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Project Management for a Country with Multiple Objectives

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Abstract This paper proposes project management for a national economy in search for new projects, even with competition between projects. Traditional Cost-Benefit does not respond to this purpose. Indeed Cost-Benefit is only interested in one specific project and not in a competition between projects. In addition all goals (objectives) have to be translated into money terms, leading sometimes to immoral consequences. On the contrary Multi-Objective Optimization takes care of different objectives, whereas the objectives keep their own units. However different methods exist for the application of Multi-Objective Optimization. The author tested them after their robustness resulting in seven necessary conditions for acceptance. Nevertheless these seven conditions concern only Discrete Optimization and not Continuous Optimization or Interactive Multi-Objective Methods. MOORA (Multi-Objective Optimization by Ratio Analysis coupled with Reference Point Theory) and MULTIMOORA (MOORA plus the Full Multiplicative Form), assisted by Ameliorated Nominal Group and Delphi Techniques, satisfy the seven conditions, although in a theoretical way. A simulation exercise illustrates the use of these methods, ideals to be strived for as much as possible.

Keywords Project management, cost-benefit, multi-objective optimization, robustness, ameliorated nominal group and Delphi techniques, full multiplicative form, MOORA, MULTIMOORA
JEL classification C44, D81, E17, O22, P11

1. A move to project management

Project management assumes "that the project to be analysed will constitute a new economic activity . . . in practice, however, many projects will only modify an existing economic activity" (UN Industrial Development Organization 1978, p. 5). In addition different competing projects will be considered and a final choice will be made by Multiple Objective Optimization.

Project management is subject of an evolution concerning the objectives to strive after. If before the stress was put on market analysis, net present value, internal rate of return and other micro-economic targets, macro-economic objectives receive more and more attention such as employment, value added and the influence on the balance of payments. Attention for social well being goes even a step further with for instance environment and pollution. Employment is a human right, sometimes even written

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down in national constitutions, such as in the Belgian Constitution under article 23 (Belgian Senate 1994).

2. An example of project management

Cost-Benefit Analysis represents the traditional used method with the following disadvantages. In traditional cost-benefit analysis, only one single project is examined without looking after other projects or other alternative uses.

Cost Benefit Analysis takes a monetary unit as the common unit of measurement for benefits and costs. Indeed, even benefits are expressed in the chosen monetary unit, either in a direct or in an indirect way. In this way, cost-benefit presents a materialistic approach, whereby for instance unemployment and health care are degraded to monetary items, which is even immoral with a human life translated in the results of an insurance contract. Nevertheless cost-benefit is used in many transport models. People are more easily solution-minded than objective-oriented. Cost-Benefit analysis is a product of this way of thinking. Cost-Benefit studies will have fewer and fewer chances today than before.

Multi-Objective Optimization will take care of the disadvantages of Cost-Benefit.

(i) Let us take the example of the location of a seaport. All possible locations of seaports will be considered.

  - A first alternative consists of the installation as a riverside port, inland and on the river itself, capable of receiving huge ships. The possibility to bring the huge ships so far inland is an important advantage of this project, reflected in the willingness of the ship owners to pay high demurrage and local taxes for this solution. The Port of Antwerp, the second of Europe, is located 80km inland with partly open docks and partly locks. On the contrary, Rotterdam, the first port of Europe is located immediately near the sea and in open docks.[1]
  - A second alternative possesses the same advantages as the first belonging also to a riverside port but installed behind locks. This project also means fewer problems with low and high tide, but investments costs are higher given the necessity to foresee locks and docks.
  - A third alternative is located as a seaport immediately near the sea but behind locks, which means fewer tidal problems, but again with huge investment costs.
  - A fourth alternative consists of a terminal also immediately near the sea but in open docks i.e. without locks. This alternative means fast delivery of the goods but with a severe problem of salinity, caused by the open dock system at the seaside.

[1] In a country like Thailand an inland port is out of the question as the coastline is extremely large relative to the surface of the country. Actually new ports are constructed at the seaside.

- A fifth alternative would mean a container terminal on a dam or on an artificial island in sea with transshipping from huge to smaller ships and fast delivery of the goods. Investment costs however are extremely high translated into high depreciation costs for the dam or the island.

(ii) *Even broader, other investment opportunities in the country have also to be taken into consideration* (Adler 1967). It could be that the government instead of financing a new port for instance likes to spend money on the economy and the infrastructure of a less well being region.

(iii) *The objectives can keep their own units*. In order to define an objective better we have to focus on the notion of attribute. Keeney and Raiffa (1993, 32–38) present the example of the objective "reduce sulfur dioxide emissions" to be measured by the attribute "tons of sulfur dioxide emitted per year". An attribute should always be measurable. Simultaneously we aim to satisfy multiple objectives, whereas several alternative solutions or projects are possible, characterized by several attributes. An alternative should be quantitatively well defined. An attribute is a common characteristic of each alternative such as its economic, social, cultural or ecological significance, whereas an objective consists in the optimization (maximization or minimization) of an attribute. The term "criteria", in the meaning of desirable, is a bit weaker than objectives.

