strategic- and three from tactical level of management. Including these two levels only (strategic and tactical) is a justified limitation, as geopolitical occurrences are less likely to directly influence the operational level. Following experts belong to the strategic level: (i) CEO of a dynamically developing Polish franchise company from the food sector; (ii) CEO of a British – American consulting company that offers emerging markets entry support and market reports; (iii) President of an institution promoting tourism, with international management and stock exchange experience. Tactical level experts encompassed: (i) Central- and Eastern Europe (CEE) Administrative Manager of an international corporation operating in chemical sector; (ii) Internal Auditor of a CEE oil trust, a former Wall Street employee; (iii) Owner and Managing Director of a media corporation, that includes a record label, an multi-channel internet radio station and a music promotion agency, operating on 64 foreign markets.

Saaty, Vargas [2012, p. 23] define AHP as a tool for enhancement of decision-making processes, which provides the objective mathematics to process the inescapably subjective and personal preferences of an individual or a group in making a decision. AHP allows to choose optimal decision variants basing on pre-defined criteria describing the decision problem [Strojny, Baran 2013, p. 50]. AHP application is advised when the decision problem can be presented in form of a hierarchy with elements independent from each other [Saaty, 2005]. High complexity is another argument in favour of practical applications of AHP (e.g. [Gawlik 2016; Gawlik, Jacobsen 2016; Grzesik, Kwiecińska 2017]).

In elaborated AHP model all six experts provided pairwise comparisons of suitability of extracted seven indexes determining the operational- and host-country environment of international companies. The AHP-required consistency ratio of obtained answers of less than 10% has been preserved [Davoodi 2009, p. 344; Marona, Wilk 2016, p. 61]. Model framework and research outcomes will be presented below.

Proposal of a decision-making model incorporating geopolitical determinants of functioning of international enterprises

The proposed symbolic mathematical model aims at enhancing managerial decision-making under geopolitical circumstances. It has two layers: a factual- and a preference sub-model. The first includes interdependencies internal to the environment of the decision problem. The second serves for analysis of the outcome of the decision process and its possible scenarios.

Wierzbicki [2018, pp. 74-75] recalls Simon's [1957] phases of analytical problem solving: intelligence, design and choice, expanding it by implementation and monitoring. The model built here focuses on the second phase (design) and will be built in three steps: (I) identification of model variables; (II) definition of dependencies between variables; (III) structuring variables accordingly to their types and interrelations:

I. Identification of model variables:

- external parameters:
  - o deterministic: $A = \{a_i\}$, $i = \{1,2,...5\}$; $B = \{b_l\}$, $l = \{1,2,...6\}$ – determinants of operating environment a_i (culture in organizational aspect, ethics, legal regulations, skills, social responsibility); determinants of host-country environment b_l (culture in individual aspect, economic-, political- and technological factors, subsidiary & host-country interdependence); k – coefficient representing a general number of wrong managerial decisions (percentage value resulting from semi-structured direct interviews from the initial factor selection phase – 10% to 20%); y_O, y_H – total number of managerial decisions taken in operating- and host-country environment (respectively). Although external parameters are relevant, they remain beyond the control of the decision maker;
  - o probabilistic: d_O, d_H – external disturbance in operating- or host-country environment;
- decision variables: $X = \{x_j\}$, $j = \{1,2,...7\}$ – indexes describing the development level of international enterprises (flexibility, level of income, number of clients, operating profit, product diversification, structure of backlog of orders, survival ratio,). Under decision-maker's control;
- variables of state:
  - o main function: Y: $y = f(x)$ – final decision: aggregation of all possible combinations of decision variables paired with their weights. Resulting decision-making function can be optimized;
  - o components of the main function: C_O, C_H – correct decisions taken in operating- or host-country environment (respectively); W_O, W_H – wrong decisions (respectively).

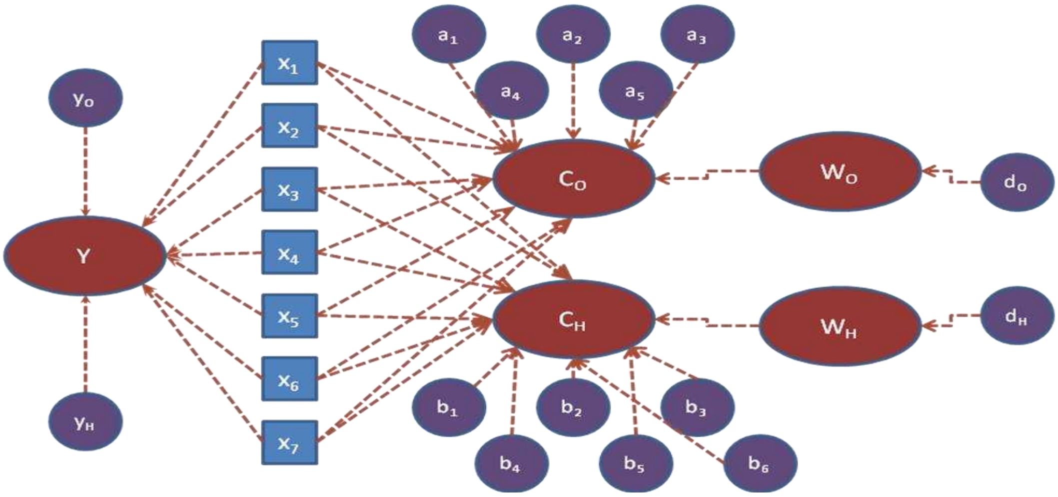
II. Definition of dependencies between variables:

