A SAMPLE GLOSSARY OF SYSTEMS ANALYSIS

(Prepared for the Preliminary Version of the
Handbook of Applied Systems Analysis)

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April 1978 WP-78-12

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INTRODUCTION

> Glossary: A partial dictionary that gives, for a collection of terms, brief and inaccurate explanations.
>
> \- R.D. Specht

> Every short statement...is misleading (with the possible exception of my present one).
>
> \- Alfred Marshall

Every activity -- and systems analysis is no exception -- tends to develop its own vocabulary. Indeed, systems analysis, because of its interdisciplinary nature, has been more prone than most not only to invent new words for new concepts but also -- and more often -- to borrow established terms from the disciplines it employs and to change their meaning, sometimes slightly, sometimes grossly, sometimes inconsistently. The result of this can be confusion, misunderstanding, and failure of communication.

This glossary is an attempt at resolving part of the ambiguity. Sometimes, the best that can be hoped is that the reader will be warned of a pitfall, for we cannot hope to fill them all in, or even to identify them all. For example, when a word in common use in systems analysis has three different meanings, whose differences are often not to be determined by context, there is little we can do beyond noting this unfortunate practice. Clearly, we are in no position to dictate "proper" usage to the disparate community of systems analysts. On the other hand, we have made judgments about the wise use of terminology -- stressing some meanings and ignoring others. We hope that the result will be of use not only to the reader who is not well versed in the literature of systems analysis but also to all members of the systems analysis community.

The glossary, as it stands now, is tentative. It has been prepared for the preliminary version of the *Handbook of Applied Systems Analysis*, and the terms included are those used in the *Handbook*. We invite criticism and suggestions from our readers: What terms should be added or deleted? What definitions are incorrect or incomplete? Does the glossary "work" as intended?

The glossary, besides being part of the _Handbook_, is also the beginning of a major task: the compilation of a multilingual glossary of terms of systems analysis. We would therefore appreciate it if comments and proposed additions were divided into two parts: one with respect to the _Handbook_ glossary, and the second with respect to the projected multilingual glossary.

The Way It Works

The structure of the glossary is designed to highlight interrelations among concepts -- among the terms we sought to explain. The present sample consists of some 50 articles arranged in alphabetical order; approximately 170 terms are defined. A defined term is an "entry." Entries are marked by underscoring and double brackets [[________]] and may head an article or occur within an article. Each term has only one entry, which may be located by referring to the index. If a term is simply underscored within an article, it is a cross reference, i.e., it is defined as an entry somewhere else in the glossary, and the index should be referred to. The final version of the index will use page numbers to indicate the location of entries and in addition will register all occurrences of a term (cross references as well as entries). A rough version of this expanded index is appended, as is a Russian-English index to the glossary's entries.

The glossary and its index were prepared by means of the ED and NROFF text processing programs on IIASA's UNIX Operating System. This accounts for some anomalies of punctuation and for the use of double brackets and underscoring, which may seem less than ideal. The final version will be typeset, and these unaesthetic elements eliminated.

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analysis, feasibility	................systems analysis
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analysis, risk	................risk
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programming, nonlinear	...............optimization
programming, stochastic	...............optimization
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risk analysis [Syn. for: risk assessment]	risk
risk assessment	risk
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risk-prone decision maker	utility
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simulation, man-machine	simulation
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state of the world	
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stochastic programming	optimization
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TERM	SEE:
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welfare function	...............utility
zero-sum game	...............game theory

[[a fortiori analysis]]

A fortiori analysis is a method of treating uncertainty that stacks the cards against one alternative (often the one intuitively preferred) by resolving questions of uncertainty in favor of another alternative. If the initially preferred alternative is still preferable, one has a stronger case in its favor.
See also: sensitivity analysis, contingency analysis.

[[alternative]]

One of the mutually exclusive courses of action that are considered as means of attaining the objectives. Typically, the alternatives differ in their nature or character, not only in quantitative details. By mutually exclusive we mean that the alternatives are competitive in the sense that if A is selected, B cannot be chosen. A course of action that combines features selected from both A and B would be a new alternative. (The synonym "option" is often used in association with the decision maker, as in "the decision maker's options were...")

[[consequence]]

A consequence is a result of a course of action (or of a decision) taken by the decision maker (Synonym: outcome; see impact).

In analysis, the consequences of a course of action are determined (predicted) by the use of models.

The consequences that one would like to have, particularly those that contribute positively to the attainment of objectives, are referred to as [[benefits;]] the consequences that one would like to avoid or minimize are [[costs.]]

The consequences that do not bear very much on the main objectives and are not evaluated in the analysis but that may affect the objectives of other groups of people are referred to as spillovers or externalities.

A [[consequence tree]] is a graph showing what further consequences will be caused by some direct consequence of a course of action. For example, one alternative to stimulate the economy may be to lower taxes. This will result in an increase of average family income, which will in time influence the number of cars, which will have an impact on traffic conditions, on environmental pollution, and so on.

In the literature on decision theory it is customary to speak about one [[multiattribute consequence]] of a course of action instead of saying "the action has several consequences." Accordingly, the term [[single-attribute consequence]] is used when the course of action has only one consequence that is being considered (e.g., monetary profit). Within the context of decision theory, attributes are those features of a consequence that are taken into account in the evaluation of this consequence by the decision maker. One speaks, more precisely, about [[value-relevant attributes.]]

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In mathematical formulations one speaks about a mapping from the space of courses of action [[(action space)]] into the space of consequences [[(consequence space).]] In a deterministic case the mapping from action space to consequence space is a point-to-point mapping. This means that a given course of action has a given and certain consequence. In a case of risk or uncertainty the mapping from action space to consequence space is a point-to-set mapping; that is, a given course of action may have any one of the consequences contained in a given set.

In analysis, the mapping from action space to consequence space is described by a model.

[[constraint]]

Constraints are limitations imposed by nature or by man that do not permit certain actions to be taken. Constraints may mean that certain objectives cannot be achieved.

The actions, alternatives, consequences, and objectives that are not precluded by the constraints are referred to as [[feasible.]]

In a particular analysis study, some constraints may have to be considered [[stiff]] or unquestionable, others - from among those imposed by prior decisions - may be [[elastic]] or removable if the analysis proves a good case for it. For example, the natural water supply in a region is a stiff constraint, while the money or manpower allocated to fulfill a certain task may be an elastic constraint.

It is useful to distinguish [[short-run]] and [[long-run]] constraints: for example, existing legislation is a constraint in the short run, but not necessarily in the long run.

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In mathematical terms, if the notions of action space, consequence space, and objective space are introduced, the constraints determine a [[feasible set]] in each of those spaces.