(iv) *Many separate objectives*. Economic welfare (Pigou 1920) comprises micro- and macroeconomics. Microeconomics would include attributes such as: yearly capacity to be reached, net present value (NPV), internal rate of return (IRR) and payback period. Macro-economics would include increase in Gross Domestic Product (GDP), surplus in the current account of the balance of payments, direct and indirect employment increase and ENPV. Indirect employment is measured by Input-Output techniques. ENPV means Economic Net Present Value, i.e. discounted revenues before national taxes, minus discounted investments, exclusive of subsidies. ENPV is different from GDP, but represents in macro-economics the counterpart of NPV, also with deduction of investments.

Sustainable development would include: no overproduction due to the capacity already installed, banning all kind of pollutants and ameliorating the quality of life.

Satisfaction of all stakeholders is still another series of objectives. Stakeholders mean everybody interested in a certain issue. Due to consumer sovereignty and the economic law of decreasing marginal utility, consumer surplus, level of salaries, leisure time and again employment at the local and national level have to be taken into consideration. In addition, conflicts may arise between local and national authorities. Conflicts between all these points of view have to be avoided.

Some attributes like NPV, ENPV, GDP, balance of payments surplus and consumer surplus are expressed in money terms, like dollars or Euros. However, a Euro in consumer surplus cannot be compensated for instance with a GDP-Euro.

In addition, IRR is expressed in a percentage, the payback period in months or years, employment in number of persons per year, transport, for instance, in TEU, etc. Consequently, a serious problem of normalization is present.

Normalization means reduction to a normal or standard state. However, the term got many interpretations but the stress is mainly put on the unification of diverting systems of measurement. As decision making is interested in measurement, normalization in technology is a main starting point, whereas scales of measurement and measurement of quality may be troublesome (for more on normalization, see Brauers 2007).

3. The seven conditions of robustness in multi-objective methods

For the researcher in multi-objective decision support systems the choice between many methods is not very easy. Indeed numerous theories were developed since the forerunners: Condorcet (the Condorcet Paradox, against binary comparisons, 1785, LVIII), Gossen (law of decreasing marginal utility, 1853), Minkowski (Reference Point, 1896, 1911) and Pareto (Pareto Optimum and Indifference Curves analysis 1906, 1927) and pioneers like Kendall (ordinal scales, since 1948), Roy et al. (ELECTRE, since 1966), Miller and Starr (multiplicative form for multiple objectives, 1969), Hwang and Yoon (TOPSIS, 1981) and Saaty (AHP, since 1988).

We intend to assist the researcher with some guidelines for an effective choice. In order to distinguish the different multi-objective methods from each other we use the qualitative definition of robustness: the most robust one, as robust as, ..., simple robust, less robust than etc. with the meaning found in Webster's new Universal Unabridged Dictionary for robust: strong; stronger, strongest.[2]

The most robust multi-objective method has to satisfy the following conditions.

(i) The method of multiple objectives in which all stakeholders are involved is more robust than this one with only one decision maker or different decision makers defending their own limited number of objectives. All stakeholders mean everybody interested in a certain issue (Brauers 2007, 454–455).

The method of multiple objectives in which all stakeholders are involved, namely also the consumers, has to take into consideration consumer sovereignty too. The method considering consumer sovereignty is more robust than this one which does not respect consumer sovereignty. Community indifference loci measure consumer sovereignty. Solutions with multiple objectives have to deliver points inside the convex zone of the highest possible community indifference locus (these solutions are defined in Brauers 2008b, 98–103).

No *Interactive Methods* are examined in which the researcher acts in dialogue with the decision maker and eventually changes his first point of view (the Dialogue Stage after the Calculation Stage). This way of acting is not possible with stakeholders. The stakeholders show a consensus on: the method, the objectives,

[2] For further information on Robustness and Multiple Objectives, see Brauers and Zavadskas (2010b).

the importance of the objectives and the alternatives. If afterwards a stakeholder will contest the outcome the whole exercise has to be repeated again. If there is nevertheless a final decision maker which opposes his own stakeholder group then in the case of failure the responsibility will fall entirely on him.

(ii) The method of multiple objectives in which all non-correlated objectives are examined is *more robust than* this one considering only a limited number of objectives (Brauers, Ginevičious 2009, 125–126).

The objectives have to be non-correlated, or their correlation can not be quantified or it is assumed that correlation is absent. Correlation is rather studied in econometric models, either in their autoregressive, reduced or structural form (for more details, see Brauers 2004, 17–18).

(iii) The method of multiple objectives in which all interrelations between objectives and alternatives are taken into consideration at the same time is *more robust than* this one with interrelations only examined two by two (for the proof of this statement, see Brauers 2004, 118-122).

(iv) The method of multiple objectives which is non-subjective is *more robust than* this one which uses subjective estimations for the choice and importance of the objectives and for normalization.