- functions – choosing proper weights of decision variables (economic condition measures) allows to foresee the changes in external parameters (environmental factors) and accordingly adapt the state variables in order to obtain a possibly optimal final decision;
- relations – because the values of some variables can be attributed to more than one variable, not every interdependency between variables is a function; in such situations variables represent deterministic or probabilistic relations;

III. Structuring variables accordingly to their types and interrelations (Figure 1):

- deterministic variables are marked on the Influence Diagram with solid lines;
- probabilistic variable are marked with dotted lines.

Figure 1. A multicriteria decision-making model for environmental uncertainty



Source: own elaboration.

The relation of a random variable of state (managerial decision) and a decision variable (weights of indexes) is probabilistic, as unexpected changes in external variables are possible. Nevertheless, they are unlikely to happen, so this relation will be treated as deterministic. In result a decision-making function can be proposed (Eq. 1), where a variable of state that represents a managerial decision is a function of environmental determinants (external parameters of operating- and host-country environment) and of weights of indexes describing the development level of an enterprise (decision variables).

$$Y = y_O(C_O - W_O) + y_H(C_H - W_H) \qquad \text{[Eq. 1]}$$

Eq. 1 can be explained as follows: a possibly optimal managerial decision is a sum of weights of all correct decisions (C_O) minus all wrong decisions (W_O) taken within the operating environment ($.._O$), multiplied by their sum (y_O) plus weights of all good (C_H) minus all wrong (W_H) decisions taken within the host-country environment ($.._H$), multiplied by their sum (y_H). Exact weights come from AHP expert evaluations.

$$C_O = \sum_{i,j=1}^{n} a_{ij} x_j \qquad \text{[Eq. 2]}$$

where i = {1,2,…5}, j = {1,2,…7}

Eq. 2. shows that a correct decision taken within the operating environment (C_O) is a sum of weights of all arithmetic products of determinants of operating environment (external parameters a_{ij}) and weights of enterprise development indexes (decision variables x_j).

$$W_O = kd_O \qquad \text{[Eq. 3]}$$

Eq. 3. shows that a wrong decision taken within the operating environment (W_O) is the effect of a random external disturbance coming from this environment (d_O) augmented by an empirically determined coefficient k representing a general number of wrong decisions. The probabilistic nature of this disturbance makes it hard to foresee.

Equations describing the host-country environment are analogic (Eq. 4 & 5).

$$C_H = \sum_{l,j=1}^{n} b_{lj} x_j \qquad \text{[Eq. 4]}$$

where l = {1,2,…6}, j = {1,2,…7}

$$W_H = kd_H \qquad \text{[Eq. 5]}$$

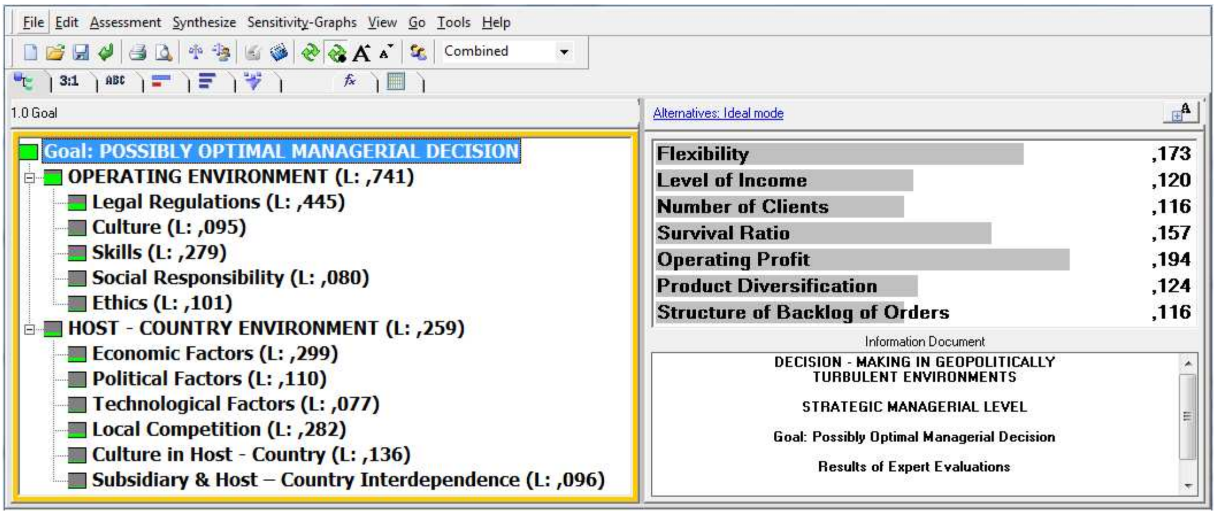
Eq. 6 represents a function describing a decision-making process in a geopolitically unstable environment in relation to operating- and host-country environment determinants.

