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Reflections on the Scientific and Political Significance of Decision Theory

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Introductory Remark

The following exposition is an intermediate report and an attempt to analyze the various approaches that can be classified under the name of decision theory; their common characteristics, their relationships to the system of science and to the practice of political decision are to be investigated. Hereby, some basic remarks concerning the concept of science, on the relationship between theory and practice and on the role of research and development in modern social systems are produced. A good part of the following presentation is dedicated to these basic problems. In the description of the characterisitics of decision theory, the main weight will be laid on the difficulties which such a science brings with itself. The existing partial theories and specific models are to be mentioned only peripherally. It is, however, considered important to retain these results without contradictions; at least, comparable with the present statement. The description of the mathematical formulations and empirical procedures is not attempted here. At the present stage of investigation, only a sketch of the considerations is possible. It lies in the nature of the subject that terminological difficulties arise (especially in a presentation in German, since there barely exists a linguistic convention in this area). It is to be understood that the formulations given here demand further precision and clarification.

I. The considered sciences, created in the last two decades under the titles operations research, cybernetics, information theory, game theory, system-engineering, to mention only the most important, have many common starting points and overlappings. This is not surprising if one considers their origin. They are all products of the Second World War. It began with the "obligatory service" of scientists for the solution of new organizational and technical tasks of modern warfare which went beyond the competence of the military and engineers generally. The development of radar, the supplying of continent-wide theaters of war and the development of strategies, presented problems in planning and decision which could not be solved in the orthodox manner with a sufficiently high expectation of success. The results of this scientific cooperation produced not only new technologies such as that of communications, of data processing, or of astronautics, but those first efforts have lead to new independent sciences with increasingly peaceful applications. They have also become important and necessary tools of planning, of politics, and development. In the United States, for example, the scientists occupied in these fields run into the tens of thousands; many million dollars are annually spent for furthering and -- above all -- for applying these techniques.

The common characteristics of the above-mentioned disciplines are to be explained through the cause of their advent: they have been invented for situations under a concrete condition (Handlungszwang) in which the scientist not only officiates as an advisor in the orthodox sense, but also as a co-responsible "decision-aide". For this the following motives are characteristic with respect to these disciplines:

The stakes are very high. The expenses of faulty decisions are so great that it pays to found and secure the decision with the best available means, or even to develop new methods for "preparing" the decisions (for example, with problems of defense strategies, with problems of the support of under-developed countries, with problems of atomic technology and space travel).

The respective problems cannot be solved in the orthodox manner -- they are too voluminous and complex (for example, the space program). Greater rationality as well as increased economy is desired (for example, through automation).

Systems are desired which offer effective safeguards against catastrophes caused through insufficiencies and deficiencies (for example, a defense system safe against Herostratos and chance; an economic system effectively secured against crises).

Knowledge is required as to which goals ought to be pursued sensibly.

It becomes evident that the goals anticipated politically and ideologically are too crude and too general to derive from them directives for a concrete and far-reaching decision: "historistic" programs prove to be less and less effective as practicable norms for political decision. (For example, developmental planning or defense politics.)

There is, in addition, the ubiquitous conviction that in the face of these requirements a scientific manner of proceeding is meaningful and promises to be effective. In the age of "scientification" this speculation is current; it does in turn, however, fall under suspicion as a positivistic philosophy of history. Scientific attitude with the

claim of absoulte objectivity comes dangerously near to uncritical faith in progress. The justification of scientification is to be deduced from its effects: scientific method -- specifically the method of the natural sciences -- has become the most effective tool for the shaping of reality ('scientific method' unfortunately has no corresponding term in German. The methods that are being referred to here are naturally not only "natur-wissenschaftlich"; what is meant here, is the specific mode of procedure and not its object.):

> Wissenschaft ("science") progressively spreads like a disease. . . . Exact methods can hardly ever be shaken off again.
>
> (O. MORGENSTERN)

> That attitude, which places the rational sciences and technology in the center of thought, offers greater chance of survival than the sulky annoyance about technology which often characterizes the Western intellectual!
>
> (K. STEINBUCH)

The scientific method has become the modern analogy to the program of Spinoza, to investigate the world "more geometrico".