1. *For the choice of the objectives and the alternatives*. A complete set of representative and robust objectives is found after Ameliorated Nominal Group Technique Sessions with all the stakeholders concerned or with their representatives (see Appendix A).

   Subjectivity can still be present in the choice of the objectives and of the alternatives. Political dominance can lead to this choice, either from above in centralization or federalism or from bottom up after the substitution principle or by confederation. In absence of any form of dominance convergence of ideas could lead to non-subjectivity. However, what is meant by non-subjectivity? In physical sciences, a natural law dictates non-subjectivity without deviations. In human sciences, for instance in economics, an economic law will state the attitude of men in general but with exceptional individual deviations. Outside these human laws in the human sciences unanimity or at least a certain form of convergence in opinion between all stakeholders concerned will lead to non-subjectivity. This convergence of opinion, concerning the choice of the objectives, has to be brought not by face to face methods but rather by methods such as the Ameliorated Nominal Group Technique (see Appendix A). Convergence on the importance of the objectives is supported by the Delphi Method (therefore see Appendix B).

   Alternatives have to be well defined too. If alternatives concern projects the whole theory on project analysis enters into the picture.

We only consider *Discrete Optimization* and not continuous one. In Continuous Optimization the solution (alternative) originates from the approach itself.[3] For instance linear programming could be used for Continuous Optimization (for an example, see Brauers 2004, 115–117).

2. *For normalization.*The method of multiple objectives which does not need external normalization is more robust than this one which needs a subjective external normalization (Brauers, 2007). Accordingly, the method of multiple objectives which uses non-subjective dimensionless measures without normalization is more robust than this one which uses for normalization subjective weights (weights were already introduced by Churchman et al. in 1954 and 1957) or subjective non-additive scores like in the traditional reference point theory (Brauers, 2004, 158-159).

   The Additive Weighting Procedure (MacCrimmon 1968, 29–33, which was called SAW, Simple Additive Weighting Method by Hwang and Yoon 1981, p. 99) starts from the following formula:

$$\max U_j = w_1 x_{1j} + w_2 x_{2j} + \ldots + w_i x_{ij} + \ldots + w_n x_{nj}, \tag{1}$$

   where U_j is overall utility of alternative j with $j = 1, 2, \ldots, m$, m number of alternatives. Weight of attribute i, w_i, indicates as well as normalization as the level of importance of an objective, $\sum_{i=1}^{i=n} w_i = 1$, $i = 1, 2, \ldots, n$, x_{ij} is response of alternative j on attribute i.

   Reference Point Theory is non linear, whereas non-additive scores replace the weights. The non-additive scores take care of normalization.

3. *For giving importance to an objective.* With weights and scores importance of objectives is mixed with normalization. Indeed weights and scores are mixtures of normalization of different units and of importance coefficients. On the contrary Delphi can determine the importance of objectives separately from normalization. In addition, as all stakeholders concerned are involved, the Delphi method is non-subjective (see Appendix B).

(v) The method of multiple objectives based on cardinal numbers is more robust than this one based on ordinal numbers: "an ordinal number is one that indicates order or position in a series, like first, second, etc." (Kendall and Gibbons 1990, p. 1). Robustness of cardinal numbers is based first on the saying of Arrow (1974, p. 256): "Obviously, a cardinal utility implies an ordinal preference but not vice versa" and second on the fact that the four essential operations of arithmetic: adding, subtracting, multiplication and division are only reserved for cardinal numbers (see also Brauers et al. 2009, 137–138).

(vi) The method of multiple objectives which uses the last recent available data as a base is more robust than this one based on earlier data (Brauers et al. 2009, p. 133).

[3] Hwang and Masud (1979, 6–7) call Continuous Optimization rather Multiple Objective Decision Making (MODM) as associated with Design Problems in contrast to MADM (Multiple Attribute Decision Making) being involved with Selection Problems.

(vii) Once the previous six conditions fulfilled the use of two different methods of multi-objective optimization is more robust than the use of a single method; the use of three methods is more robust than the use of two, etc.

Consequently we have to find a method which satisfies all conditions, inclusive the seventh condition. This is the case with MOORA (Multi-Objective Optimization by Ratio Analysis) composed of two methods and eventually assisted with the Ameliorated Nominal Group Technique and with Delphi. Up till now no other theory is known including three or more methods.

4. Multi-Objective Optimization by Ratio Analysis (MOORA)[4]

4.1 The two parts of MOORA

The method starts with a matrix of responses of different alternatives on different objectives:

$$\mathbf{x_{ij}},$$

with x_{ij} as the response of alternative j on objective i, $i = 1,2,\ldots,n$ as the objectives and $j = 1,2,\ldots,m$ as the alternatives. MOORA goes for a ratio system in which each response of an alternative on an objective is compared to a denominator, which is representative for all alternatives concerning that objective. For this denominator the square root of the sum of squares of each alternative per objective is chosen:[5]

$$x_{ij}^* = \frac{x_{ij}}{\sqrt{\sum_{j=1}^m x_{ij}^2}} \tag{2}$$

with x_{ij}^* a dimensionless number representing the normalized response of alternative j on objective i. These dimensionless responses of the alternatives on the objectives belong to the interval $[0,1]$.