[[contingency analysis]]

Contingency analysis is a method of treating uncertainty that explores the effect on the alternatives of changes in the environment in which the alternatives are to function. This is a "what-if" type of analysis, with the what-ifs being external to the alternative, in contrast to a sensitivity analysis, where the parameters of the alternatives are varied.
See also: a fortiori analysis.

[[course of action]]

A means available to the decision maker by which the objectives may be attained.

A systems analysis usually considers several possible courses of action, which are then referred to as alternatives or as the decision makers's options.

[[criterion]]

A criterion is a rule or standard by which to rank the alternatives in order of desirability. The use of "criterion" to mean "objective" is incorrect.
See objective.

[[decision maker]]

A decision maker is a person, or group of people (e.g., a committee), who makes the final choice among the alternatives. Synonym: decision taker.

[[decision theory]]

Decision theory is a body of knowledge and related analytical techniques of different degrees of formality designed to help a decision maker choose among a set of alternatives in light of their possible consequences. Decision theory can apply to conditions of certainty, risk, or uncertainty. [[Decision under certainty]] means that each alternative leads to one and only one consequence, and a choice among alternatives is equivalent to a choice among consequences. In [[decision under risk]] each alternative will have one of several possible consequences, and the probability of occurrence for each consequence is known. Therefore, each alternative is associated with a probability distribution, and a choice among alternatives is equivalent to a choice among probability distributions. When the probability distributions are unknown, one speaks about [[decision under uncertainty.]]

Decision theory recognizes that the ranking produced by using a criterion has to be consistent with the decision maker's objectives and preferences. The theory offers a rich collection of techniques and procedures to reveal preferences and to introduce them into models of decisions. It is not concerned with defining objectives, designing the alternatives or assessing the consequences; it usually considers them as given from outside, or previously determined.

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Given a set of alternatives, a set of consequences, and a correspondence between those sets, decision theory offers conceptually simple procedures for choice. In a decision situation under certainty the decision maker's preferences are simulated by a single-attribute or multiattribute value function that introduces ordering on the set of consequences and thus also ranks the alternatives.

Decision theory for risk conditions is based on the concept of utility (see utility, sense B). The decision maker's preferences for the mutually exclusive consequences of an alternative are described by a utility function that permits calculation of the expected utility for each alternative. The alternative with the highest expected utility is considered the most preferable.

For the case of uncertainty, decision theory offers two main approaches. The first exploits criteria of choice developed in a broader context by game theory, as for example the [[max-min rule,]] where we choose the alternative such that the worst possible consequence of the chosen alternative is better than (or equal to) the worst possible consequence of any other alternative, or the [[max-max rule]] where we choose the alternative such that the best possible consequence of the chosen alternative is better than (or equal to) the best possible consequence of any other alternative.

The second approach is to reduce the uncertainty case to the case of risk by using [[subjective probabilities,]] based on expert assessments or on analysis of previous decisions made in similar circumstances.

See also: game theory, optimization, utility, value.

[[Delphi method]]

A technique to arrive at a group position regarding an issue under investigation, the Delphi method consists of a series of repeated interrogations, usually by means of questionnaires, of a group of individuals whose opinions or judgments are of interest. After the initial interrogation of each individual, each subsequent interrogation is accompanied by information regarding the preceding round of replies, usually presented anonymously. The individual is thus encouraged to reconsider and, if appropriate, to change his previous reply in light of the replies of other members of the group. After two or three rounds, the group position is determined by averaging.

[[demand]]

[A] As a term in economics, demand means the amount of a commodity (good or service) that would be purchased at a given price. An associated term is [[demand function,]] which presents the demand-versus-price relationship. A demand function for a given commodity is compared with a corresponding [[supply function]] to determine the [[equilibrium price:]] a price at which the supply offered matches the demand.

[B] In another usage, demand means the amount of a commodity required for a certain purpose. It often relates to the future, as in: "the world energy demand in the year 2030 will be 35 terawatts." Implicit in this statement is that the price of energy as well as other economic conditions will be such that 35 terawatts will be consumed (purchased) if technically available.

[[discount rate]]

It is assumed that a monetary unit received today is worth more than a monetary unit to be received a year from now. This assumption requires that, in order to determine the present value of future sums, the analyst use an interest rate to discount these future sums. If i is the assumed annual interest or discount rate, expressed as a decimal, the present value of x monetary units to be received n years from now is given by the formula:

$$\text{Present value} = \frac{x}{(1+i)^n}$$

Discount rates are used when comparing alternatives that differ in the time-character of their flows of costs and benefits; to compare them, costs and benefits are discounted to the same year. There are no clearcut rules as to what an appropriate discount rate should be in a given case.

[[dominance]]

An alternative is said to be dominant with respect to a second alternative whenever one or more of the consequences of the first are superior (i.e., preferred according to some criterion) to the corresponding consequences of the second, and all others are equally valued.

[[economy of scale]]

Relative saving ("economy") realized when the size of a plant, enterprise, etc., is increased. For example, lower production cost of an automobile due to production of a large number of cars of the same type is due to economy of scale.

There may also exist a [[diseconomy of scale,]] where the increased size contributes to an increase in unit cost.

[[effectiveness]]

In systems analysis, the effectiveness of an alternative is usually represented by an aggregative expression approximating the totality of output or performance aspects of that alternative that are relevant to goal attainment. Ideally, it is a single quantitative measure that can be used to evaluate the performance level achieved in attaining the objectives.

[[efficiency]]

Program A is said to be more efficient than program B if, for a given cost, a chosen aggregated measure of its positive results (such as effectiveness or benefit) is greater than that for program B.

[[environment]]

Environment is most often used as a synonym of state of nature, a concept useful in modeling. It embraces all external factors or forces that are beyond the influence of the decision maker but nevertheless affect the consequences of his action.

Environment is also occasionally used as a synonym of state of the world. The difference between the two concepts is that state of the world can include the consequences of a course of action as well as the external factors, while the state of nature comprises the external factors only.

[[evaluation]]

Evaluation as used in a technical sense in the United States means assessment of a government program's past or ongoing performance. The key issue in [[program evaluation]] is to determine the extent to which the program, rather than other factors, has caused any changes that have been observed.

[[experimentation]]

In systems analysis, experimentation is the process of determining the results of a proposed course of action or program by conducting an experiment on a smaller scale in which the course of action is applied to a sample drawn from the future target group. An example would be a test of a new health policy in a restricted region instead of the whole country, or a test on a randomly selected sample of the population. The results are best when the experiment is controlled -- i.e., when the test and control groups are chosen before program implementation in such a way that they are as similar as possible. In this way, any differences that are observed during the experiment can be ascribed to the program.