$$Y = y_O\left(\sum_{i,j=1}^{n} a_{ij} x_j - kd_O\right) + \left(\sum_{l,j=1}^{n} b_{lj} x_j - kd_H\right) \qquad \text{[Eq. 6]}$$

where i = {1,2,…5}; l = {1,2,…6}; j = {1,2,…7}

Variables in Eq. 6 are qualitative. AHP expert evaluations provide a hierarchy of decision criteria. They come as the result of transposition of qualitative (immeasurable) criteria into quantitative (measurable) ones via AHP pairwise comparisons process. Obtained numbers equal the weights of variables of the model (Figure 2).

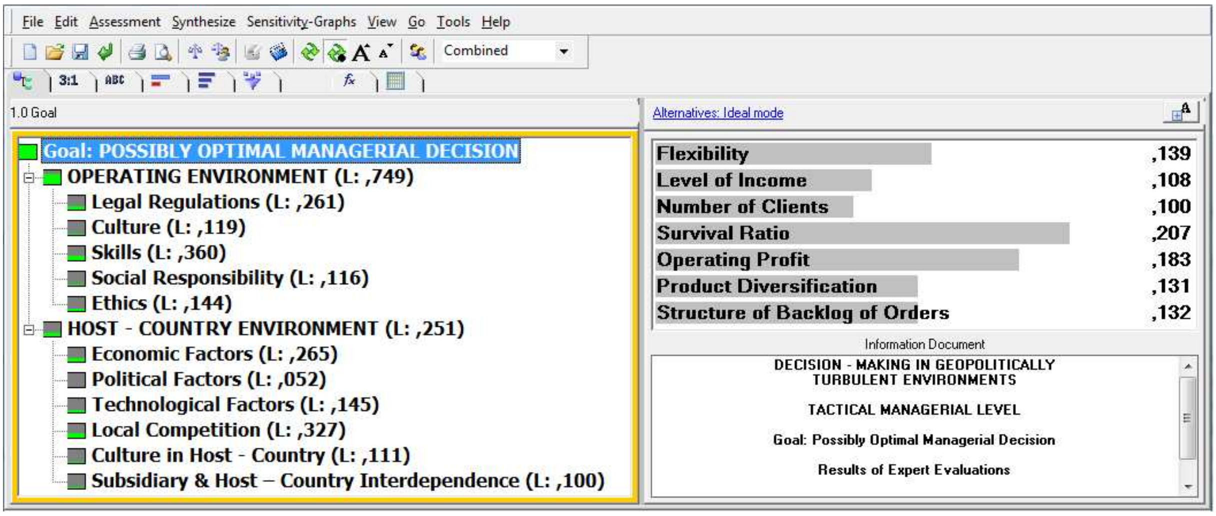
Figure 2. Weights of variables of the model – strategic level of management



Source: own elaboration based on expert evaluation results (Expert Choice, ver. 11.1.3805).

Figure 3 shows results of expert evaluations at tactical managerial levels.

Figure 3. Weights of variables of the model – tactical level of management



Source: own elaboration based on expert evaluation results (Expert Choice, ver. 11.1.3805).

The right window of both screenshots shows the weights of each index of company's development, which equals its relevance for the main goal of decision-making. Left windows present the grading of relevance of decision criteria. At strategic level of management the efficient set of decision criteria includes: (i) operating profit, (ii) flexibility and (iii) survival ratio. At tactical level of management it is composed of same indexes, although in different order: (i) survival ratio, (ii) operating profit and (iii) flexibility. A conclusion follows.

Concluding remarks

The presented research resulted in construction of a dynamic decision-making model, incorporating geopolitical determinants of turbulent decision environment. The proposed decision-making function can be: (i) optimized, e.g. by raising the weights of correct decisions in operating- and host-country environments (C_O, C_H) to the possible optimum; (ii) minimized, e.g. by lowering the weights of wrong decisions (W_O, W_H), which lowers the risk of faulty decisions.

Practical applications of the elaborated solution are almost unlimited, as geopolitical determinants of the decision environment of international companies can be substituted by other hierarchies of factors that influence the functioning of companies. The model can be used for decision problems in which the decision criteria are evaluated through qualitative factors. The main limitation of the research came from restricting the number of environmental determinants. Nevertheless this solution has been earlier proven to be rational. Further research should concentrate on extending the research methodology by Artificial Neural Networks and Fuzzy Logic, for a more accurate modelling of decision environment.

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