The new tendency towards "engaged science" has, however, not remained without consequences for science and its ideology. The classic ideal of science provides it with the exclusive task of striving for new knowledge since new knowledge means progress in an absolute sense and thus has to be considered as desirable "for its own sake". The practical usefulness of this knowledge is hardly considered as a problem of science: it will eventually show itself. Science constitutes a reality of its own, an autonomous province besides the "extrascientific" world.

This ideal has proved itself to be quite effective. Science as a generator of "innovation" isolated from the vicissitudes of the world of events is an important element of modern social systems.

The new disciplines to be discussed here do, however, represent a type of science, which cannot be fitted into this program:

> They are not to produce knowledge for its own sake without consideration for its future application, but rather in view of concrete tasks of action. Their results are recommendations for action. The scientist is a participant ("player") in planning and the decision.

The decision-process itself becomes the scientific object. It is questionable whether such activity should still be called science. If one nevertheless does, a revision of the concept of science is connected with it, which would make the traditional ideal one extreme case on a scale. The basis of such a theory of science cannot only be an "epistemology", since knowing is only a component of acting. Nor could a linguistico-analytical theory of science (sprachanalytische Wissenschaftstheorie) fulfill this role. One would need a "theory of action" ("Handlungslehre") as basis which would conceive knowing as a requirement of acting. In this following sense a science would lose, however, many of what have been up to this point typical characteristics:

> A science which goes this far, gives up its objectivity as well as its immunity. Tomorrow's science will not be objective . . . future science will not be politically immune.
>
> (CHURCHMAN)

The above-mentioned fear of a positivism in disguise is invalidated through such a concept of science -- or at least weakened. When the activity of science surrenders its apodictic claim of objectivity, and when it, including its targets and values, is subjected to historical change and the interplay of forces, it loses the character of a "patent ideology" and of a rigid, absolute authority.

II. Attempts are not lacking to draw the consequences from this, and to systematize the above-mentioned new disciplines according to their common qualities and characteristics, and to relate the whole to the system of traditional sciences. An entire chain of suggestions for "Umbrella concepts" and collective designations exists, of which, however, so far none has been accepted. In contrast to the specification according to field of object, as in common use in the traditional sciences (Physics, Economics), the new disciplines are characterized through a great range of objects (cybernetic observations are adequate for economic as well as biological circumstances), for which reason a classification according to methods and approaches recommends itself more. It could be surmised, that a designation like "general methodology", "system science" or "Praxeology" (OSKAR LANGE) will prevail as a guiding concept. One may consider this question of nomenclature as secondary, and be of the opinion that only results are interesting. Concepts, however, are programs. A name delimits the designated. And the designation of this "theory of action" (Handlungslehre) determines its role. To mention only a negative example: It has become common usage in German to translate "operations research" with "Unternehmensforschung". This may be understood in an era of an economic boom, but this designation, if it does not completely exclude, does not at least allude to the non-economic applications of this discipline (as for example the application to city and regional planning, research planning, politics).

The science to be discussed here is thus one of action, in particular of purpose-oriented actions ("zweckrationales handeln", WEBER). Such a science is simultaneously:

Deductive (like mathematics) since it deduces conclusions for axiomatic systems and constructs models for various types of actions.

Inductive (like physics), since it assimilates empirical evidence on behavioral patterns into hypotheses, which form the basis for theories.

Instrumental (like engineering), since it develops the means and methods for application in concrete situations.

Pragmatic, since it continually considers this applicability and participates in the application itself (as in medicine).

Such a science is of "metascientific" character, since it:

cannot be incorporated into any of the existing sciences;

refers to many of the existing sciences;

has as an object the process of science;

develops new methods;

establishes a language that is adequate to speak about science, and to carry on research on research;

allows occasionally to carry over indications from one science into the other;

uncovers structural relations between different sciences;

investigates relationships between research, development, and implementation, identifies the connections between science and its applications, and neutralizes the polarity of theory and practice.