Experimentation is used whenever current knowledge and understanding of factors such as social attitudes and group preferences are not sufficient to provide dependable model-based predictions. (See: model)

[[externality]]

An externality is a consequence not considered in analysis. An externality that affects the interests of other groups of people or other decision makers is referred to as a [[spillover.]] If the effects of an externality are appreciable, it may have to be taken into account (internalized) in the analysis.

The term externality derives from economics, where externalites are costs or benefits not taken into account in a transaction or system of transactions. For example, the cost borne by others when an industry pollutes a stream would be referred to as an externality.

[[forecast]]

A forecast is a statement, usually in probabilistic terms, about the future state or properties of a system based on a known past and present.

A [[conditional forecast]] states in probabilistic terms what the future will be if a course of action is taken.

A forecast that states with a high degree of confidence what the future will be is referred to as [[prediction.]]

A forecast that is a hypothesis rather than a formally justified inference from past data is referred to as a scenario.

Forecasting techniques range from expert judgements to mathematical forecasting models. The [[forecasting lead]] (forecasting horizon), is the length of time ahead of now for which one can make a reasonable forecast. It depends, in the general sense, on available data.

A forecast that makes itself come true is referred to as a [[self-fulfilling forecast.]] For example, a forecast for the rapid growth of a certain city may encourage business to locate there, thus causing the forecast to be realized.

[[game theory]]

Game theory is a branch of mathematical analysis developed to study decision making in [[conflict situations.]] Such a situation exists when two or more decision makers who have different objectives act on the same system or share the same resources. There are [[two-person]] and [[multiperson games.]] Game theory provides a mathematical process for selecting an [[optimum strategy]] (that is, an optimum decision or a sequence of decisions) in the face of an opponent who has a strategy of his own.

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In game theory one usually makes the following assumptions:

(1) Each decision maker [["player"]] has available to him two or more well-specified choices or sequences of choices (called [["plays").]]

(2) Every possible combination of plays available to the players leads to a well-defined end-state (win, loss, or draw) that terminates the game.

(3) A specified payoff for each player is associated with each end-state (a [[zero-sum game]] means that the sum of payoffs to all players is zero in each end-state).

(4) Each decision maker has perfect knowledge of the game and of his opposition; that is, he knows in full detail the rules of the game as well as the payoffs of all other players.

(5) All decision makers are rational; that is, each player, given two alternatives, will select the one that yields him the greater payoff.

The last two assumptions, in particular, restrict the application of game theory in real-world conflict situations. Nonetheless, game theory has provided a means for analyzing many problems of interest in economics, management science, and other fields.

[[impact]]

Impact is used in three different ways:

[A] as synonymous with consequence;

[B] to mean any consequence (beneficial or adverse) that reaches beyond the direct purpose of a given course of action, as in: "the impact of the new steel plant on employment opportunities in the region;"

[C] as in [B], but the meaning restricted to adverse consequences, as in: "the impact of industrial growth on the ecological environment."

[[implementation]]

Implementation means the process of carrying out a course of action. Implementation starts at the decision and terminates when the objectives are attained.

[[input-output (Leontief) analysis]]

Input-output (Leontief) analysis is a technique developed for quantitatively analyzing the interdependence of producing and consuming units in an economy. Input-output analysis studies the interrelations among producers as buyers of each other's outputs, as users of resources, and as sellers to final consumers. For example, if a planner wishes to expand the activities of some industry, or some component of final consumption, an input-output analysis can tell what amount of other manufactured goods, resources, and labor this requires.

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In an [[input-output model]] the output product of each sector of the economy is set equal to the input consumption of that product by other industries plus the consumption by final consumers. All inputs and outputs are expressed in the same units (usually in monetary units per unit of time, for example in schillings/year). One denotes a_{ij} the worth of output product of sector i required as input by sector j to produce one unit's worth of its product. Then, if we denote $x_1, x_2, \ldots x_n$ the output products of the sectors, the basic relation of the model is:

$$x_i = \sum_{j=1}^{n} a_{ij} x_j + y_i$$

where y_i is the consumption of product i by final consumers. In a model with three sectors, we have, for example, for the output product x_2:

$$x_2 = a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + y_2$$

which reads: "out of the total output x_2 the amount $a_{21}x_1$ is used by sector 1 to produce output $x_1, \ldots,$ and the amount y_2 is consumed by final consumers."

The parameters a_{ij} are referred to as [[technological coefficients.]] They are usually arranged into a table called the [[technological interdependence matrix]] for the system being modeled.

[[iterative process]]

An iterative process is a process for calculating a desired result by means of a repeated cycle of operations. An iterative process should be convergent, i.e., it should come closer to the desired result as the number of iterations increases.

[[model]]

A model is a device, scheme, or procedure typically used in systems analysis to predict the consequences of a course of action; a model usually aspires to represent the real world (to the degree needed in analysis) -- for example, a relation between some observed phenomena.

A model can be [[formal]] (e.g., a mathematical expression, a diagram, a table) or [[judgmental]] (e.g., as formed by the deductions and assessments contained in the mind of an expert).

Some models are [[causal]] -- i.e., they reflect cause-effect relationships. Others are [[correlation models,]] which do not necessarily reveal whether some of the observed phenomena are the cause of the others. An example is correlation models used for weather forecasting; note that the farmer who predicts rain on the basis of some observed phenomena and his past experience is using a judgmental correlation model.

A [[deterministic model]] generates the response to a given input by one fixed law; a [[stochastic model]] picks up the response from a set of possible responses according to a fixed probability distribution (stochastic models are used to simulate the behavior of real systems under random conditions.

A [[dynamic model]] can describe the time-spread phenomena (dynamic processes) in a system. A [[static model]] describes the system at a given instant of time and in an assumed state of equilibrium.

Among the formal, mathematical models an [[analytic model]] is formed by explicit equations. It may permit an analytic or numerical solution.

An analytic model is [[linear]] if all equations in the model are linear.

We speak of a [[simulation model]] if the solution, i.e., the answer to the question which the analyst has posed, is obtained by experiments on the model rather than by an explicit solution algorithm. A typical example is [[stochastic simulation,]] where one wants to obtain probabilistic properties of a system's response by evaluating the results of a large number of simulation runs on the model.

In some analyses the model by which one predicts the outcome of a course of action must take into account that this outcome depends also on actions taken by other decision makers. If the assumption can be made that those decision makers optimize some defined objective functions, and all the other aspects of the system can also be formalized, an [[optimization model]] (e.g., a linear programming model) can be used to determine the system's response to a course of action. In [[role-playing models]] those decision makers (and perhaps some other elements of the system as well) are simulated by human actors.