Dimensionless Numbers, having no specific unit of measurement, are obtained for instance by deduction, multiplication or division. The normalized responses of the alternatives on the objectives belong to the interval $[0,1]$. However, sometimes the interval could be $[-1,1]$. Indeed, for instance in the case of productivity growth some sectors, regions or countries may show a decrease instead of an increase in productivity i.e. a negative dimensionless number.[6]

[4] Brauers and Zavadskas launched MOORA in 2006

[5] Brauers and Zavadskas (2006, 451–457) prove that the most robust choice for this denominator is the square root of the sum of squares of each alternative per objective.

[6] Instead of a normal increase in productivity growth a decrease remains possible. At that moment the interval becomes $[-1,1]$. Take the example of productivity, which has to increase. Consequently, we look after a maximization of productivity e.g. in European and American countries. What if the opposite does occur? For instance, take the change from USSR to Russia. Contrary to the other European countries productivity decreased. It means that in formula (4) the numerator for Russia would have been negative with the whole ratio becoming negative. Consequently, the interval becomes: $[-1,1]$ instead of $[0,1]$.

For optimization these responses are added in case of maximization and subtracted in case of minimization:

$$y_j^* = \sum_{i=1}^{i=g} x_{ij}^* - \sum_{i=g+1}^{i=n} x_{ij}^* \tag{3}$$

with $i = 1, 2, \ldots, g$ as the objectives to be maximized, $i = g+1, g+2, \ldots, n$ as the objectives to be minimized, y_j^* is the normalized assessment of alternative j with respect to all objectives. An ordinal ranking of the y_j shows the final preference.

For the second part of MOORA the Reference Point Theory is chosen. In reference point theory non-additive scores take care of normalization:

$$\mathbf{x_j} = (s_1 x_{1j}, s_2 x_{2j}, \ldots, s_i x_{ij}, \ldots, s_n x_{nj}) \tag{4}$$

with s_i as the score of objective i, $i = 1, 2, \ldots, n$ and x_j as the row vector of utility for alternative j, $j = 1, 2, \ldots, m$. In this way reference point theory obtains the following normalized matrix:

$$(\mathbf{x_{ij}^*}), \tag{5}$$

where $x_{ij}^* = s_i x_{ij}$. A reference point has still to be chosen: $\{r_1, r_2, \ldots, r_i, \ldots, r_n\}$ with n objectives. This reference point vector may have different values:

(i) The *Maximal Objective Reference Vector* approach is called realistic and non-subjective as the co-ordinates, which are selected for the reference point (r_i), are realized in one of the candidate alternatives. In the example A (10;100), B (100;20) and C (50;50) the maximal objective reference point r_m results in: (100;100). The maximal objective vector is self-evident, if the alternatives are well defined, as for projects in project analysis and project planning.

(ii) The co-ordinates q_i of an *Aspiration Objective Reference Point*, are formed as follows: $q_i \leq r_i$ with $i = 1, 2, \ldots, n$, n the number of objectives, $(r_i - q_i)$ being a subjective element.

The aspiration objective reference point moderates its aspirations by choosing smaller coordinates than with the maximal objective reference point, namely q_i. Indeed though subjective, stakeholders may be more moderate in their expectations.

(iii) The *Utopian Objective Reference Vector*, contrary to the Aspiration Objective one, gives higher values to the co-ordinates of the reference point: $r_i^* = r_i + \varepsilon_i$. The higher values, though becoming subjective, are understandable for instance for Performance Management, such as for student evaluation and for any performance in the private and the public sector.

Otherwise, being non-subjective, the *Maximal Objective Reference Point* is preferred. However the problem remains that the choice of the scores remain subjective, which is not the case if the dimensionless numbers x_{ij}^* of formula (2) are taken as scores with consequently an increase in robustness.

The problem of the definition of the distances between the coordinates of the reference point and of the alternatives remains.

The *Minkowski Metric* brings the most general synthesis for measuring the distances between the coordinates of the alternatives and the reference point coordinates (Minkowski 1896, 1911):

$$\min M_j = \left\{ \sum_{i=1}^{i=n} (r_i - x_{ij}^*)^\alpha \right\}^{1/\alpha}, \tag{6}$$

where M_j is Minkowski metric for alternative j, r_i is the i^{th} co-ordinate of the reference point. From the Minkowski formula, the different forms of Reference Point Theory are deduced. The metric shows these forms depending on the values given to α.

With the *rectangular distance metric* $\alpha = 1$, the results are very unsatisfactory. Assume a reference point (100;100), then the points (100;0), (0;100), (50;50), (60;40), (40;60), (30;70), and (70;30) all show the same rectangular distance and they all belong to the same line: $x + y = 100$. Ipso facto, a midway solution like (50;50) takes the same ranking as the extreme positions (100;0) and (0;100). In addition, the points: (30;30), (20;40), (40;20), (50;10), (25;35), (0;60) and (60;0), all belonging to the line: $x + y = 60$, show the same rectangular distance to a reference point (50;40). Even worse, theoretically for each line an infinite number of points will result in the same ranking, meaning a weak robustness.