Such a science is, according to this nature, "interdisciplinary". In all these disciplines, representatives of the most various fields have

participated from the beginning: engineers, mathematicians, biologists, economists, sociologists, political scientists, physicists and philosophers. Apart from graduate programs in operations research, today there hardly exists a training for these new sciences, and therefore as usual commonly carried out and developed by the most different types of specialists. Optimists and enthusiasts may see a possibility for the restoration of the widely-mourned universitas litterarum in this fact.

III. As indicated, there exists today no such meta-science in a rigorous and consistent form. Only attempts and tendencies exist. The present state of development reveals on the whole two main tendencies or foci which can be summarized under the names of 'systems research' and 'decision theory'.

The object of system theory is the behavior of systems. A system is a multi-variable entity (a communication system, a process of production, an ecology, a biological organism, a military organization). The behavior of systems is described through the temporal sequence of their states. Systems are decomposed into components which are linked to each other according to cause-effect relationships. These relationships do not present themselves here as fluctuations of matter or energy. In contrast to the traditional physics or technology "fluctuations of information" are being considered. Information is the substrate that is transported and transformed (e.g., the message about a flow of energy). This characteristic results from the intention to investigate mainly the organization, control and regulation of a given system. Systems research is not limited to the observation of existing systems. Among its main intentions is the design of systems which have to fulfill a specific

purpose or mission. Especially important in this context are the so-called "man-machine-systems" for which an adequate work distribution between human and mechanic components has to be determined. The categories of system theory, such as "determinateness", "stability", "feed-back", (Ruckkoppelung), "complexity", "card-indexing", "self-organization", "learning" are so constructed that they do in fact allow a characterization of the most diverse systems. Under the heading of systems theory can also be counted theories of design and of heuristics. It embraces large areas of cybernetics, of operations research, theory of communications, and also parts of game theory -- besides results of human engineering, psychology, communications and modern statistics.

In comparison to this, under decision theory can be gathered all those activities which inspect the problem of the adequate determination of an action that transfer a given situation into another situation which is most appropriate in view of the goals and intentions of the "actor". The class of the situations of decision which are thus to be regarded, ranges from that of the politician to that of the economist or the military up to that of the scientist or even the chess player. "Risk", "strategy", "utility", "rationality", "expectation", "goal" are relevant concepts for all these situations.

This dichotomy of the present situation of "Praxeology", designates, as mentioned above, only focal points of development. A decision maker including his counterpart can obviously be conceived as a system; and on the other hand the decision of a system presents itself also as a sequence of decisions. In the following mainly those approaches will be investigated which have here been designated as decision theory.

IV. The phenomenon of decision has so far been a realm of philosophy, theology and historical science, to a certain degree also of psychology. Along with this, the question about the "essence" of decision has pushed the problem of technology and the practice of decision largely into the background. The "philosophy of practical reason" has only found little interest in the last decades. The process leading to a decision has hardly ever been the object of scientific investigation. Commonly the capacity for difficult decision is considered as the privilege of the blessed individual. One could hardly learn it; rules and prescriptions would not exist for it. Foresight, prudence, sense of responsibility would be factors, that could not be described more closely. Rules of decision, such as had been indicated for example by MACCHIAVELLI were immoral and cynical; the maxims of the moral philosophers are considered as trivial and obvious. For everyday use "common sense" is by all means sufficient. And the athlete of the consequential and difficult decision, the hero of solitary resolution, and the "resolute ('decision-happy') personality with decades of experience" is a most sought-after rarity as newspaper ads indicate every day.