In a [[man-machine model]] an actor or actors play roles while other parts of the model are implemented on a computer.

A formal model has a [[structure]] (the form of an equation, for example) and [[parameters]] (the values of coefficients in an equation, for example). Determination of both the structure and parameters is [[model identification;]] determination of parameters on the basis of experimental data is [[model estimation.]]

The check of a proposed model against experimental data other than those used for parameter estimation is model validation. See also verification.

[[objective]]

An objective is something that a decision maker seeks to accomplish or to obtain by means of his decision. A decision maker may have more than one objective (the [[multiple-objectives]] case).

An objective may be specified in a more or less general fashion, may be quantified or not quantified, and is usually part of a [[hierarchy of objectives.]] The term [[goal]] is sometimes used to denote a very general objective (at the top of the hierarchy) and [[target]] is used to mean a very definite objective. Example: "The goal of allocating money to the municipality was to increase the quality of urban life. The immediate objectives were to improve public transportation and fire services. A 10% reduction of average travel time from home to work and a 70% decrease of average alarm-to-action time taken by the fire brigades were set forth as targets".

The multiple objectives of a single decision maker are usually [[competitive:]] i.e., the improvement in one of them is associated with a deterioration in another (usually because of limited resources or because of other constraints).

Competitive objectives are sometimes referred to as [[conflicting objectives.]] However, one should speak about a conflict and about conflicting objectives only if there are two or more decision makers who have different objectives and who act on the same system or share the same resources. In the example given above, the director of urban transportation and the director of city fire services have conflicting objectives. At the same time the mayor of the city, if he were the single decision maker, would look at these objectives as competitive.

If the two directors are left without a coordinating influence by the mayor (who would, for example, decide how to allocate the resources), a conflict situation may result. (see game theory).

With the mayor's interventions, the system becomes a hierarchy of decision makers, and the conflict may be resolved.

When the extent to which an objective is attained is measurable on some appropriate scale, one can speak about the degree of attainment of the objective.

In systems analysis, one often uses [[proxy objectives:]] objectives other than the original ones, but such that are measurable and can be quantitatively discussed. A proxy objective should at least point in the same direction as the original one; for example, "reduction of mean travel time" in urban transportation is a proxy for "improved services."

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In a mathematical description, the measures of the multiple objectives $Q_1, Q_2, \ldots, Q_n$ are considered to be coordinates of a point in the n-dimensional [[objective space.]] Then, the [[target values]] $T_1, T_2, \ldots, T_n$ prescribed for the n objectives are considered to be coordinates of the [[target point]] in this space. When the target value requirements are set forth as some intervals rather than single numbers, they define a region in the objective space that is referred to as a [[target set.]]

[[operations research]]

Operations research (operational research in Britain) as understood today is essentially identical to systems analysis. Historically, it was a narrower area of activity that stressed quantitative methods and did not concern itself with trade-offs between objectives and means or with problems of equity. It was defined by the Operational Research Society of Great Britain as follows (Operational Research Quarterly, 13(3): 282, 1962):

Operational research is the attack of modern science on complex problems arising in the direction and management of large systems of men, machines, materials and money in industry, business, government and defence. Its distinctive approach is to develop a scientific model of the system, incorporating measurements of factors such as chance and risk, with which to predict and compare the outcomes of alternative decisions, strategies or controls. The purpose is to help management determine its policy and actions scientifically.

[[opportunity cost]]

Opportunity cost is defined as the advantage forgone as the result of the acceptance of an alternative. It is measured as the benefits that would result from the next best alternative use of the same resources that was rejected in favor of the one accepted. Opportunity cost is difficult, perhaps impossible, to measure precisely.

[[optimization]]

Optimization is an activity that aims at finding the best (i.e., optimal) solution to a problem. For optimization to be meaningful there must be an objective function (see below) to be optimized and there must exist more than one [[feasible solution,]] i.e., a solution which does not violate the constraints.

The term optimization does not apply, usually, when the number of solutions permits the best to be chosen by inspection, using an appropriate criterion (see decision theory).

One distinguishes [[single-objective]] and [[multiobjective optimization.]] In the first case the objective is [[scalar-valued]] (it can be measured by a single number); in the second, the objective is [[vector-valued]] (its value is expressed by an n-tuple of numbers).

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In mathematical terms, the formulation of an optimization problem involves [[decision variables,]] $x_1, x_2, \ldots, x_n$, the [[objective function,]]

$$Q = f(x_1, x_2, \ldots, x_n)$$

and constraint relations, usually of the form

$$g_i(x_1, x_2, \ldots, x_n) \leq 0 \ , \ i = 1, 2, \ldots, m \ .$$

The [[optimal solution]] (or "solution to the optimization problem") are values of decision variables $\hat{x}_1, \hat{x}_2, \ldots, \hat{x}_n$ that satisfy the constraints and for which the objective function attains a maximum (or a minimum, in a minimization problem).

Very few optimization problems can be solved analytically, that is, by means of explicit formulae. In most practical cases appropriate computational techniques of optimization (numerical procedures of optimization) must be used. Among those techniques [[linear programming]] permits the solution of problems in which the objective function and all constraint relations are linear; [[nonlinear programming]] does not have this restriction, but can manage many fewer decision variables and constraints; [[integer programming]] serves to solve problems where the decision variables can take only integer values; [[stochastic]] or [[probabilistic programming]] must be used for problems where the objective function or constraint relations contain random-valued parameters (in the latter case, the problem is referred to as a a [[chance-constrained problem).]]

A special class is [[dynamic optimization problems,]] where the decision variables are not real numbers or integers but functions of one or more independent variables -- functions of time or space coordinates, for example. Dynamic optimization problems are sometimes referred to as "optimal control problems." There exist special techniques to solve such problems; they often make use of [[discretization]] of the independent variables, for example dividing the time axis into a number of intervals and considering the solutions to be constant over those intervals.

A single-objective optimization problem may have (and usually does have) a single-valued, unique solution.

The solution to a multiobjective problem is, as a rule, not a particular value, but a set of values of decision variables such that, for each element in this set, none of the objective functions can be further increased without a decrease of some of the remaining objective functions (every such value of a decision variable is referred to as [[Pareto-optimal).]]

[[resource analysis]]

The process of determining the economic resource impacts of alternative proposals for future courses of action. While in resource analysis, physical quantities are often ultimately translated into monetary terms, the real aim is to measure the probable "resource drain" on the economy that would result from various possible actions. The resource analyst must not only give attention to economic costs but also has to determine if it is feasible to obtain needed physical material and manpower in the required time period.

