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MULTI-CRITERIA DECISION AIDING PROCEDURE UNDER RISK AND UNCERTAINTY

Abstract

Decision making under uncertainty is a very important area of decision theory. Uncertainty implies that in certain situations a person does not have the information which would adequately describe, prescribe or predict a system, its behavior or other characteristics, deterministically and numerically. Thus uncertainty relates to a state of the human mind, i.e., lack of complete knowledge about something.

In this paper we propose an interactive multicriteria decision aiding procedure which enables to take into consideration together uncertainty and risk factors. The uncertainty factors we consider when we don't know the probabilities of the states of nature. The risk factors are applied when we are able to estimate the probability distributions.

The proposed procedure uses scenario planning technique to deal with uncertainty and Monte Carlo simulation to deal with risk factors.

Proposed decision aiding procedure is illustrated by the complete numerical example.

Keywords

Multicriteria decision aiding, risk, uncertainty. Monte Carlo simulation, scenario planning.

Introduction

Rapid technological progress, particularly in the field of information and telecommunication technologies (ICT), and the increasing economic globalization, taking place at the turn of the 20^{th} and 21^{st} centuries, result in a significant volatility of the macroeconomic environment, which has a considerable impact on the business world.

In consequence, the influence that these factors exert on economic and business decisions has to be taken into account in the decision-making. The issues relating to decision analysis and aiding under incomplete information remain important part of operational research, in particular of multi--criteria decision aiding.

Uncertainty implies that in the certain situation a person does not possess the information which quantitatively and qualitatively is appropriate to describe, prescribe or predict deterministically and numerically a system, its behavior or other characteristics [26]. Thus uncertainty relates to a state of the human mind i.e. lack of complete knowledge about something [24].

In earlier works term "Risk" was applied to the situations in which probabilities of outcomes are known objectively, recently term "Risk" means a chance of something bad happening [10]. The term "Uncertainty" is applied to the problems in which exist alternatives with several possible outcomes. The sources of uncertainty may be divided into two main groups: internal sources of uncertainty and external ones. Internal sources of uncertainty are created by imprecision of human judgments concerned with specification of preferences or values or to assessment of consequences of actions [24]. In the MCDA approach we can find a wide range of methods and techniques to deal with uncertainty created by internal factors: sensitivity analysis (e.g. [21]), fuzzy set approach (e.g. [16, 3]), rough set approach (e.g. [12]). External uncertainty refers to lack of knowledge about the consequences of our choices [24]. For those types of problems the following methods are applied: probabilistic models and expected utility (e.g. [14, 1, 22]), pair wise comparisons based on stochastic dominance (e.g. [4, 17]). The risk measures as surrogate criteria are also applied (e.g. [18, 23, 13]). In such problems where we have to take into account external uncertainty the scenario planning may be applied (e.g. [15, 11, 20, 25]).

While considering the traditional division of the issues relating to decision making under incomplete information into the issues relating to decision making under uncertainty and the issues relating to decision making under risk, one can notice that both cases have so far been treated independently (both in scientific literature and in business practice), e.g. decision situations have been analysed as under uncertainty or as under risk.

We think, based on the previously conducted research, that management (especially strategic management) comprises a number of decision-related areas, where uncertainty factors and risk factors should be considered jointly and decisions should be evaluated based on many criteria. In such situations, however, decision aiding requires the development of an appropriate methodology for decision analysis and aiding.

This paper discusses the proposal of the multi-criteria decision aiding procedure under uncertainty and risk, which is a modification of the method presented in the paper [9]. The multi-criteria decision aiding method which has been developed takes into account both uncertainty factors and risk factors.

To incorporate uncertainty factors, the scenario-based approach was adopted, while the Monte Carlo simulation* was applied to deal with risk factors. The decision aiding process was carried out with the use of the interactive method, which allowed to take into account individual preferences of a decision maker (DM) without the necessity of making prior assumptions about them.

To analyse numerical (computational) problems, we created a numerical example, which is the main part of the paper. It was based on the data assumed and illustrates the possibilities of practical applications of the presented decision aiding methodology. Spreadsheets were created to aid decision making based on this method and to test its practical applications (including numerical problems).

The results presented in the paper indicate that the proposed approach to decision aiding, incorporating many evaluation criteria and uncertainty and risk factors, can be effectively implemented in a spreadsheet supplemented with the simulation device and can become a useful tool to aid real life decision problems.

1. Decision aiding under uncertainty and risk**

This section of the paper deals with the multi-criteria decision aiding procedure under risk and uncertainty. The procedure uses the scenario-based method to incorporate uncertainty factors and the Monte Carlo simulation to reflect risk factors. To compare and aid the process of selecting alternatives, we developed a multi-criteria interactive decision aiding method. The method comprises eight main stages, listed below:

1. Formulation of potential decision alternatives.
2. Determination of the evaluation criteria for each alternative.
3. Identification of uncertainty factors.
4. Planning of the scenarios of the environment development.

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* Monte Carlo simulation can be found in [2].
** This part of the paper presents the modified procedure, discussed in the [9].

5. Identification of risk factors.
6. Development of strategic financial plans.
7. Performing the Monte Carlo simulation.
8. Selection of the alternative with the use of the interactive decision aiding method.

The stages of the procedure created, aiding the selection of a decision alternative under uncertainty and risk, are discussed below in detail.

1.1. The formulation of decision alternatives

The first stage involves an analysis which aims to construct the set of potential decision alternatives. Let us assume that the set of alternatives is finite and it will be denoted as follows:

$$W = \{w_1,..., w_M\}$$

1.2. The determination of the evaluation criteria

Next, the evaluation criteria for alternatives are determined. They should allow to compare decision alternatives and reflect the goals of the Decision Maker (DM).

Let us assume that the evaluation criteria can have a directional, point or interval character. They can measure both quantitative characteristics (then they are measures on a ratio scale) and qualitative attributes (noted on an ordinal scale).

To simplify the notation and improve its clarity, we assume, further in the paper, that all the criteria have a directional character and should be maximised. (Minimised, point or interval criteria can be taken into account after their simple transformations).

The set of evaluation criteria for the alternatives is denoted by:

$$K = \{k_1,..., k_J\}$$

1.3. The identification of uncertainty factors

Based on the results of the analysis of the economic macro-environment, the third stage involves identifying uncertainty factors which may have an impact on the values of the evaluation criteria for the decision alternatives which we are considering. These are the factors which remain beyond DM's control and the probability of their occurrence cannot be objectively determined. In practice, they are mainly legislative factors (the introduction or modification of business-related legislation), social factors (change in fashion or lifestyle, etc.), and technological factors (new technical or technological developments).

Next, we determine the set of potential future values for each uncertainty factor. At this stage we can use heuristic techniques, such as "brain storming" or the "Delphi method". The following notation is used:

C – the number of uncertainty factors,

N^z – a set of potential values for factor z (z = 1,…,C) with elements denoted as follows:

$$N^z = \{n_1^z, ..., n_{wz}^z\}$$

where **wz** denotes the number of analyzed values of factor **z**.

1.4. The planning of the scenarios of the environment development

Taking into consideration the set of values of uncertainty factors determined at the previous stage, we plan the scenarios of the economic environment development. The set of scenarios should include all the situations considered. As a result, the set of scenarios can be specified as:

$$S = \{s_1, ...s_{ls}\} = N^1 x N^2 x ... N^Z$$

It is, then, the Cartesian product of the sets of potential values of all uncertainty factors. The number of scenarios **ls** equals the product of the number of values which can be taken by each uncertainty factor: w1x w2 x ….x wz. The examples of scenarios created for strategic analysis can be found in the papers [7, 9].