Anyone who in face of these opinions deals with the phenomenon of decision by scientific means -- especially by those of natural science -- falls under the suspicion of designating something as decision, which in no manner corresponds to the "essence" or "character" of decision. Obviously it cannot be only just a question of carrying over of scientific concepts -- even if tempting analogies are present. One would all too easily arrive at forbidden biologisms. Concepts like "struggle for survival", "natural growth", etc., should at least be excluded from the basic investigations. Only the ways of reasoning of science should be

transferred, as has been discussed above. The question, whether the objects of such an investigation are really or could at all be decisions in the commonly accepted sense of the word, should not be discarded as unessential. The scientific use of a concept is often accompanied by essential conceptual shifting and narrowing (consider, for example, the precision of the concepts of force and energy on the past century). The clarification of a concept is at least necessary to avoid endless discussions on whether the essential has really been grasped.

The object "decision" actually brings with itself a number of remarkable consequences for its scientific investigation. First: any scientific activity is itself a sequence of decisions. These decisions rest on value systems, which are particular for science. The selection of research objects as "scientifically interesting", the formation of concepts, the determination of norms for scientific accuracy, already rest on conventions and traditions of a "pre-scientific character", which are nothing else than value systems. Since a science dealing with decision necessarily also contains a science of values, can one distinguish methodically a special value system, namely that of science? Does one not then silently or even unadmittedly assign to this special value system a superiority over all other value systems, that would be unjustified according to the very standards proper to science?

Without resolving this paradox: the "scientifically more adequate" position is that which also includes the scientific value systems in the investigation and surrenders their claim for absolute objectivity. The scientific value system is also subject to change; it has its place in the antagonism between value systems, and the scientist is nolens volens

a political partner in the resulting controversy. This is valid for any science, but in particular for a science of decision.

In face of recent political developments, the increasing influence of the scientists on politics is extensively discussed. The role of the "advisors" on the international political decisions in the United States furnished a special occasion for numerous critical remarks on academic know-it-alls. This development will continue nevertheless, since no other alternative is at hand. The institution of science has changed its role. The unavoidable consequence of the scientification of politics is the politization of science.

V. Before the question is attempted as to what should be understood as a decision, one must choose one of the two following standpoints:

A. The standpoint of the external observer, who studies the behavior of a decision-making system "from outside" without involvement;

B. The standpoint of the decision-maker: the scientist himself has to decide, or he joins the party of a decision-maker.

In both cases the determination of an object system (O system) is dealt with; in the first case one wants to understand, that is predict the behavior of the decision-making object. In Case B the object is to be changed through active behavior in a desired sense. Determination is equivalent to reduction of uncertainty. This can come about through the improvement of prognostic capacities or through active intervention.

In Case A rules on the decision behavior of an O-system are to be determined empirically. This is done by constructing a model of the

object in question which contains the knowledge about this object. This model is sufficient when it permits deduction of the behavior of the object through the knowledge of given past situations for a future situation, that is to say, to prognosticate. For this purpose one must look for the determinants which direct the behavior. If one takes the behavioristic standpoint -- or more neutral: that of "verhaltenstheorie", this information can only be received from observed behavior. When is it possible, under such circumstances, to characterize a behavior pattern as controlled by decision? Is not decision a concept derived from introspection which can only be applied to other subjects which we normally regard as sufficiently alike to ourselves? There are easy and difficult decisions, but the consumption of energy for a decision seems to be immeasurably small, and thus hardly detectable for an external observer. Identifying decision acts by measuring the physical effort involved is as good as excluded; it remains to try the approaches of the theory of communication.

According to this standpoint decision processes have to be identified and analyzed on the basis of the order and the structure of the sequence of states which describe the object-behavior, from its "behavioral trajectory". If one imagines the manifold of possible states of the system as geometrical space, the behavior of the system is mapped into a path in this space. Each point of this path is labeled by that point in time in which the system assumes this particular state. Of course, considered retrospectively, this part forms a single trajectory without proliferations. This, however, is different if the behavioral trajectory is to be extrapolated into the future. Then the extension of the past trajectory will generally proliferate into various future

possibilities. This "fan" will be the narrower the better the knowledge of the behavior of the system to be observed. This bundle of possible and more or less expected trajectories will diverge with increasing distance from the starting point, that means with increasing temporal range of prediction. These prognostic fans are as a consequence of imperfect determinateness of the system.