[[risk]]

[A] In decision theory and in statistics risk means uncertainty for which the probability distribution is known. Accordingly, [[risk analysis]] means a study to determine the outcomes of decisions along with their probabilities -- for example, answering the question: "what is the likelihood of achieving a 1,000,000 schilling profit in this alternative?"

In systems analysis, a decision maker is often concerned with the probability that a project (the chosen alternative) cannot be carried out with the time and money available. This risk of failure may differ from alternative to alternative and should be estimated as part of analysis.

[B] In another usage, risk means an uncertain and strongly adverse impact, as in "the risks of nuclear power plants to the population are...." In that case, risk analysis or [[risk assessment]] is a study composed of two parts, the first dealing with the identification of the strongly adverse impacts, and the second with determination of their respective probabilities. Compare risk-benefit analysis.

[[role-playing]]

A type of simulation in which persons (referred to as [[actors]] or players), sometimes with the aid of computers, act out roles as parts of the system being analyzed.

For example, experts in different fields may be called upon to simulate the behavior (to predict the response) of specific segments of a regional or national economy being studied.

A role-playing simulation in which the actors (players) act out roles as decision makers is called [[gaming.]] In gaming, the players usually have different and conflicting objectives (in business gaming and war gaming, for example). The players may act as individuals or may be combined into coalitions, or opposing teams.

[[satisficing]]

Satisficing is an alternative to optimization for cases where there are multiple and competitive objectives in which one gives up the idea of obtaining a "best" solution.

In this approach one sets lower bounds for the various objectives that, if attained, will be "good enough" and then seeks a solution that will exceed these bounds. The satisficer's philosophy is that in real-world problems there are too many uncertainties and conflicts in values for there to be any hope of obtaining a true optimization and that it is far more sensible to set out to do "well enough" (but better than has been done previously).

[[scenario]]

A scenario is an outline of a hypothesized chain of events. The term is used to denote [A] a forecast based on loose assumptions rather than on a more formal inference from the past or [B] a synopsis of a proposed course of action.

[[secondary decision]]

Secondary decisions are those choices made by the analyst that determine the way in which systems analysis of a given problem or issue will be performed. They include making the simplifying assumptions by which a complex issue will be made tractable in analysis, choosing the forms of models, selecting the techniques of computation and simulation, deciding what data have to be acquired, judging what support by experts of various disciplines to use in performing the analysis, and so on.

The secondary decisions are distinguished from [[primary decisions,]] that is, the decisions to be taken by the decision maker and related to the object problem or issue to which a systems analysis is applied.

[[sensitivity analysis]]

A procedure to determine the sensitivity of the outcomes of an alternative to changes in its parameters (as opposed to changes in the environment; see contingency analysis, a fortiori analysis). If a small change in a parameter results in relatively large changes in the outcomes, the outcomes are said to be sensitive to that parameter. This may mean that the parameter has to be determined very accurately or that the alternative has to be redesigned for low sensitivity.

[[simulation]]

Simulation is the term applied to the process of modeling the essential features of a situation and then predicting what is likely to happen by operating with the model case by case -- i.e., by estimating the results of proposed actions from a series of imaginary experiments (imaginary because they are performed on the representation of the situation, the model, rather than on the situation itself).

Most frequently, the simulation is a [[computer simulation]] in which the representation is carried out numerically on a digital computer. It may also be done on an analogue computer or by means of a physical representation, say by a wooden airfoil in a wind tunnel. [[Man-machine simulation]] is a simulation that em-

ploys a man-machine model.
Also see: role playing, gaming.

[[state of the world]]

State of the world, in connection with a course of action, means the aggregate of natural, economic, social, cultural, and other conditions on which the presumed consequences must depend and to which the course of action must be matched. A forecast of the state of the world is required to predict the results of any course of action.
See environment.

[[suboptimization]]

Suboptimization refers to the analysis to assist a lower level decision as a step toward the attainment of a higher level objective to which the lower level decision is to contribute. Thus, an optimization of a city's streetcar operations would be a suboptimization if the higher level aim is to optimize the entire public transport system.

Analysts and decision makers must always suboptimize -- that is, consider actions that pertain to only part of the elements that enter a problem -- neglecting some things and fixing others arbitrarily. Even if all suboptimization problems relevant for a higher level problem are successfully solved, this will not mean, usually, that the higher level problem will be optimized. One could usually do better by treating all partial problems and their interrelationships, simultaneously.

[[systems analysis]]

This term has many different meanings. In the sense adopted for the Handbook, systems analysis is an explicit formal inquiry carried out to help someone (referred to as the decision maker) identify a better course of action and make a better decision than he might otherwise have made. The characteristic attributes of a problem situation where systems analysis is called upon are complexity of the issue and uncertainty of the outcome of any course of action that might reasonably be taken.

Systems analysis usually has some combination of the following: identification (and re-identification) of objectives, constraints, and alternative courses of action; examination of the probable consequences of the alternatives in terms of costs, benefits, and risks; presentation of the results in a comparative framework so that the decision maker can make an informed choice from among the alternatives.

The typical use of systems analysis is to guide decisions on issues such as national or corporate plans and programs, resource use and protection policies, research and development in technology, regional and urban development, educational systems, and health and other social services. Clearly, the nature of these problems requires an interdisciplinary approach.

There are several specific kinds or focuses of systems analysis, for which different terms are used.

A systems analysis related to public decisions is often referred to as a [[policy analysis]] (in the United States the terms are used interchangeably).

A systems analysis that concentrates on comparison and ranking of alternatives on the basis of their known characteristics is referred to as [[decision analysis.]]

That part or aspect of systems analysis that concentrates on finding out whether an intended course of action violates any constraints is referred to as [[feasibility analysis.]]

A systems analysis in which the alternatives are ranked in terms of effectiveness for fixed cost or in terms of cost for equal effectiveness is referred to as [[cost-effectiveness analysis.]]

[[Cost-benefit analysis]] is a study where for each alternative the time stream of costs and the time stream of benefits (both in monetary units) are discounted (see: discount rate) to yield their present values. The comparison and ranking are made in terms of net benefits (benefits minus cost) or the ratio of benefits to costs.

In [[risk-benefit analysis,]] cost (in monetary units) is assigned to each risk, so as to make possible a comparison of the discounted sum of these costs (and of other costs as well) with the discounted sum of benefits that are predicted to result from the decision. The risks considered are usually events whose probability of occurrence is low, but whose adverse consequences would be important (e.g., events such as an earthquake or explosion of a plant).
See: operations research.

[[trade-off]]

Trade-off means an exchange of one quality or thing for another. Thus, in comparing alternative configurations for transport aircraft, it may be possible to trade off speed for payload and still maintain the same total transport capability per month in the system.