With $\alpha = 2$, radii of concentric circles, with the reference point as central point, will represent the *Euclidean Distance Metric*. Applying the Euclidean distance metric for the first example, which is given above, the outcome is very unusual. The midway solution (50;50) is ranked first with symmetry in ranking for the extreme positions: (100;0) and (0;100); the same for (60;40) and (40;60), for (30;70) and (70;30) etc. meaning a weak robustness (a problem arises for TOPSIS as TOPSIS is based on Euclidean distances, Hwang and Yoon 1981, 128–134).

Radii of concentric spheres represent the Euclidean Distance Metric characterized by three attributes, with the reference point for center. For more than three attributes the corresponding manifolds are geometrically not possible to demonstrate. It is also not clear if many solutions do or do not try to fight for optimality.

With $\alpha = 3$, negative results are possible if some co-ordinates of the alternatives exceed the corresponding co-ordinate of the reference point. Again, it is also not clear if many solutions do or do not try to fight for optimality in the case of $\alpha > 3$, with exception of $\alpha \to \infty$. Indeed, in this special case of the Minkowski Metric only one distance per point is kept in the running, an increase in robustness. The Minkowski Metric becomes the Tchebycheff *Min-Max Metric* (Karlin and Studden 1966, p. 280). If the following matrix is given:

$$(\mathbf{r_i} - \mathbf{x_{ij}^*}), \tag{7}$$

then this matrix is subject to the Min-Max Metric of Tchebycheff:

$$\min_j \max_i |r_i - x_{ij}^*|, \tag{8}$$

where $|r_i - x_{ij}^*|$ means the absolute value if x_{ij}^* is larger than r_i for instance by minimization.

This reference point theory starts from the already normalized ratios as defined in the MOORA method, namely formula (2).

4.2 The importance given to an objective by the attribution method in MOORA

It may look that one objective cannot be much more important than another one as all their ratios are smaller than one (see eq. 2). Nevertheless it may turn out to be necessary to stress that some objectives are more important than others. In order to give more importance to an objective its ratios could be multiplied with a *Significance Coefficient*.

The *Attribution of Sub-Objectives* represents another solution. Take the example of the purchase of fighter planes (Brauers 2002). For economics the objectives, concerning the fighter planes, are threefold: price, employment and balance of payments, but there is also military effectiveness. In order to give more importance to military defense, effectiveness is broken down in, for instance, the maximum speed, the power of the engines and the maximum range of the plane. Anyway, the Attribution Method is more refined than that a coefficient method could be as the attribution method succeeds in characterizing an objective better. For instance for employment the coefficient method is changed into two numbers characterizing the direct and the indirect side of employment separately. Anyway either the method with Significance Coefficients or the method with the Attribution of Sub-Objectives has to be based on a Delphi exercise with all stakeholders or their representatives (for Delphi see Appendix B).

5. MULTIMOORA

MULTIMOORA[7] is composed of MOORA and of the Full Multiplicative Form of Multiple Objectives and in this way as up till now no other approach is known satisfying the precious six conditions of robustness and including three or more methods.[8] MULTIMOORA becomes the most robust system of multiple objectives optimization under condition of support from the Ameliorated Nominal Group Technique and from Delphi.

5.1 The Full Multiplicative Form of Multiple Objectives

Besides additive utilities, a utility function may also include a multiplication of the attributes. The two dimensional $u(y,z)$ can then be expressed as a multi-linear utility function (Keeney and Raiffa 1993, p. 234):

$$u(y,z) = k_y u_y(y) + k_z u_z(z) + k_{yz} u_y(y) u_z(z) \tag{9}$$

The danger exists that the multiplicative part becomes explosive. The multiplicative part of the equation would then dominate the additive part and finally would bias the

[7] Brauers and Zavadskas launched MULTIMOORA in 2010 (Brauers and Zavadskas 2010a).

[8] MOORA (Multi-Objective Optimization by Ratio Analysis) was explained in Section 4 above.

results. It could happen if the factors are larger than 1, unless the weights for the multiplicative part are extremely low.

Considering these and the previous shortcomings, preference will be given to a method that is nonlinear, non-additive, does not use weights and does not require normalization. Will a Full-Multiplicative Form respond to all these conditions? Econometrics is familiar with the multiplicative models like in production functions (e.g. Cobb-Douglas and Input-Output formulas) and demand functions (Teekens and Koerts 1972), but the multiplicative form for multi-objectives was introduced by Miller and Starr (1969, 237–239).

The following n-power form for multi-objectives is called from now on a full-multiplicative form in order to distinguish it from the mixed forms:

$$U_j = \prod_{i=1}^{n} x_{ij}, \tag{10}$$

where U_j is overall utility of alternative j. The overall utilities (U_j), obtained by multiplication of different units of measurement, become dimensionless.