There are also cases where the prognostic fan consists only of very few trajectories which can be well distinguished and which can be considered discrete alternative proliferations of the past trajectory. When in the previous case the different trajectories could be weighted with different degrees of expectations (a path can be more or less 'probable'), now each of the parts has a high degree of expectation. It is impossible for the experimenter or observer to determine the choice of the parts from the preceding behavior of the object. Such proliferation-points of future trajectories will be understood as situations of decision. They are singularities in the observer's model of the object behavior.

If this interpretation is accepted then also a die or a rat in the maze of a psychologist are making decisions, because their behaviors display such singularities of selection from discrete sets of alternatives. This is not miraculous at all, because dice are deliberately designed to have six stable equilibrium states each of which can be reached by a great manifold of trajectories. Depending on the initial conditions of a throw, it is in this complicated way that there is not the slightest chance for prediction. For this reason a die is most appropriate as a "synthetic decision maker" in a parlor game or as an oracle. A maze is

deliberately designed to impose discrete alternatives to a confined rat. The psychologist is playing against the rat. He is betting on his behavior. Once the rat has learned the task he has lost the property of a decision-making system. There is a number of behaviorists' jokes on this subject: "From his point of view", after having learned his task, the rat could claim to have conditioned the experimenter: Finally, the rat has taught him to dispense food whenever the rat chooses to walk through the maze.

The observer's model determines the events of decision for his object system. They are the events of alternative expectations of behavior. Each decision of the object system programs a segment of its observed behavioral trajectory by actuating one particular trajectory from the set of those conceived by the observer. Decision theory from standpoint A looks for 'motives' for this choice, i.e., for determinants in order to improve the object model. The better he succeeds in this attempt the more the object loses the property of making decisions in the class of situations considered.

VI. Case B is different. An Actor System (A-System) is in the position to have to program its behavior in face of an object system (O-System). The Actor System must act (is under "hundlungszwang"), if non-action or passing the next move is also considered a mode of action. A decision situation is given if one of several alternative possibilities of action has to be chosen. Again it depends upon the A-System when this will be the case; in any moment it can pause and search for alternative courses of action, or it can submit itself to the inertia of its previous

behavior. It seems to be a psychological characteristic of this decision process that it is carried out "consciously".

Once the alternative possibilities of behavior have been generated the burden of decision could be delegated to a mechanism -- say a die or an oracle. This, however, is advisable only in those rare cases if there is no reason to prefer one of the several alternatives. Otherwise, one looks for arguments and tries to weight them until the symmetry of perplexity in face of the alternatives has been disturbed in favor of one of them. It is characteristic for conscious decision-making that its preparation consists in "reducing the problematic" of decision. The process of motivation is continued until it has become clear that the final choice has to be this or that and nothing else. Afterwards, it would become "irrational" to choose one of the other alternatives.

Decision without motive does not seem to exist. Andre Gide in his novel, "Dungeons of the Vatican", makes his hero Lafcadio try in vain to commit the "act gratuit". The endeavor to commit a crime without a motive must fall. As long as there is no culprit, society looks for motives until it finds a plausible suspect -- even if he is not the "true" criminal. He is considered the true culprit until justice and society have found a more plausible one. This is a basis of all criminology and any writing of history. Decision theory has a task to help in generating appropriate alternatives and to reduce the uncertainty of choice among them until one of them is clearly preferable. It hardly needs mention that, of course, wrong decisions cannot be excluded by this procedure. Obviously, the process of motivation can be based only on the existing knowledge of what the A-System considers desirable and on its knowledge

about the behavior of the O-System. (This knowledge can have been acquired from standpoint A.)

In the following, standpoint B will be assumed. All real cases are mixtures of A and B because there is nothing like an uninvolved observer in his pure form (almost no observation remains without effect on what has been observed).