In value analysis and decision theory the concept of trade-offs in the decision maker's preferences is used extensively as a basis for establishing multiattribute value functions and

multiattribute utility functions.
See: value, utility.

[[uncertainty]]

Because of an unfortunate use of terminology, in systems analysis discourse, the word "uncertainty" has both a precise technical meaning and its loose natural meaning of an event or situation that is not certain.

In decision theory and statistics a precise distinction is made between a situation of risk and one of uncertainty. There is an uncontrollable random event inherent in both of these situations. The distinction is that in a risky situation the uncontrollable random event comes from a known probability distribution, whereas in an uncertain situation the probability distribution is unknown.

[[utility]]

[A] In economics, utility means the real or fancied ability of a good or service to satisfy a human want. An associated term is [[welfare function]] (synonym: utility function -- not to be confused with utility function in decision theory; see below), which relates the utility derived by an individual or group to the goods and services that it consumes. [[Marginal utility]] is the change in utility due to a one-unit change in the quantity of a good or service consumed.

[B] In decision theory, utility is a measure of the desirability of consequences of courses of action that applies to decision making under risk -- that is, under uncertainty with known probabilities.

The concept of utility applies to both single-attribute and multiattribute consequences.

The fundamental assumption in [[utility theory]] is that the decision maker always chooses the alternative for which the expected value of the utility [[(expected utility)]] is maximum.

If that assumption is accepted, utility theory can be used to predict or prescribe the choice that the decision maker will make, or should make, among the available alternatives. For that purpose, a utility has to be assigned to each of the possible (and mutually exclusive) consequences of every alternative. A [[utility function]] is the rule by which this assignment is done, and depends on the preferences of the individual decision maker.

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In utility theory, the utility measures u of the consequences are assumed to reflect a decision maker's preferences in the following sense:

(i) the numerical order of utilities for consequences preserves the decision maker's preference order among the consequences;

(ii) the numerical order of expected utilities of alternatives (referred to, in utility theory, as gambles or [[lotteries)]] preserves the decision maker's preference order among these alternatives (lotteries).

For example if alternative A can have three mutually exclusive consequences, x,y,z, and the decision maker prefers z to y and y to x, the utilities u_1,u_2,u_3 assigned to x,y,z must be such that $u_3>u_2>u_1$.

If the probabilities of the consequences x,y,z are $p_1,p_2,1-p_1-p_2$, respectively, the expected utility of alternative A is calculated as

$$E(u|P) = p_1u_1 + p_2u_2 + (1-p_1-p_2)u_3$$

where P means the probability distribution, characteristic for the alternative (i.e. $p_1,p_2,1-p_1-p_2$).

If the decision maker prefers alternative B, which has probability distribution Q, to alternative A, the utility assignments in both alternatives must be such that

$$E(u|Q) > E(u|P).$$

Utility theory provides a basis for the assignment of utilities to consequences by formulating necessary and sufficient conditions to satisfy (i) and (ii).

A utility function is defined mathematically as a function $u(\cdot)$ from the set of consequences Y into the real numbers that provides for satisfaction of (i) and (ii).

There exist various methods for constructing utility functions. The best-known method is based on indifference judgments of the decision maker about specially constructed alternatives (lotteries).

Utility theory permits one to distinguish [[risk-prone,]] [[risk-neutral]] and [[risk-averse decision makers.]]

For example, if the mutually exclusive payoffs x_1, x_2, x_3 of an alternative A are all expressed in the same units (e.g., schillings), the decision maker is risk-prone if he prefers the alternative A (prefers the lottery) to receiving, with no risk, the expected value of the payoffs (calculated directly as $E(x|P) = p_1x_1 + p_2x_2 + (1-p_1-p_2)x_3$). This preference can also be expressed as

$$E(u|P) > u(E(x|P))$$

i.e., the expected utility of the lottery to the risk-prone decision maker is larger than the utility of the expected value of the consequence.

The risk-neutral and risk-averse decision makers are defined accordingly.

Tne [[multiattribute utility function]] is defined as a function u(.) from the set of multiattribute consequences into the real numbers. This means that it applies to cases where each of the mutually exclusive consequences has several attributes. Multiattribute utility functions, besides having properties (i) and (ii), also express the decision maker's trade-offs among the attributes (compare multiattribute value function). Several special forms of multiattribute utility functions have been developed, including the additive and the multiplicative forms.

[[validation]]

Validation is the process of increasing the confidence that the outputs of the model conform to reality in the required range. In some cases the model's output can be compared to data from historical sources or from an experiment conducted for validation. A model can never be completely validated; we can never prove that its results conform to reality in all respects; it can only be invalidated. Predictive models can be validated only by judgment, since a model may fit past data well without having good predictive qualities.

[[value]]

Value can be either objective or subjective; in the latter case it means subjective worth or importance. For example, "the value of future benefits to the decision maker," "the value of clean air to the society".

For the purposes of analysis, the subjective values must be measured on some scale. These measures of value should be based on preferences expressed by the person or group of interest.

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In [[value analysis,]] one considers that the value v is related to the physical or other objective measure y of a consequence by a subjectively defined [[value function,]] so that $v = f(y)$. A value function usually departs from proportionality, i.e., it usually is a nonlinear dependence.

A typical example is the subjective value of money to an individual: the first 1,000 schillings in his savings account are probably of more value to him than the 1,000 schillings that would increase the state of his account from 100,000 to 101,000 schillings.

The value of a multiattribute consequence with value-relevant attributes $y_1, y_2, \ldots, y_n$ can be expressed by a [[multiattribute value function,]] $v(y_1, y_2, \ldots y_n)$.

A multiattribute value function must satisfy the following condition:

$$v(y_1, y_2, \ldots, y_n) \geq v(y_1', y_2', \ldots, y_n')$$

if and only if the multiattribute consequence $(y_1, y_2, \ldots, y_n)$ is preferred or indifferent to $(y_1', y_2', \ldots, y_n')$.

Several theories exist according to which a multiattribute value function $v(\cdot)$ can in appropriate cases be expressed as an aggregate of single-attribute functions $v_i(\cdot)$. For example, the additive [[conjoint measurement theory]] assumes that

$$v(y_1, y_2, \ldots, y_n) = \sum_{i=1}^{n} v_i (y_i).$$

See also: utility, decision theory.

[[verification]]

A (computer) model is said to be verified if it behaves in the way that the model builder wanted it to behave. This means that the instructions are correct and have been properly programmed. One check for verification is to hold some of the variables constant to determine whether the output changes in anticipated ways as other variables are changed. Another typical check is to test how the model behaves in limit situations.

Compare: validation.