Stressing the importance of an objective can be done by adding an α-term or by allocating an exponent (a Significance Coefficient) on condition that this is done with unanimity or at least with a strong convergence in opinion of all the stakeholders concerned. Therefore, a Delphi exercise may help (see Appendix B).

How is it possible to combine a minimization problem with the maximization of the other objectives? Therefore, the objectives to be minimized are denominators in the formula:

$$U'_j = \frac{A_j}{B_j} \tag{11}$$

with $A_j = \prod_{g=1}^{i} x_{gi}$, i is the number of objectives to be maximized, and $B_j = \prod_{k=i+1}^{n} x_{kj}$, $n-i$ is the number of objectives to be minimized, U'_j is the utility of alternative j with objectives to be maximized and objectives to be minimized.

If $x_{ij} = 0$ it means that an objective is not present in an alternative. A foregoing filtering stage can prescribe that an alternative with a missing objective to be an optimum is withdrawn from the beginning. Otherwise exceptionally the nonsense situation of a zero factor in multiplication is corrected by giving to the missing objective an extremely low symbolic value.

As no complete data are available for an economy with strong market aspects and satisfying all robust conditions we will limit us to a simulation exercise. Contrary to a lot of other definitions, simulation is defined here in a rather broad sense. Gordon et al. (1970) give the most complete description of simulation as mechanical, metaphorical, game or mathematical analogs. They conclude: “are used where experimentation with an actual system is too costly, is morally impossible, or involves the study of problems which are so complex that analytical solution appears impractical.” (Gordon et al. 1970, p. 241)

6. A simulation exercise for Project Management in a country with controlled market economy

6.1 Limitations for simulation with respect to robustness

Not respected:

Condition 1: the stakeholders interested in the issue are not consulted.

Condition 2: all objectives are perhaps not present.

Condition 4: non-subjectivity in the choice of the objectives and their importance is not guaranteed.

Condition 6: the use of recent data is not relevant.

Respected:

Condition 3: all interrelations between objectives and alternatives are taken into consideration at the same time.

Condition 4: does not need external normalization.

Condition 5: is based on cardinal numbers.

Condition 7: once the previous conditions 3, 4 (partly), 5 and 7 are fulfilled the use of two different methods of multi-objective optimization is more robust than the use of a single method; the use of three methods is more robust than the use of two. MULTIMOORA is in that case.

6.2 In the simulation the following objectives are foreseen

(i) Maximization of Net Present Value (NPV) expressed in money terms (m. $): Net Present Value = discounted Revenues exclusive local and direct and indirect government taxes, inclusive rent on industrial land and depreciation, but minus investments;

(ii) maximization of the Internal Rate of Return (IRR) expressed as a % interest rate, considering NPV equal to zero at the end of the project period;

(iii) minimization of the payback period of NPV, expressed in years and months;

(iv) maximization of government income: local and direct and indirect government taxes in $10,000;

(v) maximizing direct and indirect local and national employment; indirect employment found by local and national input-output tables in person-years;

(vi) maximizing the increase in Gross Domestic Product (GDP) in m. $;

(vii) minimization of the risk on (v) and (vi) in %;

(viii) maximization of net increase per $100,000 in the balance of Payments;

(ix) maximization of hard currency to be provided by foreign sources for investment, expressed in money terms (m. $).

Appendix C gives the detailed tables for MOORA and the Multiplicative Form. Neither project A, B or C is dominating, which means that a ranking has to bring the solution. Project A is the best for 4 objectives, project C also for 4 objectives and project B shows mostly in between solution. Table 1 gives the reaction of the projects on the objectives after the MULTIMOORA approach.

Table 1. The reaction of the projects on the objectives after the MULTIMOORA approach

Projects	MOORA Ratio System	MOORA Reference point	Multiplicative form	MULTIMOORA
A	1	2	1	1
B	2	1	2	2
C	3	3	3	3

MULTIMOORA is in fact the summary of three distinct approaches. Consequently only MULTIMOORA has to be considered with as result:

$$A\ \mathbf{P}\ B\ \mathbf{P}\ C \quad (\mathbf{P}\text{ preferred})$$

There is a small deviation in the reference point part of MOORA but one may conclude for MULTIMOORA that project A with its larger GDP and income for government is preferred above B, an in between solution. Project C comes in the last position in spite of its very favorable employment total.

7. Conclusion

For a researcher in multi-objective decision support systems the choice between the many methods for multi-objective optimization is not very easy. We intended to assist the researcher with some guidelines for an effective choice. In order to distinguish the different multi-objective methods from each other we use a qualitative definition of robustness comparable to: strong; stronger, strongest.

The most robust multi-objective method has to satisfy the following conditions.

(i) The method of multiple objectives in which all stakeholders are involved is more robust than this one with only one decision maker or different decision makers defending their own limited number of objectives. All stakeholders mean everybody interested in a certain issue. Consequently, the method of multiple objectives has to take into consideration consumer sovereignty too.