VII. In order to design a decision model a methodical trick is most useful. It is assumed that the burden of decision has to be delegated to a "machine" and it is asked how such a machine would have to look, which data would have to be fed into it, etc. This is to be understood only as a paradigm and does not mean that the decision has to be really delegated to a machine. This thinking model has become a useful tool if one wants to understand what is meant by "learning", "intelligence", "perception", or "decision". Such a machine becomes a 'mirror' or one's understanding of these processes and properties, because it displays a behavior "homomorphic" to our formulated ideas. Comparing the behavior with what is "meant", our ideas and formulations of what we mean can be revised and made more precise. At least in principle, everything that can be formulated as a rule about behavioral trajectories can be mechanized.

But also the real delegation to a machine is gaining practical importance. Computers are programmed according to a decision model and they are made to trace the consequences of different strategies, for example, sequences of action. Or the machine may be given the role of the object system, and one may play "against" it. For many cases where the task of determining "optimal decisions" cannot be delegated to the

machine (which is possible now for only very few standard types of decision tasks). Machines can be successfully applied for simulating the real case ("Ernstfall"). Simulation techniques are the modern analogy of the sandbox of classical army general-staffs. They have become a valuable tool for training and education.

VIII. The decision model is a homomorphic mapping of a decision situation or a class of such situations. It has the following components:

an Actor System (A-System) which has to decide;

an Object System (O-System) which is affected by the decision.

The A-System can be an individual, a group or organization which is given as a system of people, machines and rules.

The O-System is the object, the opponent, the enemy, or the friend with whom to cooperate. Sometimes it is advisable to ascribe "actor" characteristics to the O-System, particularly in all those cases where O produces such reactions to the actions of A which can be best understood as being "interest-oriented".

As a rule, all those phenomena and entities should be included in A which are under control of A, e.g., which sufficiently reliably carry out the actions of A. (The case of unreliability in one's own rank and file has its own problems.)

The data and relationships entering into the model can be classified as follows:

The variables are under control of A. They define the decision space, that means the manifold of alternatives. In order to talk about a decision situation it must contain more than one possibility. Of course, the decision space contains only those

alternatives which have been identified and which can be realized within the possibilities of the finite potential of A. These variables of O which are of importance for A and the states of which can be observed or deduced indirectly (essential variables). The regularities (constraints) in the behavior of O as functions between observables. Here, for example, belong all scientific results about the behavior of O. These relations are the constituents of A's "picture" of O.

The expectations about the effects of the alternative actions of A. They consist of all the knowledge about how the variables controlled by A's influence on the essential variables of O. These are relations which connect both kinds of variables with each other. Usually these expectations are risky or uncertain.

A goal or an intention of A determining which states of O are desirable and which ought to be avoided. Sometimes an ordering according to the degree of desirability of the possible states of O has been established. Here the gross objective function, according to which only the states of the object system are evaluated, has to be distinguished from the net-objective function in which the cost of the actions leading to the attainment of a certain state of O are balanced against the value of attaining that state.

The attitude of A towards the decision situation. It is formulated as a decision criterion. A can act cautiously, pessimistically, suspiciously, and so on. The decision criterion reflects A's attitude towards his own uncertainty

and ignorance. Decision criteria are relations between types or degrees of uncertainties about expected effects and evaluations of situations. They represent the "psychology" of A.

Rules of behavior which exclude certain measures of A (although the potential of A would 'technically' allow for them), or which prescribes certain actions although they might be of little direct usefulness for A. Into this category belong social standards, ethical principles, etc.

Such restrictions can also be considered as constraints in the decision space. They are listed here separately only in order to emphasize them as independent factors of influence.

Each of these components of a decision model has its own difficulties. Variables can be sets of logical alternatives, ordinal scales, or continuous. Relations between variables can be logical functions, probability distributions, or continuous differentiable functions.