GLOSSARY INDEX
RUSSIAN-ENGLISH
указатель

термин	см.
альтернатива (alternative)	...............alternative
альтернатива (course of action)	...............course of action
альтернатива (option)	...............alternative
анализ (evaluation)	...............evaluation
анализ модели на адекватность (validation)	...............validation
анализ, оценка программы (program evaluation)	...............evaluation
анализ по методу ,,затраты-выгода,, (cost-benefit analysis)	...............systems analysis
анализ по методу ,,затраты-эффективность,, (cost-effectiveness analysis)	...............systems analysis
анализ по методу ,,риск-выгода,, (risk-benefit analysis)	...............systems analysis
анализ ресурсов (resource analysis)	...............resource analysis
анализ решений (decision analysis)	...............systems analysis
анализ риска (risk analysis)	...............risk
анализ риска (risk assessment)	...............risk
анализ социально-экономических решений (policy analysis)	...............systems analysis
анализ чувствительности альтернативы (к изменениям внешней среды) (contingency analysis)	

термин	см.
	contingency analysis
анализ чувствительности альтернативы (к изменениям характеризующих ее параметров)(sensitivity analysis)	sensitivity analysis
аналитическая модель (analytic model)	model
афортиори анализ (a fortiori analysis)	a fortiori analysis
балансовая модель (input-output model)	input-output (Leontief) analysis
вариант решения (alternative)	alternative
вариант решения (course of action)	course of action
векторная оптимизация (multiobjective optimization)	optimization
векторная цель (vector-valued objective)	optimization
вербальная модель (judgmental model)	model
верификация (verification)	verification
влияние (impact)	impact
внешняя среда (environment)	environment
возможность неудачи (risk of failure)	risk
выгода (benefit)	consequence
выигрыш (payoff)	game theory
годовая норма дисконта времени (discount rate)	discount rate
горизонт прогнозирования (forecasting lead)	forecast
дерево исходов (consequence tree)	consequence
детерминированная модель (deterministic model)	model

термин	см.
динамическая модель (dynamic model)	...............model
долгосрочное ограничение (long-run constraint)	...............constraint
доминирование (dominance)	...............dominance
допустимая альтернатива (feasible action)	...............constraint
допустимая альтернатива (feasible alternative)	...............constraint
допустимая (т.е., удовлетворяющая ограничениям) цель (feasible objective)	...............constraint
допустимое действие (feasible action)	...............constraint
допустимое решение (feasible solution)	...............optimization
допустимый результат (feasible consequence)	...............constraint
допустимый (т.е., удовлетворяющий ограничениям) исход, результат (feasible consequence)	...............constraint
жесткое ограничение (stiff constraint)	...............constraint
задача оптимального управления (optimal control problem)	...............optimization
задача оптимизации в динамической постановке (dynamic optimatization problem)	...............optimization
задачи оптимизации со стохастическими ограничениями (chance-constrained problem)	...............optimization

термин	см.
затрата (cost)	...............consequence
значение (value)	...............value
значение цели (target value)	...............objective
игра (play)	...............game theory
игра двух лиц (two-person game)	...............game theory
игра многих лиц (multiperson game)	...............game theory
игра с нулевой суммой (zero-sum game)	...............game theory
игровая имитационная модель (role-playing model)	...............model
игровое имитационное моделирование (role-playing)	...............role-playing
игрок (player)	...............game theory
идентификация модели (model identification)	...............model
иерархия целей (hierarchy of objectives)	...............objective
имитационная модель (simulation model)	...............model
имитационные игры (gaming)	...............gaming
имитация (simulation)	...............simulation
исследование операций (operations research)	...............operations research
исход (при многих критериях) (multiattribute consequence)	...............consequence
исход (принимаемых решений) (consequence)	...............consequence
итеративный процесс (iterative process)	...............iterative process
компромис (tradeoff)	...............tradeoff
конкретно определенная цель (target)	...............objective

термин	см.
конфликтная ситуация (conflict situation)	...............game theory
конфликтные цели (conflicting objectives)	...............objective
корреляционная модель (correlation model)	...............model
кратко-срочное ограничениие (short-run constraint)	...............constraint
критерий (attribute)	...............attribute
критерий (criterion)	...............criterion
критерий, учитываемый при оценке решения (value relevant attribute)	...............consequence
курс действий (alternative)	...............alternative
курс действий (course of action)	...............course of action
курс действий (option)	...............alternative
линейная модель (linear model)	...............model
линейное программирование (linear programming)	...............optimization
лицо, принимающее решение (decision maker)	...............decision maker
лицо, принимающее решение, нейтрально относящего к риску (risk-neutral decision maker)	...............utility
лицо, принимающее решение, склонное избегать риска (risk-averse decision maker)	...............utility
лицо, принимающее решение, склонное к риску (risk-prone decision maker)	...............utility

термин	см.
лотерея (lottery)	utility
максимаксный критерий (max-max rule)	decision theory
максиминный критерий (max-min rule)	decision theory
маргинальная полезность (marginal utility)	utility
матрица, описывающая баланс (technological interdependence matrix)	input-output (Leontief) analysis
машинная имитация (computer simulation)	simulation
машинная модель (computer model)	model
метод ,,дельфи,, (delphi method)	Delphi method
методология построения и анализа балансовых моделей (input-output (Leontief) analysis)	input-output (Leontief) analysis
многокритериальная функция полезности (multiattribute utility function)	utility
многокритериальная функция ценности (multiattribute value function)	value
множество допустимых) целей, альтернатив, и т.д. (feasible set)	constraint
модель (model)	model
модель, реализуемая на ЭВМ (computer model)	model
модель, учитывающая причинно-следственные связи (causal model)	model

термин	см.
нелинейное программирование (nonlinear programming)	..............optimization
неопределенность (uncertainty)	..............uncertainty
неучитываемое при анализе влияние решения на внешние системы (spillover)	..............externality
неучитываемое при анализе последствие решения (externality)	..............externality
ограничение (constraint)	..............constraint
однокритериальное последствие (single-attribute consequence)	..............consequence
однокритериальный исход (single-attribute consequence)	..............consequence
ожидаемая полезность (expected utility)	..............utility
определение допустимых цели, решений и т.д. (feasibility analysis)	..............systems analysis
определение ценности обьектов и конкретных значений обьективно измеренных величин (value analysis)	..............value
оптимальная стратегия (optimum strategy)	..............game theory
оптимальное решение (optimal solution)	..............optimization
оптимальный по парето (Pareto-optimal)	..............optimization