(ii) The method of multiple objectives in which all non-correlated objectives are considered is more robust than this one considering only a limited number of objectives.

(iii) The method of multiple objectives in which all interrelations between objectives and alternatives are taken into consideration at the same time is more robust than this one with interrelations only examined two by two.

(iv) The method of multiple objectives which is non-subjective is more robust than this one which uses subjective estimations for the choice and importance of the objectives and for normalization.

- *For the choice of the objectives*. A complete set of representative and robust objectives is found after Ameliorated Nominal Group Technique Sessions with all the stakeholders concerned or with their representatives.
- *For normalization*. The method of multiple objectives which does not need external normalization is more robust than this one which needs a subjective external normalization. Consequently, the method of multiple objectives which uses non-subjective dimensionless measures without normalization is more robust than this one which uses subjective weights or subjective non-additive scores like in the traditional reference point theory.
- *For giving importance to an objective*. With weights and scores importance of objectives is mixed with normalization. On the contrary Delphi can determine the importance of objectives separately from normalization.

(v) The method of multiple objectives based on cardinal numbers is more robust than this one based on ordinal numbers.

(vi) The method of multiple objectives which uses the last recent available data as a base is more robust than this one based on earlier data.

(vii) Once the previous six conditions fulfilled the use of two different methods of multi-objective optimization is more robust than the use of a single method; the use of three methods is more robust than the use of two, etc.

Multi-Objective Optimization by Ratio Analysis (MOORA), composed of two methods: ratio analysis and reference point theory starting from the previous found ratios, responds to the seven conditions. If MOORA is joined with the Full Multiplicative Form for Multiple Objectives a total of three methods is formed under the name of MULTIMOORA. In addition if MULTIMOORA is joined with the Ameliorated Nominal Group Technique and with Delphi the most robust approach exists for multi-objective optimization up to now.

It has to be accentuated that satisfying the seven conditions signifies a theoretical goal to be reached as much as possible. Paraphrasing Steuer we can say that we are in a situation trying to optimize each objective to "the greatest extent possible."[9] A

[9] "Since multiple objective problems rarely have points that simultaneously maximize all of the objectives, we are typically in a situation of trying to maximize each objective to the greatest extent possible." (Steuer, 1989, p. 138)

simulation exercise illustrates the use of these methods, ideals to be strived for as much as possible.

If the simulation exercise for a country with controlled market economy in search for new projects has no practical consequences, in any case it provides a learning experience with MULTIMOORA in its triple composition.

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Appendix A: Assistance by the Ameliorated Nominal Group Technique

The Nominal Group Technique, which is explained here, was ameliorated by Brauers (1987, 2004, 44–64) but the Nominal Group Technique was first elaborated by Van de Ven and Delbecq (1971).

A1. The Original Nominal Group Technique

The nominal group technique consists of a sequence of steps, each of which has been designed to achieve a specific purpose.

(i) The steering group or the panel leader carefully phrases as a question the problem to be researched. Much of the success of the technique hinges around a well-phrased question. Otherwise the exercise can easily yield a collection of truisms and obvious statements. A successful question is quite specific and refers to real problems. The question has to have a singular meaning and a quantitative form as much as possible.

(ii) The steering group or the panel leader explains the technique to the audience. This group of participants is asked to generate and write down ideas about the problem under examination. These ideas too have to have a singular meaning and a quantitative form as much as possible. Participants do not discuss their ideas with each other at this stage. This stage lasts between five and twenty minutes.

(iii) Each person in round-robin fashion produces one idea from his own list and eventually gives further details. Other rounds are organized until all ideas are recorded.

(iv) The steering group or the panel leader will discuss with the participants the overlapping of the ideas and the final wording of the ideas.

(v) The nominal voting consists of the selection of priorities, rating by each participant separately, while the outcome is the totality of the individual votes. A usual procedure consists of the choice by each participant of the n best ideas from his point of view, with the best idea receiving n points and the lowest idea the lowest point. All the points of the group are added up. A ranking is the democratic result for the whole group.

The Original Nominal Group Technique can be characterized as weak robust as the participants expressed too much their personal feeling. Amelioration was proposed for that reason.

A2. The Ameliorated Nominal Group Technique

As there was too much wishful thinking even between experts better results were obtained if the group was also questioned about the probability of occurrence of the event. In this way the experts became more critical even about their own ideas. The probability of the group is found as the median of the individual probabilities.

Finally, the group rating (R) is multiplied with the group probability (P) in order to obtain the effectiveness rate of the event (E):

$$E = R \times P$$

Once again, the effectiveness rates of the group are ordered by ranking. One may conclude that the Ameliorated Nominal Group Technique is more robust than the Original Nominal Group Technique. In our research it is clear that the Ameliorated Nominal Group Technique concerns the search for a complete set of representative and robust objectives and sub-objectives.

Appendix B: The assistance by the Delphi Technique

The Delphi method is a method for obtaining and processing judgmental data. It consists of a sequenced program of interrogation (in session or by mail) interspersed with feedback of persons interested in the issue, while everything is conducted through a steering group. We advocate the most this method as it also takes care of: quantitative treatment; expert knowledge; anonymity; convergence.