1.5. The identification of risk factors for each alternative

Stage 5 involves identifying the risk factors for each alternative. These are the factors which have an impact on the values of evaluation criteria and such that the probability distribution for their values in the future can be assessed. In practice, the factors will mainly include such characteristics of the alternatives as investment costs, demand, selling prices, per-unit costs of production, sales costs and costs of management and administration.

In relation to risk factors, we need to collect additional information which will allow to determine the probability distributions of their occurrence. The sources of data on the unknown parameters of a financial plan can be:
- the results of the statistical analysis of historical data,
- the forecasts based on statistical econometric models incorporating the error distribution of a forecast,
- expert opinions.

The BestFit module, part of the Decision Tools Suite package, can be applied to estimate the probability distributions based on historical data. The module allows to find the distribution and parameters with the best fit to historical data and to cooperate directly with the MS Excel spreadsheet. The examples of estimates of probability distributions for risk factors can be found in the paper [6, 7].

1.6. The development of strategic financial plans

Next, a strategic financial plan is developed for each situation (i.e. for each pair: decision alternative/scenario). The financial plan is the basis for the calculation of the evaluation criteria. Thus, the number of financial plans which have to be developed is M x 1s (the number of alternatives x the number of scenarios).

The starting point for the development of a financial plan for the situation considered is the creation of sales forecasts (including the alternative and the scenario of the environment development) and the investment costs plan. Based on this model, operating costs, divided into fixed costs and variable costs, are estimated. This allows to create profit and loss account forecasts on an operating level. Then, based on additional assumptions about the indices of working capital turnover (inventories and receivables) and payables due dates, we determine the demand for working capital and stabilise the balance. The balance sheet forecasts allow to create cash-flow statement forecasts with the use of the indirect method. The examples of strategic financial plans can be found in the paper [8].

1.7. The conduct of the Monte Carlo simulation

Based on the estimates of probability distributions for risk factors (discussed in 1.5) and the models of strategic financial plans (discussed in 1.6), we conduct the Monte Carlo simulation, which generates the distributions of the values of evaluation criteria for each scenario of the environment development. If the financial plan models are created in the MS Excel spreadsheet, we can use the @Risk module, part of the Decision Tools Suite package by Palisade, to carry out the simulation. An example of the simulation carried out with the use of the @Risk module can be found in the papers [5, 7].

As a result of the simulation, we obtain an evaluation vector for each alternative. The components of the vector are the distributions of the evaluation criteria variables:

$$X_i^k = [X_{i,1}^k, \ldots, X_{i,ls}^k]$$

denotes the vector which consists of distribution functions of the *k*-th evaluation criterion for the *i*-th alternative for the next scenarios, whereas the matrix:

$$X^k = [X_{ij}^k]_{M,\text{ls}}$$

includes the value distributions of the *k*-th evaluation criterion for all alternatives and scenarios (k = 1,…,ls).

1.8. The interactive method used for the comparison of alternatives*

Following the calculation of the values of evaluation criteria for each decision alternative, we carry out the multi-criteria analysis which aims to indicate the most favourable alternative of the strategy in the light of the assumed evaluation criteria and DM's preferences or, at least, to select the decision alternatives which are definitely the worst and should be rejected.

Now, we present the proposal of the interactive multi-criteria decision aiding with the use of the scenario-based method. A decision aiding procedure allows DM to evaluate trade-offs both between the evaluation criteria and between the outcomes that are certain and the outcomes that are possible in favourable conditions. Moreover, we assume that during the decision aiding process we will not expect DM to define his preferences a priori, but only to provide this information during the decision-making process, as a result of the analysis and assessment of the solution proposals. Let us assume that the matrix:

$$E(x^k) = [E(x_{ij}^k)]_{M,\text{ls}}$$

* The idea of proposed method is based on the concept of Interactive Multiple Goal Programming presented in [19].

includes the expected values of the k-th evaluation criteria for the subsequent scenarios. Moreover, let us assume that the matrix:

$$x^k(p_k) = [x_{ij}^k]_{M,\mathrm{ls}}$$

includes the values of the k-th evaluation criterion for the subsequent scenarios calculated for the assumed probability value p_k, and these values guarantee the probability that a particular variable will have a lower value of at least p_k, which may be defined as below:

$$P(X_{i,j}^k \geq x_{i,j}^k) = p_k$$

Furthermore, let us assume that for probability p_k:

$$\bar{x}_i^k = \min_{j=1,\ldots,ls} x_{ij}^k$$

means the worst value of the k-th criterion for the i-th decision alternative whose probability is p_k. Let $\mathbf{x_{io}}$ denote the "**ideal optimistic**" solution, defined below:

$$x_{io} = [x_{io},_k : x_{io,k} = \max_{i=1,\ldots,M} \max_{j=1,\ldots,ls} x_{ij}^k ; k = 1,\ldots, J]$$

Whereas $\mathbf{x_{ip}}$ is an "**ideal pessimistic**" solution:

$$x_{ip} = [x_{ip},_k : x_{ip,k} = \max_{i=1,\ldots,M} \bar{x}_{ij}^k ; k = 1,\ldots, J]$$

Vector $\mathbf{x_{arp}}$, defined below, is referred to as a "**current solution**":

$$x_{arp} = [x_{arp},_k : x_{arp,k} = \min_{i=1,\ldots,M} \bar{x}_{ij}^k ; k = 1,\ldots, J]$$

Potency matrix P^r is noted as follows:

$$P^r = \begin{bmatrix} x_{io} \\ x_{ip} \\ x_{arp} \end{bmatrix}$$

where index r = 1,2,3,… denotes the number of the algorithm iteration which generated matrix P.

Let us also assume that matrix P^0 is constructed in the way similar to the one discussed above, but with the use of the matrix of expected values of each criterion $E(x^k)$. The decision aiding procedure can be described in three main steps:

Step 1

DM is presented with potency matrix P^0 calculated on the basis of the expected values. Then, for each criterion *k*, DM defines the probability value at which he will analyse the values of a given evaluation criterion. The first potency matrix P^1 is calculated and presented to DM. DM chooses either to accept the values and move to Step 2 or to correct the adopted values of probabilities p_k.

Step 2

Following the analysis of the potency matrix, DM chooses the criterion for which the value of the current (pessimistic) solution should be improved. He specifies the accepted value of the pessimistic solution of criterion d_k, which fulfills the condition $x^k_{arp} < d^k \leq x^k_{ip}$ for the specified probability of realizing p_k.

DM can change the required values of probabilities p_k for particular evaluation criteria and is then presented with the accordingly improved potency matrix.

Step 3

The alternatives that do not fulfil the condition specified by DM in Step 2 are deleted from the set of the decision alternatives and a new potency matrix P^r is calculated. DM compares the values in potency matrix P^r and P^{r-1} and evaluates whether he accepts the consequences of his requirements.

a) If DM accepts the new solution, we go back to Step 2.
b) If DM rejects the new solution, we restore the deleted alternatives and then go back to Step 2.

Stop condition

The procedure stops when there is only one alternative left in the set of decision alternatives and DM accepts the solution.

2. The numerical example

Now we present the numerical example which illustrates the application of the proposed multi-criteria decision aiding procedure under uncertainty and risk to the selection of a company's investment alternative. The example has been developed based on the assumed data.