A mathematical model on this general level of consideration is not very profitable. At most some conditions for formulating the various entities and their relations can be derived. Mathematical models become interesting and powerful, however, if particular classes of decision situations are to be investigated. (Like two-persons-zero-sum games, transportation problems, tasks of regulation and control.) In any case, mathematics does not start before all the variables and relations mentioned have been appropriately determined, i.e., after the model has been constructed. The process of constructing the model is not very well understood; it is usually "empirical". Defining appropriate concepts and rules of measurement brings along a host of difficult problems for each of

the model components. In recent years, considerable effort has been invested into these problems, the results of which, taken by themselves, would already justify the existence of decision theory. These results permit us to distinguish and to describe a great number of realistic decision situations -- even if the subsequent mathematical treatment of the decision model is still a long way off.

The anatomy of decision processes has made their characteristics manifest; it permits the possibility to distinguish cases and their characteristic properties. Thus, the strictly antagonistic two-person-zero-sum game will be a very rare situation in reality, since most conflict situations have also cooperative traits. Nonetheless, the mathematical model of this extreme case, together with those of some other extreme cases, determine the range of variation in which real situations are contained as mixed forms, thus, e.g., allowing for the definition of a "degree of antagonism".

A few of these considerations are to be discussed in the following in order to demonstrate the modes of reasoning and the difficulties of decision theory.

IX. Let us consider the question of the goals, objectives, and intentions of A. The question is answered once it has been specified which values are to be assigned to the various situations of O- and the A-System. In addition, there has to be an imperative: "Try to achieve a situation which assumes a value as high as possible".

Apart from the fact that an actor very frequently doesn't know himself what he wants, several other difficulties remain:

Which point in time does the set of considered situations refer to? Or is it the sequence of situations, a period of time which has to be evaluated? How to compare this year's business profit with that of next year? Which inconveniences are people willing to invest to the benefit of a higher degree of happiness for their grandchildren? Which interval of planning is reasonable? How to discount the value of different situations into one particular point of time?

Real situations are distinguished by their multi-variability, that means by the multitude of aspects according to which they are to be evaluated. Apartments are evaluated not only according to their rent, but also according to their plan, their location, their heat insulation properties, and so on. A military situation is not only evaluated according to the losses of the opponent but also to one's own losses. Each dollar spent for a particular research project cannot be spent for any other project. The scientific success of a company cannot be measured by profit alone but also by its liquidity, its share of the market, the number of orders, its position among the competitors, etc.

Usually a situation is characterized by man "On-the-one-hand; but-on-the-other-hand" statements: from one particular standpoint situation S_1 is to be preferred to situation S_2, but with respect to another standpoint it is just the other way around. Which situation is to be preferred? How to map the vector of evaluations under different aspects on one linear scale?

A further difficulty lies in the fact that subjective utilities of different persons cannot be added. The reason for this is

that the degree of pain or pleasure cannot be transmitted from one person to another. In no way can the measures of satisfaction of different persons be compared with each other. According to the theory of measurement the reason for this is that utility scales are difference scales (like temperature as measured on the Centigrade scale), the zero and the unit of which are arbitrarily agreed upon. In addition, there are no situations in which these fixed points of two subjective scales can be compared with each other (in contrast to the Fahrenheit and Centigrade scales); This fact becomes particularly important if social welfare functions are to be constructed. How is the utility for a single person computed into the utility of society? How can the utility function of an institution be derived from the utility function of its members? Decades of attempts by economists to define a social welfare function which could be determined empirically, have been frustrated.

Nonetheless such social welfare functions are required in order to determine the value of research institute or of a park in a town, or of a public transportation system. Any facility is useful only for some A system. In the cases mentioned, however, the A-System is not a single person and not a profit-oriented institution;

A goal has a form: "A wants to produce situation X". Here usually X is only a partial X aspect of a total situation. Other, implicit aspects of this situation are nonetheless important, unless X has to be obtained "at any price". Every positively

formulated goal implies a long list of tacitly implied conditions which exclude many straightforward ways to the goal. In order to construct a goal-function all the tacit assumptions have to be made explicit.