термин	см.
оптимизационная модель (optimization model)	...............model
оптимизация (optimization)	...............optimization
оптимизация при наличии одной целевой функции (single-objective optimization)	...............optimization
осуществление (implementation)	...............implementation
отказ от поиска оптимального решения (satisficing)	...............satisficing
оценка (evaluation)	...............evaluation
оценка альтернатив при неблагоприятных внешних условиях (a fortiori analysis)	...............a fortiori analysis
оценка модели (model estimation)	...............model
параметр (attribute)	...............attribute
параметры модели (model parameters)	...............model
партия (play)	...............game theory
переменные (decision variable)	...............optimization
переход от непрерывной к дискретной постановке задачи (discretization)	...............optimization
платеж (payoff)	...............game theory
платежная функция (payoff function)	...............game theory
полезность (utility)	...............utility
последствие принимаемых решений (consequence)	...............consequence
последствие решения (impact)	...............impact
потери от принимаемого решения (opportunity cost)	...............opportunity cost

термин	см.
потребность (demand)	...............demand
предсказание (prediction)	...............forecast
принятие решений в условиях неопределенности (decision under uncertainty)	...............decision theory
принятие решений в условиях определенности (decision under certainty)	...............decision theory
принятие решений в условиях риска (decision under risk)	...............decision theory
проверка (verification)	...............verification
прогноз (forecast)	...............forecast
пространство альтернатив (action space)	...............consequence
пространство исходов (consequence space)	...............consequence
пространство целей (objective space)	...............objective
пространство целей (target set)	...............objective
противоречивые цели (competitive multiple objectives)	...............objective
реализация (implementation)	...............implementation
результат при многих критериях (multiattribute consequence)	...............consequence
результат принимаемых решений (consequence)	...............consequence
решение (основное) (primary decision)	...............secondary decision
решение о том, как проводить системный анализ (secondary decision)	...............secondary decision

термин	см.
риск (risk)	...............risk
равновесная цена (equilibrium price)	...............demand
самовыполняющийся прогноз (self-fulfilling forecast)	...............forecast
системный анализ (systems analysis)	...............systems analysis
скалярная оптимизация (single-objective optimization)	...............optimization
скалярная цель (scalar-valued objective)	...............optimization
снижение удельных затрат при расширении производства (economy of scale)	...............economy of scale
состояние мира (state of the world)	...............environment
состояние мира (state of the world)	...............state of the world
состояние природы (state of nature)	...............environment
спрос (demand)	...............demand
статическая модель (static model)	...............model
стохастическая имитация (stochastic simulation)	...............model
стохастическая модель (stochastic model)	...............model
стохастическое программирование (probabilistic programming)	...............optimization
стохастическое программирование (stochastic programming)	...............optimization
структура модели (model structure)	...............model
субоптимизация (suboptimization)	...............suboptimization

Термин	См.
субъективная вероятность (subjective probability)	decision theory
сценарий (scenario)	scenario
теория игр (game theory)	game theory
теория полезности (utility theory)	utility
теория принятия решений (decision theory)	decision theory
теория сопряженных измерений (conjoint measurement theory)	value
технологический коэффициент (technological coefficient)	input-output (Leontief) analysis
точка в пространстве целей (target point)	objective
увеличение удельных затрат при расширении производства (diseconomy of scale)	economy of scale
условный прогноз (conditional forecast)	forecast
участник игры (actor)	role-playing
участник игры (decision maker)	game theory
участник эксперимента (player)	role-playing
формальная модель (formal model)	model
функция благосостояния (welfare function)	utility
функция выигрыша (payoff function)	game theory
функция полезности (utility function)	utility
функция предложения (supply function)	demand
функция спроса (demand function)	demand
функция ценности (value function)	value

ТЕРМИН	СМ.
характеристика (attribute)	attribute
целевая функция (objective function)	optimization
цели (multiple objectives)	objective
целочисленное программирование (integer programming)	optimization
цель (goal)	objective
цель (objective)	objective
цель (вытекающая из исходных и сформулированная более конкретно) (proxy objective)	objective
ценность (value)	value
человеко-машинная имитация (man-machine simulation)	simulation
человеко-машинная модель (man-machine model)	model
эксперимент (experimentation)	experimentation
экспериментирование (experimentation)	experimentation
эластичные ограничения (elastic constraint)	constraint
эффективность (effectiveness)	effectiveness
эффективность (efficiency)	efficiency

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decision maker,   *X    Ent: alternative
decision maker   *X    Ent: decision theory
decision maker   *X    Ent: environment
decision maker   *X    Ent: risk
decision maker   *X    Ent: secondary decision
decision maker   *X    Ent: utility
decision maker,"   *X    Ent: value
decision maker   *X    Ent: consequence
decision maker   *X    Ent: course of action
decision maker   *X    Ent: objective
decision maker   **X   Ent: systems analysis
decision maker   **X Ent: externality
decision maker   **X Ent: game theory
decision maker   *E
decision maker, risk-averse   **E(kwic for: risk-averse decison maker)  Ent: utility
decision maker, risk-neutral   **E(kwic for: risk-neutral decision maker)  Ent: utility
decision maker, risk-prone   **E(kwic for: risk-prone decision maker)  Ent: utility
decision makers   *X    Ent: role-playing
decision maker's   *X    Ent: trade-off
decision, primary   **E(kwic for: primary decision)  Ent: secondary decision
decision, secondary   **E(kwic for: secondary decision)  Ent: secondary decision
decision taker   ***S   Ent: decision maker Syn. for: decision maker
decision theory   *X    Ent: risk
decision theory   *X    Ent: trade-off
decision theory   *X    Ent: uncertainty
decision theory,   *X    Ent: utility
decision theory;   *X    Ent: utility
decision theory.   *X    Ent: value
decision theory   *X    Ent: consequence
decision theory).   *X    Ent: optimization
decision theory   *E
decision under certainty   **E  Ent: decision theory
decision under risk   *E   Ent: decision theory
decision under uncertainty.   *E   Ent: decision theory
decision variables,   *E   Ent: optimization
Delphi method  *E
demand  *E
demand function,   *E   Ent: demand
deterministic model   *E   Ent: model
discount rate   **X   Ent: systems analysis
discount rate   *E
discretization   *E    Ent: optimization
diseconomy of scale,   *E   Ent: economy of scale
dominance  *E
dynamic model   *E   Ent: model
dynamic optimization problem   **E    Ent: optimization
economy of scale  *E
effectiveness   *X    Ent: efficiency
effectiveness  *E
efficiency  *E
elastic constraint   **E    Ent: constraint
environment;   *X   Ent: sensitivity analysis
environment.   *X   Ent: state of the world
environment   *X    Ent: contingency analysis
environment  *E
equilibrium price:   *E   Ent: demand
```