2.1. The formulation of the problem and decision alternatives

Let us assume that we consider the case of a consumer electronics manufacturer. The company specialises in a narrow segment of this market (characterised by high growth dynamics) and is a market challenger (it has the second largest market share). The main competitor, the market leader, builds its strategy on systematic innovation in the functionality of the products, which forces other market participants to introduce similar solutions.

The management board recognizes the need to modernize the production facilities in order to facilitate the application of the latest technological developments in the manufactured goods.

As a result of preliminary technical and technological analyses, several opportunities to modernize the production plant have been identified. Firstly, the modernisation is carried out in stages, over the span of four years, and financed with the company's own funds. The second alternative involves the purchase a new production line in addition to the existing one and its launch within the first year. The third alternative is the construction of an entirely new production line as a replacement of the existing one and its launch within the first year. Due to high investment costs, the last project may be financed through the increase in the company's equity capital or with a long-term loan.

In order to provide basis for comparison with the current situation, we also consider the possibility that the company chooses not to make the investment and continues to operate in an unchanged manner. The set of decision alternatives consists of five elements:

$$W = \{w_1, \ldots, w_5\}$$

briefly characterized below:

Alternative 1: w_1 – refraining from the investment.

Alternative 2: w_2 – the modernisation of the production plant is carried out in stages, over the span of four years, with the capital outlays in the four years amounting to PLN 2.3m, PLN 3.1m, PLN 3.1m, PLN 3.8m, respectively. The full capacity will be reached after the completion of the investment.

Alternative 3: w_3 – the modernization of the production plant involving the installation of a new production line in addition to the existing one within the first year. The estimated capital outlay amounts to approximately PLN 10.2m and will partly be financed with a long-term loan.

Alternative 4: w_4 – the purchase of a new production line as the replacement of the existing one within the first year. The total capital outlay is estimated at PLN 20.2m, with PLN 19m financed with a long-term loan and the rest coming from the company's own funds.
Alternative 5: w_5 – the purchase of a new production line as the replacement of the existing one as in the previous alternative. The capital outlay will be financed through the increase in equity capital (PLN 18m) and the rest will come from the company's own funds.

2.2. The determination of the evaluation criteria

Alternatives will be compared based on the analysis of the five-year period from 2007 to 2011. Let us assume that five evaluation criteria have been determined in order to compare the decision alternatives. Thus, the set of criteria may be noted as follows:

$$K = \{k_1,...,k_5\}$$

The characteristics of the adopted criteria are:
Criterion 1: k_1 – **SALES**: the level of sales in 2011. The criterion is used to assess the market position of the company at the end of the analysed period. The higher the value of this criterion is, the better.
Criterion 2: k_2 – **NPV**: the updated net present value of the project calculated at the discount rate of 12%. The outlays are covered by the value of own capital at the beginning of the analysed period, the cash-flow values in the next years based on the cash-flow forecast, and the residual value equal to the value of net assets at the end of the last year. The criterion is a commonly used measure of investment profitability. The higher the value of this criterion is, the better.
Criterion 3: k_3 – **ROE:** return on equity in 2011 calculated by dividing net income by equity capital. The criterion reflects the expected return on shareholder capital after the completion of the project. The higher the value of this criterion is, the better.
Criterion 4: k_4 – **MAX_DR:** maximum debt ratio in the whole analysed period calculated as the ratio of the sum of short- and long-term loans to total assets. The criterion is a measure of financial risk of the project. The lower the value of this criterion is, the better.
Criterion 5: k_5 – **MIN_IC:** minimum interest coverage ratio in the analysed period calculated as the ratio of operating income to financial costs (in this case, interest expense). The criterion also measures the financial risk of the investment (loss of liquidity in the analysed period). The higher the value of this criterion is, the better.

2.3. The identification of uncertainty factors

Let us assume that the analysis conducted allowed to identify two main uncertainty factors: market growth dynamics (in the given market segment) and the behaviour of the main competitor.

Thus, the number of uncertainty factors is C=2 and N^1 denotes the set of potential values of a factor relating to market growth dynamics, while N^2 denotes the set of values relating to the behaviour of the competition.

Let us assume that there are two alternatives relating to the situation on the market: stable high market absorption dynamics and a significant slowdown in these dynamics (due to market saturation). We can write:

$$N^1 = \{n_1^1, n_2^1\}$$

where:

n_1^1 denotes stable market growth dynamics,

n_2^1 denotes a slowdown in market growth dynamics.

Let us assume that while considering the potential impact of the competition, we also identified two possible situations. One situation is when the main competitor completes the development of and successfully launches a new product with improved functionality, which will lead to a decrease in sales of other manufacturers. The other situation assumes that the project of the main competitor is not completed successfully, which will not adversely affect the position of other manufacturers. Thus, we can write:

$$N^2 = \{n_1^2, n_2^2\}$$

where:

n_1^2 denotes lack of the negative impact from the main competitor,

n_2^2 denotes the negative impact due to a new product launched by a competitor.

2.4. The planning of the scenarios of the environment development

The next stage involves the planning of four scenarios of the environment development based on the characteristic factors defined and the sets of values adopted for these factors. The scenarios are presented below in Table 1.

Table 1

List of scenarios

Factor / Scenario	N_1	N_2
S_1	n_1^1	n_1^2
S_2	n_2^1	n_1^2
S_3	n_1^1	n_2^2
S_4	n_2^1	n_2^2

We can see that Scenario 1 assumes stable high market growth dynamics and the lack of a negative impact from the main competitor. Scenario 2 also includes the lack of a negative impact from the competition, but it also predicts a less optimistic market growth. Scenario 3 assumes that high market growth dynamics are accompanied by a negative impact from the competition. Scenario 4 is definitely the least favourable: it assumes both a slowdown in market growth dynamics and a negative impact from the main competitor.

2.5. The identification of risk factors

Let us assume that during further analysis of the decision alternatives the following risk factors have been identified:

– projected market absorption,
– projected market share,
– investment costs,
– main operating costs.

Export opinions are used to assess the probability distributions for particular factors.

2.5.1. Market absorption

The next two tables present the projected market sizes in consecutive years. The projections are delivered by independent experts.

Table 2

Projected market absorption for scenarios S1 and S3

Market Forecast	2007	2008	2009	2010	2011
Expert 1	1 620 000 000	1 765 800 000	1 907 064 000	2 021 487 840	2 102 347 354
Expert 2	1 580 000 000	1 738 000 000	1 877 040 000	1 989 662 400	2 089 145 520
Expert 3	1 520 000 000	1 702 400 000	1 821 568 000	1 912 646 400	1 950 899 328
Expert 4	1 550 000 000	1 689 500 000	1 790 870 000	1 880 413 500	1 918 021 770
Expert 5	1 580 000 000	1 722 200 000	1 842 754 000	1 934 891 700	1 973 589 534
Expert 6	1 650 000 000	1 831 500 000	1 978 020 000	2 096 701 200	2 201 536 260
Expert 7	1 490 000 000	1 594 300 000	1 674 015 000	1 707 495 300	1 741 645 206
Expert 8	1 490 000 000	1 609 200 000	1 721 844 000	1 825 154 640	1 916 412 372
Expert 9	1 570 000 000	1 727 000 000	1 865 160 000	1 977 069 600	2 075 923 080
Expert 10	1 585 000 000	1 727 650 000	1 848 585 500	1 941 014 775	2 038 065 514
Average	**1 563 500 000**	**1 710 755 000**	**1 832 692 050**	**1 928 653 736**	**2 000 758 594**
Standard deviation	**52 283 947**	**69 465 173**	**87 790 583**	**108 178 070**	**129 017 321**