Dalkey and Helmer (1963) used Delphi in its present form for the first time around 1953. The essential features of Delphi are:

(i) A group of especially knowledgeable individuals;

(ii) inputs with a singular meaning and quantitative as much as possible;

(iii) the opinions about the inputs are evaluated with statistical indexes;

(iv) feedback of the statistical indexes with request for re-estimation, also after consideration of reasons for extreme positions;

(v) the sources of each input are treated anonymously;

(vi) two developments: meeting and questionnaires. The organization of a meeting produces quicker results. However, the meeting has to be organized in such a way that communication between the panel members is impossible. Therefore, a central computer with desk terminals, television screen and computer controlled feedback is advisable.

As an example of Delphi a music competition ended with 12 finalists (Brauers, 2008a). Beside the personal preferences of the jury members, different music schools or tendencies exist. Total points and the medians were the same for the first four candidates but for the 5th and the 6th ranks, the laureates were reversed. However, the large diversion between the first and the third quartiles illustrated a possible frustration between the jury members for the laureates ranking 5 and 6 and the other finalists ranking 7, 8, 9, 10, 11 and 12. At that moment Delphi interferes. The voting is repeated several times. In the beginning skewness is still too large but then a new round may help. Delphi experiences a better convergence in opinion as the medians and quartiles approach more and more to one another in different rounds until convergence as much as possible is reached and automatically robustness is increased. At that moment, the ranking of the finalists in the positions 5 till 12 may be entirely reversed, but the members of the jury, like the public and the press, will be more satisfied.

In a project of multiple objectives optimization the stakeholders or their representatives are asked to give for instance a single, double or triple importance to an objective.

Appendix C

C1. Simulation of Project Planning by MOORA

Table C1. Simulation for the Ratio System and for Reference Point of MOORA

	NPV max	IRR max	Payback min	Gov. income max	Employment max	GDP max	Risk min	Bal. of paym. max	Investment max		
Matrix of responses of alternatives on objectives: (x_{ij})											
A	1	14	9	200	600	20	20	3.5	2.5		
B	1.6	16	7	150	800	13.5	25	4	1.5		
C	2	17	5	80	1,200	10	30	3.8	1.25		
Sum of squares and their square roots											
A	1	196	81	40,000	360,000	400	400	12.25	6.25		
B	2.56	256	49	22,500	640,000	182.25	625	16	2.25		
C	4	289	25	6,400	1,440,000	100	900	14.44	1.5625		
Σ	8	741	155	68,900	2,440,000	682	1925	43	10		
root	2.74955	27.221	12.45	262.488	1562.05	26.12	43.875	6.53376	3.17214		
Objectives divided by their square roots and MOORA										sum	rank
A	0.3637	0.5143	0.7229	0.76194	0.384	0.766	0.4558	0.536	0.788	2.9348	1
B	0.58191	0.5878	0.5623	0.57145	0.51215	0.5168	0.5698	0.61221	0.47287	2.723	2
C	0.72739	0.6245	0.4016	0.30478	0.76822	0.3828	0.6838	0.5816	0.39406	2.698	3
Reference Point Theory with Ratios: co-ordinates of the reference point equal to the maximal objective values											
r_i	0.72739	0.6245	0.4016	0.76194	0.76822	0.766	0.4558	0.61221	0.78811		
Reference Point Theory: deviations from the reference point										max	min
A	0.364	0.1102	0.3213	0	0.38411	0	0	0.0765	0	0.38411	2
B	0.14548	0.0367	0.1606	0.19049	0.25607	0.2489	0.114	0	0.3152	0.31524	1
C	0	0	0	0.45716	0	0.3828	0.2279	0.0306	0.3941	0.45716	3

Note: NPV, IRR and GDP denote net present value, internal rate of return and gross domestic product, respectively.

C2. Simulation of project planning by the Full Multiplicative Form

Table C2. The Full Multiplicative Form

	1	2	3	4	5	6	7	8	9
Projects	NPV max	IRR max	3 = 1 × 2	Payback min	5 = 3 : 4	Gov. income max	7 = 5×6	Employment max	9 = 7 × 8
A	1	14	14	9	1.5555556	200	311.11111	600	186666.67
B	1.6	16	25.6	7	3.6571429	150	548.57143	800	438857.14
C	2	17	34	5	6.8	80	544	1200	652800
	10	11	12	13	14	15	16	17	18
Projects	GDP max	11 = 9 × 10	Risk min	13 = 11:12	Bal. of paym. max	15 = 13×14	Investment max	17 = 15×16	Result
A	20	3733333.3	20	186666.67	3.5	653333.33	2.50	1633333	1
B	13.5	5924571.4	25	236982.86	4.0	947931.43	1.50	1421897	2
C	10	6528000.0	30	217600.00	3.8	826880.00	1.25	1033600	3

Note: NPV, IRR and GDP denote net present value, internal rate of return and gross domestic product, respectively.