Table 3

Projected market absorption for scenarios S2 and S4

Market Forecast	2007	2008	2009	2010	2011
Expert 1	1 450 000 000	1 464 500 000	1 493 790 000	1 508 727 900	1 523 815 179
Expert 2	1 408 500 000	1 408 500 000	1 422 585 000	1 436 810 850	1 451 178 959
Expert 3	1 415 500 000	1 429 655 000	1 443 951 550	1 443 951 550	1 443 951 550
Expert 4	1 404 300 000	1 432 386 000	1 489 681 440	1 534 371 883	1 565 059 321
Expert 5	1 530 000 000	1 560 600 000	1 607 418 000	1 655 640 540	1 688 753 351
Expert 6	1 488 000 000	1 562 400 000	1 609 272 000	1 657 550 160	1 674 125 662
Expert 7	1 310 000 000	1 336 200 000	1 349 562 000	1 363 057 620	1 376 688 196
Expert 8	1 380 000 000	1 421 400 000	1 464 042 000	1 493 322 840	1 493 322 840
Expert 9	1 350 000 000	1 404 000 000	1 446 120 000	1 489 503 600	1 504 398 636
Expert 10	1 380 000 000	1 435 200 000	1 463 904 000	1 493 182 080	1 508 113 901
Average	**1 411 630 000**	**1 445 484 100**	**1 479 032 599**	**1 507 611 902**	**1 522 940 759**
Standard deviation	**64 569 016**	**69 460 059**	**79 227 360**	**91 780 522**	**97 948 489**

We assume that, in further analysis, the projected market size will be described by normal distributions, respectively for each scenario, and the parameters will be given in the last two rows of Tables 2 and 3.

2.5.2. Market share

Expert opinions on the projected market share for Alternative 1 are presented in the next two tables.

Table 4

Expert opinion on projected market share for Alternative 1, Scenarios 1 and 3

Market share	2007	2008	2009	2010	2011
Expert 1	30,00%	30,00%	29,00%	27,00%	27,00%
Expert 2	31,00%	30,00%	28,00%	26,00%	26,00%
Expert 3	29,00%	28,00%	26,00%	25,00%	25,00%
Expert 4	32,00%	32,00%	30,00%	28,00%	28,00%
Expert 5	30,00%	30,00%	30,00%	30,00%	28,00%
Expert 6	31,00%	31,00%	30,00%	29,00%	29,00%
Expert 7	30,00%	30,00%	29,00%	28,00%	28,00%
Expert 8	28,00%	27,00%	27,00%	25,00%	23,00%
Expert 9	32,00%	32,00%	32,00%	29,00%	29,00%
Expert 10	31,00%	31,00%	30,00%	28,00%	28,00%
Minimum	**28,00%**	**27,00%**	**26,00%**	**25,00%**	**23,00%**
Mode	**30,00%**	**30,00%**	**30,00%**	**28,00%**	**28,00%**
Maximum	**32,00%**	**32,00%**	**32,00%**	**30,00%**	**29,00%**

Table 5

Expert opinion on projected market share for Alternative 1, Scenarios 2 and 4

Market share	2007	2008	2009	2010	2011
Expert 1	30,00%	27,00%	26,00%	22,00%	22,00%
Expert 2	31,00%	27,00%	25,00%	21,00%	21,00%
Expert 3	29,00%	25,00%	23,00%	20,00%	20,00%
Expert 4	32,00%	29,00%	27,00%	22,00%	22,00%
Expert 5	30,00%	27,00%	27,00%	23,00%	23,00%
Expert 6	31,00%	28,00%	27,00%	24,00%	24,00%
Expert 7	30,00%	27,00%	24,00%	24,00%	23,00%
Expert 8	28,00%	24,00%	22,00%	20,00%	18,00%
Expert 9	32,00%	29,00%	27,00%	23,00%	24,00%
Expert 10	31,00%	28,00%	27,00%	23,00%	23,00%
Minimum	**28,00%**	**24,00%**	**22,00%**	**20,00%**	**18,00%**
Mode	**30,00%**	**27,00%**	**27,00%**	**23,00%**	**23,00%**
Maksimum	**32,00%**	**29,00%**	**27,00%**	**24,00%**	**24,00%**

We assumed that triangle distributions would be used to describe changes in market share in the future. The parameters of the distributions are presented in the last three rows of the tables containing the expert opinions.

2.5.3. Investment costs

Probability distributions for investment costs in the scenarios are presented below:

Table 6

Probability distributions for investment costs, Alternative 2

Investment cost	2007	2008	2009	2010
1 800 000 - 2 000 000				
2 000 001 - 2 200 000	0,05			
2 200 001 - 2 400 000	0,80			
2 400 001 - 2 600 000	0,15			
2 600 001 - 2 800 000		0,05		
2 800 001 - 3 000 000		0,10	0,15	
3 000 001 - 3 200 000		0,15	0,50	
3 200 001 - 3 400 000		0,55	0,20	
3 400 001 - 3 600 000		0,15	0,10	
3 600 001 - 3 800 000			0,05	0,10
3 800 001 - 4 000 000				0,50
4 000 001 - 4 200 000				0,35
4 200 001 - 4 400 000				0,05
	1,00	**1,00**	**1,00**	**1,00**

Table 7

Probability distributions for investment costs, Alternative 3

Investment cost	2007	2008	2009	2010
9 600 000 - 9 800 000				
9 800 001 - 10 000 000	0,05			
10 000 001 - 10 200 000	0,70			
10 200 001 - 10 400 000	0,20			
10 400 001 - 10 600 000	0,05			
SUMA	**1,00**	**0,00**	**0,00**	**0,00**

Table 8

Probability distributions for investment costs, Alternatives 4 and 5

Investment cost	2007	2008	2009	2010
19 600 000 - 19 800 000				
19 800 001 - 19 000 000	0,10			
20 000 001 - 20 200 000	0,55			
20 200 001 - 20 400 000	0,25			
20 400 001 - 20 600 000	0,10			
SUMA	**1,00**	**0,00**	**0,00**	**0,00**

2.5.4. Selected operating costs

The next tables present the parameters of the triangle distributions for main items of operating costs for Alternative 1. They show the estimated contributions of particular items in relation to total sales. We assume they were estimated based on the expert opinions similarly to the way presented in the previous section.

Table 9

Parameters of triangle distributions – Alternative 1

Materials and energy	2007	2008	2009	2010	2011
Min	64,50%	64,50%	64,50%	64,50%	64,50%
Mode	65,00%	65,00%	65,00%	65,00%	65,00%
Max	65,50%	65,50%	65,50%	65,50%	65,50%

Table 10

Parameters of triangle distributions – Alternative 1

External services	2007	2008	2009	2010	2011
Min	9,00%	9,00%	9,00%	9,00%	9,00%
Mode	10,00%	10,00%	10,00%	10,00%	10,00%
Max	11,00%	11,00%	11,00%	11,00%	11,00%

Table 11

Parameters of triangle distributions – Alternative 1

Payroll	2007	2008	2009	2010	2011
Min	13,50%	13,50%	13,50%	13,50%	13,50%
Mode	15,00%	15,00%	15,00%	15,00%	15,00%
Max	17,00%	17,00%	17,00%	17,00%	17,00%

Table 12

Parameters of triangle distributions – Alternative 1

Other expenditures	2007	2008	2009	2010	2011
Min	2,50%	2,50%	2,50%	2,50%	2,50%
Mode	3,00%	3,00%	3,00%	3,00%	3,00%
Max	5,00%	5,00%	5,00%	5,00%	5,00%

2.6. The development of strategic financial plans

The next stage involves creating financial forecasts for the years 2007--2011, based on the assumptions discussed in 2.1 for each situation (e.g. for each pair: a decision alternative – a scenario). Table 12 presents the sales forecasts for Alternative 1 – Scenario 1. The numerical values, included in the tables, were calculated using the expected distribution values of risk factors.

Table 13

Market forecast

MARKET FORECAST	2006	2007	2008	2009	2010	2011
Total market (PLN)	1 563 500 000,00	1 563 500 000,00	1 710 755 000,00	1 832 692 050,00	1 928 653 735,50	2 000 758 593,74
Market share	30,00%	30,00%	29,67%	29,33%	27,67%	26,67%
Sales revenues	**469 050 000,00**	**469 050 000,00**	**507 523 983,33**	**537 589 668,00**	**533 594 200,16**	**533 535 625,00**

The next two tables present the profit and loss account forecast, the balance sheet forecast and the cash flow forecast for a particular situation.

Table 14

Profit and loss account forecast for Alternative 1 – Scenario 1

Profit and Loss Account	2006	2007	2008	2009	2010	2011
Net sale revenues and net sale revenues equivalents including	**469 050 000,0**	**469 050 000,0**	**507 523 983,3**	**537 589 668,0**	**533 594 200,2**	**533 535 625,0**
Net revenues from the sale of finished products	469 050 000,0	469 050 000,0	507 523 983,3	537 589 668,0	533 594 200,2	533 535 625,0
Net revenues from the sale of merchandise and raw materials		0,0	0,0	0,0	0,0	0,0
Operating expenses	**455 711 450,0**	**459 041 705,0**	**496 596 160,1**	**525 943 274,9**	**522 043 298,8**	**521 986 123,6**
Depreciation	1 200 000,0	1 200 000,0	1 200 000,0	1 200 000,0	1 200 000,0	1 200 000,0
Materials and energy	304 882 500,0	304 882 500,0	329 890 589,2	349 433 284,2	346 836 230,1	346 798 156,2
External services	46 905 000,0	46 905 000,0	50 752 398,3	53 758 966,8	53 359 420,0	53 353 562,5
Taxes and charges	2 000,0	2 000,0	2 000,0	2 000,0	2 000,0	2 000,0
Payroll	70 357 500,0	71 139 250,0	76 974 470,8	81 534 433,0	80 928 453,7	80 919 569,8
Social security and other benefits	18 292 950,0	18 496 205,0	20 013 362,4	21 198 952,6	21 041 398,0	21 039 088,1
Other expenditures by kind	14 071 500,0	16 416 750,0	17 763 339,4	18 815 638,4	18 675 797,0	18 673 746,9
Cost of merchandise and raw materials sold	0,0	0,0	0,0	0,0	0,0	0,0
Gross profit/(loss)	**13 338 550,0**	**10 008 295,0**	**10 927 823,2**	**11 646 393,1**	**11 550 901,4**	**11 549 501,4**
Other operating revenues	0,0	0,0	0,0	0,0	0,0	0,0
Other operating expenses	0,0	0,0	0,0	0,0	0,0	0,0
Operating profit/(loss)	**13 338 550,0**	**10 008 295,0**	**10 927 823,2**	**11 646 393,1**	**11 550 901,4**	**11 549 501,4**
Financial revenue	0,0	0,0	0,0	0,0	0,0	0,0
Financial expenses	4 100 000,0	3 800 000,0	3 500 000,0	3 500 000,0	3 500 000,0	3 500 000,0
Gross profit/(loss) on business activities	**9 238 550,0**	**6 208 295,0**	**7 427 823,2**	**8 146 393,1**	**8 050 901,4**	**8 049 501,4**
Extraordinary profits	0,0	0,0	0,0	0,0	0,0	0,0
Extraordinary loses	0,0	0,0	0,0	0,0	0,0	0,0
Profit/(loss) before taxation	**9 238 550,0**	**6 208 295,0**	**7 427 823,2**	**8 146 393,1**	**8 050 901,4**	**8 049 501,4**
Corporate income tax	1 755 324,5	1 179 576,1	1 411 286,4	1 547 814,7	1 529 671,3	1 529 405,3
Net profit/(loss)	**7 483 225,5**	**5 028 719,0**	**6 016 536,8**	**6 598 578,4**	**6 521 230,1**	**6 520 096,2**

Table 15

Balance sheet forecast for Alternative 1 – Scenario 1

	BALANCE SHEET-ASSETS	31.12.2006	31.12.2007	31.12.2008	31.12.2009	31.12.2010	31.12.2011
A.	**Non-current assets**	**23 456 000,0**	**22 256 000,0**	**21 056 000,0**	**19 856 000,0**	**18 656 000,0**	**17 456 000,0**
I.	**Intangible assets and legal values**	0,0	0,0	0,0	0,0	0,0	0,0
II.	**Fixed tangibles**	23 456 000,0	22 256 000,0	21 056 000,0	19 856 000,0	18 656 000,0	17 456 000,0
III.	**Long-term debtors**	0,0	0,0	0,0	0,0	0,0	0,0
IV.	**Long-term investments**	0,0	0,0	0,0	0,0	0,0	0,0
V.	**Long-term prepayments**	0,0	0,0	0,0	0,0	0,0	0,0
B.	**Current assets**	**111 073 058,8**	**111 301 777,8**	**123 861 923,4**	**135 836 291,3**	**143 002 595,3**	**150 714 556,0**
I.	**Inventory**	45 602 083,3	45 602 083,3	49 342 609,5	52 265 662,2	51 877 213,9	51 871 519,1
II.	**Short-term debtors**	65 145 833,3	65 145 833,3	70 489 442,1	74 665 231,7	74 110 305,6	74 102 170,1
III.	**Short-term investments**	325 142,2	553 861,1	4 029 871,8	8 905 397,5	17 015 075,8	24 740 866,8
IV.	**Short-term prepayments**	0,0	0,0	0,0	0,0	0,0	0,0
	Total assets	**134 529 058,8**	**133 557 777,8**	**144 917 923,4**	**155 692 291,3**	**161 658 595,3**	**168 170 556,0**

	BALANCE SHEET-EQUITY AND LIABILITIES	31.12.2006	31.12.2007	31.12.2008	31.12.2009	31.12.2010	31.12.2011
A.	**Equity**	**28 383 225,5**	**33 411 944,5**	**39 428 481,2**	**46 027 059,6**	**52 548 289,7**	**59 068 385,9**
I.	**Share capital**	15 000 000,0	15 000 000,0	15 000 000,0	15 000 000,0	15 000 000,0	15 000 000,0
II.	**Outstanding share capital contributions**	0,0	0,0	0,0	0,0	0,0	0,0
III.	**Shares not distributed**	0,0	0,0	0,0	0,0	0,0	0,0
IV.	**Reserve capital**	5 900 000,0	13 383 225,5	18 411 944,5	24 428 481,2	31 027 059,6	37 548 289,7
V.	**Revaluation reserve**	0,0	0,0	0,0	0,0	0,0	0,0
VI.	**Other reserve capital**	0,0	0,0	0,0	0,0	0,0	0,0
VII.	**Profit (loss) brought forward**	0,0	0,0	0,0	0,0	0,0	0,0
VIII.	**Net profit (loss)**	7 483 225,5	5 028 719,0	6 016 536,8	6 598 578,4	6 521 230,1	6 520 096,2
IX.	**Net profit (loss) write-offs**	0,0	0,0	0,0	0,0	0,0	0,0
B.	**Creditors and provisions**	**106 145 833,3**	**100 145 833,3**	**105 489 442,1**	**109 665 231,7**	**109 110 305,6**	**109 102 170,1**
I.	**Provisions**	0,0	0,0	0,0	0,0	0,0	0,0
II.	**Long-term creditors**	0,0	0,0	0,0	0,0	0,0	0,0
III.	**Short-term creditors**	106 145 833,3	100 145 833,3	105 489 442,1	109 665 231,7	109 110 305,6	109 102 170,1
IV.	**Accruals and deferred income**	0,0	0,0	0,0	0,0	0,0	0,0
	Total Equity and Liabilities	**134 529 058,8**	**133 557 777,8**	**144 917 923,4**	**155 692 291,3**	**161 658 595,3**	**168 170 556,0**

The forecasts of the financial statements are the basis for the calculation of the values of evaluation criteria for each situation.

The values of the evaluation criteria for each situation, calculated based on the financial forecasts (taking into account the expected values of risk factors), are presented below.

Table 16

Expected criteria values (prior to the simulation)

	SALES	NPV	ROE	MAX DR	MIN IC
A1S1	533 494 018,7	19 633 186,2	43,43%	26,28%	1,12
A1S2	433 436 732,6	19 128 726,6	30,55%	26,66%	0,97
A1S3	433 415 591,0	19 119 371,2	30,70%	26,66%	0,97
A1S4	329 963 072,0	18 032 295,5	17,20%	29,34%	0,70
A2S1	586 782 731,2	38 145 671,6	131,34%	26,32%	1,48
A2S2	513 517 013,2	33 520 180,8	110,84%	27,96%	1,29
A2S3	446 709 796,3	30 624 731,8	92,41%	29,51%	1,16
A2S4	390 877 844,4	26 874 278,8	76,86%	29,79%	1,04
A3S1	600 226 508,4	93 922 519,1	168,49%	31,76%	2,26
A3S2	533 505 008,6	83 463 420,5	146,17%	31,76%	2,25
A3S3	456 802 806,1	75 883 142,8	120,12%	33,45%	2,00
A3S4	406 093 192,0	67 573 228,9	103,49%	33,44%	2,00
A4S1	647 080 104,3	79 024 211,5	179,26%	37,81%	1,50
A4S2	586 908 045,1	74 015 995,2	159,56%	37,81%	1,50
A4S3	492 461 449,2	61 787 671,7	128,70%	39,63%	1,32
A4S4	446 718 674,9	57 892 385,2	113,68%	39,63%	1,32
A5S1	646 964 175,9	89 465 354,1	82,02%	25,46%	1,86
A5S2	586 906 598,6	84 539 122,9	73,05%	25,46%	1,86
A5S3	492 451 952,9	72 311 774,9	58,97%	26,69%	1,65
A5S4	446 744 810,2	68 419 802,2	52,17%	26,69%	1,64

2.7. The conduct of the Monte Carlo simulation

The next stage involves conducting 20 Monte Carlo simulations (one for each situation). The simulations are conducted based on the financial statement forecasts, created at the previous stage, and the probability distributions for risk factors, determined in Section 2.5.

The Monte Carlo simulations are carried out with the use of financial forecast models, created in the Excel spreadsheet, and the test version of the @Risk package, available on the www.palisade.com website.

Each simulation involves performing 1,000 iterations. As a result, we generate the value distributions for the evaluation criteria for each situation. Table 17 presents the value distributions for the evaluation criteria for Alternative 1 – Scenario 1.

Table 17

Distributions for the evaluation criteria for Alternative 1 – Scenario 1

A1-S1	SALES	NPV	ROE	MAX DR	MIN IC
Minimum	393 744 352,0	-15 590 017,0	-59,14%	23,41%	-2,5
Maximum	691 684 864,0	57 601 560,0	134,97%	29,61%	4,1
Mean	533 494 018,7	19 633 186,2	43,43%	26,28%	1,1
Standard Deviation	42 587 777,0	12 843 824,8	33,28%	1,05%	1,1
Variance	1,81372E+15	1,64964E+14	0,110723463	0,000110836	1,289306274
Skewness	0,021893336	0,029807905	-0,053627716	0,329533618	-0,016696687
Kurtosis	3,082068542	2,813936299	2,699544732	2,991281803	2,818343389
Number of Errors	0	0	0	0	0
Mode	499 693 152,0	26 488 429,2	52,10%	25,47%	0,8
5,0%	464 402 624,0	-2 345 538,3	-11,33%	24,69%	-0,7
10,0%	479 295 168,0	3 025 462,3	-0,14%	24,96%	-0,3
15,0%	489 719 232,0	6 063 398,0	7,32%	25,20%	-0,1
20,0%	496 788 512,0	8 838 973,0	14,91%	25,38%	0,1
25,0%	502 238 560,0	11 071 894,0	20,67%	25,50%	0,3
30,0%	509 138 976,0	12 636 161,0	26,17%	25,67%	0,5
35,0%	517 696 512,0	14 558 067,0	31,38%	25,80%	0,7
40,0%	523 695 360,0	16 038 949,0	35,43%	25,93%	0,8
45,0%	528 360 672,0	17 979 706,0	39,16%	26,06%	1,0
50,0%	534 068 896,0	19 655 728,0	43,69%	26,22%	1,1
55,0%	539 301 248,0	21 107 544,0	46,88%	26,38%	1,2
60,0%	544 892 736,0	22 852 978,0	51,55%	26,51%	1,4
65,0%	550 030 144,0	24 650 686,0	56,19%	26,66%	1,5
70,0%	556 483 264,0	26 549 442,0	61,12%	26,79%	1,7
75,0%	561 892 096,0	28 362 112,0	67,30%	26,95%	1,9
80,0%	569 238 912,0	30 585 984,0	73,11%	27,12%	2,1
85,0%	576 150 400,0	32 901 004,0	79,79%	27,41%	2,3
90,0%	587 610 240,0	36 355 424,0	87,41%	27,68%	2,6
95,0%	603 567 872,0	40 801 132,0	97,05%	28,08%	3,1

2.8. The selection of the alternative with the use of the interactive decision aiding method

According to the decision aiding procedure, the first step involves constructing the matrices which include the expected values of evaluation criteria for each situation. The matrices are presented in Tables 18-22. The last two columns of the tables show the maximum and minimum values for each alternative. These values are used to construct potency matrix P0.

Table 18

Expected values – Criterion 1

SALES	S1	S2	S3	S4	MAX	MIN
A1	533 494 018,7	433 436 732,6	433 415 591,0	329 963 072,0	**533 494 018,7**	**329 963 072,0**
A2	586 782 731,2	513 517 013,2	446 709 796,3	390 877 844,4	**586 782 731,2**	**390 877 844,4**
A3	600 226 508,4	533 505 008,6	456 802 806,1	406 093 192,0	**600 226 508,4**	**406 093 192,0**
A4	647 080 104,3	586 908 045,1	492 461 449,2	446 718 674,9	**647 080 104,3**	**446 718 674,9**
A5	646 964 175,9	586 906 598,6	492 451 952,9	446 744 810,2	**646 964 175,9**	**446 744 810,2**

Table 19

Expected values – Criterion 2

NPV	S1	S2	S3	S4	MAX	MIN
A1	19 633 186,2	19 128 726,6	19 119 371,2	18 032 295,5	**19 633 186,2**	**18 032 295,5**
A2	38 145 671,6	33 520 180,8	30 624 731,8	26 874 278,8	**38 145 671,6**	**26 874 278,8**
A3	93 922 519,1	83 463 420,5	75 883 142,8	67 573 228,9	**93 922 519,1**	**67 573 228,9**
A4	79 024 211,5	74 015 995,2	61 787 671,7	57 892 385,2	**79 024 211,5**	**57 892 385,2**
A5	89 465 354,1	84 539 122,9	72 311 774,9	68 419 802,2	**89 465 354,1**	**68 419 802,2**

Table 20

Expected values – Criterion 3

ROE	S1	S2	S3	S4	MAX	MIN
A1	43,43%	30,55%	30,70%	17,20%	**43,43%**	**17,20%**
A2	131,34%	110,84%	92,41%	76,86%	**131,34%**	**76,86%**
A3	168,49%	146,17%	120,12%	103,49%	**168,49%**	**103,49%**
A4	179,26%	159,56%	128,70%	113,68%	**179,26%**	**113,68%**
A5	82,02%	73,05%	58,97%	52,17%	**82,02%**	**52,17%**

Table 21

Expected values – Criterion 4

MAX DR	S1	S2	S3	S4	MAX	MIN
A1	26,28%	26,66%	26,66%	29,34%	**29,34%**	**26,28%**
A2	26,32%	27,96%	29,51%	29,79%	**29,79%**	**26,32%**
A3	31,76%	31,76%	33,45%	33,44%	**33,45%**	**31,76%**
A4	37,81%	37,81%	39,63%	39,63%	**39,63%**	**37,81%**
A5	25,46%	25,46%	26,69%	26,69%	**26,69%**	**25,46%**

Table 22

Expected values – Criterion 5

MIN IC	S1	S2	S3	S4	MAX	MIN
A1	1,12	0,97	0,97	0,70	**1,1**	**0,7**
A2	1,48	1,29	1,16	1,04	**1,5**	**1,0**
A3	2,26	2,25	2,00	2,00	**2,3**	**2,0**
A4	1,50	1,50	1,32	1,32	**1,5**	**1,3**
A5	1,86	1,86	1,65	1,64	**1,9**	**1,6**

Based on the values presented above, matrix P^0 is constructed and presented to DM.

Table 23

Potency matrix P^0

	SALES	NPV	ROE	MAX_DR	MIN IC
IDEAL OPTIMISTIC	647 080 104,3	93 922 519,1	179,26%	25,46%	2,3
IDEAL PESSIMISTIC	446 744 810,2	68 419 802,2	113,68%	26,69%	2,0
CURENT SOLUTION	329 963 072,0	18 032 295,5	17,20%	39,63%	0,7

After analyzing the values in potency matrix P0 and taking into account his attitude to risk, DM makes a decision about what level of probability of achieving the values of particular criteria will allow further analysis and aiding of the decision-making process.

Let us assume that DM accepted the following values (respectively): 0.80, 0.95, 0.90, 0.95, 0.80. Based on the accepted probability levels and percentile distributions, we construct matrices which contain such criteria values for each situation that the probability of their occurrence is not lower than the value defined by DM.

For example, while analysing the data in Table 24, we can see that the selection of Alternative 1 and the occurrence of Scenario 1 with the probability of 0.80 results in sales not lower than PLN 496,788,512. The values corresponding to all the criteria are presented in the five tables below.

Table 24

Criterion 1 for probability = 0.80

SALES	S1	S2	S3	S4	MAX	MIN
W1	496 788 512,0	402 001 632,0	400 295 936,0	305 389 920,0	**496 788 512,0**	**305 389 920,0**
W2	548 861 504,0	476 524 384,0	415 883 648,0	361 734 432,0	**548 861 504,0**	**361 734 432,0**
W3	565 915 456,0	499 633 376,0	429 154 624,0	382 371 872,0	**565 915 456,0**	**382 371 872,0**
W4	600 737 216,0	549 728 192,0	460 752 864,0	419 316 448,0	**600 737 216,0**	**419 316 448,0**
W5	604 107 776,0	549 510 848,0	460 077 440,0	418 510 656,0	**604 107 776,0**	**418 510 656,0**

Table 25

Criterion 2 for probability = 0.95

NPV	S1	S2	S3	S4	MAX	MIN
W1	-2 345 538,3	457 942,1	1 515 949,5	3 478 451,0	**3 478 451,0**	**-2 345 538,3**
W2	16 524 271,0	14 949 031,0	13 699 345,0	11 910 183,0	**16 524 271,0**	**11 910 183,0**
W3	72 767 864,0	62 551 192,0	56 990 408,0	50 871 920,0	**72 767 864,0**	**50 871 920,0**
W4	58 890 912,0	54 390 064,0	44 201 056,0	42 151 648,0	**58 890 912,0**	**42 151 648,0**
W5	68 109 808,0	65 586 956,0	55 191 764,0	53 117 816,0	**68 109 808,0**	**53 117 816,0**

Table 26

Criterion 3 for probability = 0.90

ROE	S1	S2	S3	S4	MAX	MIN
W1	-0,14%	-3,52%	-4,75%	-9,57%	**-0,14%**	**-9,57%**
W2	84,07%	70,97%	55,46%	46,49%	**84,07%**	**46,49%**
W3	119,93%	102,14%	82,98%	70,11%	**119,93%**	**70,11%**
W4	129,90%	113,82%	91,14%	79,19%	**129,90%**	**79,19%**
W5	58,12%	53,30%	42,03%	37,34%	**58,12%**	**37,34%**

Table 27

Criterion 4 for probability = 0.95

MAX_DR	S1	S2	S3	S4	MAX	MIN
W1	28,08%	28,67%	28,77%	32,33%	**32,33%**	**28,08%**
W2	28,10%	29,91%	31,39%	31,89%	**31,89%**	**28,10%**
W3	33,87%	33,92%	35,57%	35,49%	**35,57%**	**33,87%**
W4	39,84%	39,99%	41,93%	42,02%	**42,02%**	**39,84%**
W5	26,88%	26,85%	28,31%	28,11%	**28,31%**	**26,85%**

Table 28

Criterion 5 for probability = 0.80

MIN IC	S1	S2	S3	S4	MAX	MIN
W1	0,15	0,15	0,17	-0,01	**0,2**	**0,0**
W2	0,41	0,38	0,30	0,28	**0,4**	**0,3**
W3	1,18	1,15	0,96	1,04	**1,2**	**1,0**
W4	0,46	0,58	0,54	0,53	**0,6**	**0,5**
W5	0,76	0,70	0,63	0,67	**0,8**	**0,6**

Based on the values presented in Tables 24-28, the first potency matrix P1 is generated and presented to DM.

Table 29

Potency matrix P^1

ITERATION 1	SALES	NPV	ROE	MAX_DR	MIN IC
Probability	**0,80**	**0,95**	**0,90**	**0,95**	**0,80**
IDEAL OPTIMISTIC	604 107 776,0	72 767 864,0	129,90%	26,85%	1,2
IDEAL PESSIMISTIC	419 316 448,0	53 117 816,0	79,19%	28,31%	1,0
CURRENT SOLUTION	305 389 920,0	-2 345 538,3	-9,57%	42,02%	0,0

While analyzing the values from the first potency matrix, we can say that choosing the best alternative in terms of the value of Criterion 1: SALES with the probability of 0.8, sales will be not lower than PLN 419m irrespective of the scenario which will develop. In the case of the most favourable scenario, there is an 80% chance that sales will not be lower than PLN 604m (if the most favourable solution is selected). Finally, choosing any decision alternative we know that, irrespective of the scenario which will develop, there is an 80% chance that sales will not be lower than PLN 305m.

DM uses the similar reasoning for each criterion (analyzed independently of the others).

Let us assume that after the analysis of the values in matrix P1, DM decided that further solutions should exclude the alternatives which gave less than a 95% chance that NPV was positive.

Fulfilling this condition (according to the procedure presented in Part 1 of this paper) means that further analysis does not include Alternative 1 and the next potency matrix P^2 is generated (Table 30).

Table 30

Potency matrix P^2

ITERATION 2	SALES	NPV	ROE	MAX_DR	MIN IC
Probability	**0,80**	**0,95**	**0,90**	**0,95**	**0,80**
IDEAL OPTIMISTIC	604 107 776,0	72 767 864,0	129,90%	26,85%	1,2
IDEAL PESSIMISTIC	419 316 448,0	53 117 816,0	79,19%	28,31%	1,0
CURRENT SOLUTION	361 734 432,0	11 910 183,0	37,34%	42,02%	0,3

When we compare the values from matrices P1 and P2 , we can see that the introduction of DM's condition has not led to the worsening of the ideal optimistic values or the ideal pessimistic values of the remaining criteria. Moreover, it has improved the current solutions for the remaining criteria. Let us assume then that DM accepts this solution.

Let us also assume that DM analyzed the values in potency matrix P2 and decided that the solution should yield a 95% chance that the maximum debt ratio was not higher than 35%.

After this condition is satisfied, Alternative 4 is deleted from the set of decision alternatives and potency matrix P3 is calculated.

Table 31

Potency matrix P^3

ITERATION 3	SALES	NPV	ROE	MAX_DR	MIN IC
Probability	**0,80**	**0,95**	**0,90**	**0,95**	**0,80**
IDEAL OPTIMISTIC	604 107 776,0	72 767 864,0	119,93%	26,85%	1,2
IDEAL PESSIMISTIC	418 510 656,0	53 117 816,0	70,11%	28,31%	1,0
CURRENT SOLUTION	361 734 432,0	11 910 183,0	37,34%	35,57%	0,3

DM compares the values from tables P2 and P3 and decides that the introduction of the last criterion has decreased the ideal optimistic value of the ROE index to 119.93%; he accepts this change. The ideal optimistic values of the remaining criteria have not fallen.

While analyzing the ideal pessimistic values, DM notices the decrease in the values of the criteria of Sales, ROE and MAX_DR, but the changes are still relatively insignificant. Let us assume that DM accepts them.

In the following two iterations DM wants to increase the expected value of ROE to 40% (with the probability of 0.90). As a result, we reject Alternative 5. Then, in the fifth iteration, DM chooses to reject these alternatives which do not guarantee 80% chance of at least 90% coverage of interest expense with operating income (MIN_IC>=0.9). We delete Alternative 2.

Table 32

Potency matrix P^4

ITERATION 4	SALES	NPV	ROE	MAX_DR	MIN IC
Probability	**0,80**	**0,95**	**0,90**	**0,95**	**0,80**
IDEAL OPTIMISTIC	565 915 456,0	72 767 864,0	119,93%	28,10%	1,2
IDEAL PESSIMISTIC	382 371 872,0	50 871 920,0	70,11%	31,89%	1,0
CURRENT SOLUTION	361 734 432,0	11 910 183,0	46,49%	35,57%	0,3

DM accepts the consequences of the requirements introduced. There is only Alternative 3 left in the set of decision alternatives and it is the indication of a final decision. Analyzing the values from matrix P^5 we can see that the selection of Alternative 3 gives an 80% chance of sales not lower than PLN 382m in the case of the unfavourable development of the environment and PLN 565m if the scenario is favourable.

Table 33

Potency matrix P^5

ITERATION 5	SALES	NPV	ROE	MAX_DR	MIN IC
Probability	**0,80**	**0,95**	**0,90**	**0,95**	**0,80**
IDEAL OPTIMISTIC	565 915 456,0	72 767 864,0	119,93%	33,87%	1,2
IDEAL PESSIMISTIC	382 371 872,0	50 871 920,0	70,11%	35,57%	1,0
CURRENT SOLUTION	382 371 872,0	50 871 920,0	70,11%	35,57%	1,0

This alternative also gives a chance to obtain NPV not lower than PLN 50m with probability of 0.95 in the case of unfavourable external conditions and as much as PLN 73m otherwise.

Irrespective of the external conditions, there is a 90% chance that ROE will not be lower than 70.11%, and in the most favourable situation it will not be less than 119%. Moreover, the values of the two other criteria are also satisfying for DM.

Finally, DM is presented the potency matrix which includes the expected values for this solution.

Table 34

Expected values for the solution

ITERATION 5	SALES	NPV	ROE	MAX_DR	MIN IC
IDEAL OPTIMISTIC	600 226 508,4	93 922 519,1	168,49%	31,76%	2,3
CURRENT SOLUTION	406 093 192,0	67 573 228,9	103,49%	33,45%	2,0

Let us assume that DM accepts the outcomes, so the decision aiding procedure stops. In the light of the analysis of the scenarios, the Monte Carlo simulation and DM's preferences, Alternative 3 should be suggested as the final solution.

Conclusion

The paper discusses the proposal of the multi-criteria decision aiding procedure under uncertainty and risk. The proposal uses the scenario method and the Monte Carlo simulation. The scenario-based method takes into account the influence of uncertainty factors. The risk factors which have an impact on the values of the evaluation criteria are described with probability distributions and the Monte Carlo simulation is used to generate the probability distributions for evaluation criteria.

The main component of the procedure proposed is the multi-criteria interactive decision-aiding method under risk and uncertainty. The method allows DM to aid the decision-making process while taking into consideration his preferences. It is notable that DM is not required to define his preferences prior to the decision aiding process (e.g. as criteria weights). DM is only asked to assess the proposals of the solutions developed in the process and indicate the directions for their improvement. This allows to take into account DM's preferences in terms of the relations between the criteria and his attitude to risk (when he defines the expected values in the subsequent iterations of the algorithm and the probability used to calculate the values in potency matrices).

The procedure proposed was implemented with the use of the MS Excel spreadsheet and the additional @Risk module for the Monte Carlo simulation. The numerical example illustrates the selection aiding process for an investment alternative. We consider five decision alternatives. Two uncertainty factors, each having two possible values, are taken into account. As a result, we need to analyse four scenarios of the environment development. Moreover, we consider seven risk factors.

We developed financial forecasts for each situation (the pair of the alternative and the scenario) and their models were recorded in the spreadsheet. Based on the spreadsheets, we conducted 20 simulations, 1,000 iterations each. As a result, we received 100 probability distributions for the evaluation criteria (20 situations x 5 criteria).

Based on the results of the previous stages of the procedure, we used the multi-criteria interactive method that we created to carry out the decision aiding process.

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