If, e.g., it is the goal to "increase agricultural food production per capita of the population", then this can be reached by increasing productivity, or by expanding the agricultural sector of the economy, but it may also be achieved by a reduction of the total population. In order to exclude both of the latter possibilities, many further conditions and side goals have to be formulated;

Political and ideological goals ('increasing general welfare', 'support of private property', 'establishing the communist society', 'guaranteeing world peace', 'the greatest happiness for the greatest number', 'completing history') are usually lacking the precision of their conditions and side goals. They demand the attainment of a target situation without stating anything about the way that leads to that target state, and without specifying the permissible "cost". In particular, they do not answer the question of possible detours: occasionally, it may be advisable to deviate from the direct path to the goal, or even to temporarily increase the distance to the goal in order to reach that goal more efficiently, or because the circumstances require it. Consequences are the restriction of liberty for the sake of preserving liberty; the limited war in order to avoid the unlimited conflict; today's privation for the sake of the

happiness of future generations. Goals of the kind mentioned do not give instructions about the means for their attainment. Hardly any decisions can be derived from them for today's behavior. This is the reason for the astonishing fact that, in spite of fundamentally different ideologies, states can display forms of behavior which in concreto are very similar to each other. The same "problematic" is demonstrated by numerous historical examples of terror in the name of the most sacred ideals.

Moral systems as standards of behavior which are independent from particular situations are also not sufficient to determine the path to the attainment of the respective goals. Most of them are prohibitive and not prescriptive, but, even more important, the "problematic" character of decision situations is usually due to conflicting principles of moral. This is the dilemma of the Schiller Type (when the obligations to one's country conflict with those to the family, or those to mankind with those to its individual representative, for example) or the drama of the Sartre type (the problem of "dirty hands": there is no alternative without moral defect).

Many of these difficulties have been treated by modern decision theory. There are quite a number of methods, models and conceptual systems for the identification of goals, for the measurement of utility, and for the analysis of value systems. Nonetheless, the whole complex is far from being sufficiently queried and ordered.

Perhaps it was Bernoulli (1735) who first tried to develop a theory of utility. He tried to determine the "moral utility" of money by

which he understood its subjective value. He postulated that this subject of value is not proportional to the amount of money; instead, the utility per unit would decrease with every additional unit. Based on some psychological assumptions he derived some kind of a marginal utility principle. His theory is normative, like all theories of utility in the subsequent 200 years -- including Gossen's theory of marginal utility. Not before 1950, Mosteller and Nogee, stimulated by the considerations of Von Neumann and Morgenstern, made first attempts to measure utility empirically: the science of utility and value becomes an empirical science. It had become clear that the great variety of human wishes cannot be derived from a couple of principles which can be regarded as common to all men. Indeed, there is no single one value system which has been accepted by all people at all times. There is neither something like the "minimum need" nor are there accepted opinions about what the word "happiness" means. This fact considerably complicates the science of value, but makes the science much more realistic. A descriptive "natural history of value systems" is still to be developed. The analytical apparatus required for this and some normative models are available, at least as approaches, and for simple cases.

X. A great number of gigantic planning tasks with long-range effects as they occur in defense politics, but also and more and more frequently in economic and technological developments, have brought the problems of goal determination to high practical relevance. Consequently, considerable research efforts have been made in this field which have brought quite a number of fundamental results which brought a substantial reorientation of the questions and the opinions about goal-directed decisions.

It has been found that the traditional action principles like "maximizing profit", "strengthening one's power", etc., are meaningful at most for short-range and very limited decisions. For decision tasks of a larger scope they are useless, not only because uncertainty increases with increasing temporal scope of the planning interval (the predictive capability for estimating risks rapidly decreases) and because the capability for developing alternative courses of action rapidly decreases, but mainly because principles of this kind are losing their meaningfulness. This is true particularly for an era of rapidly changing political conditions and technological possibilities. Value systems cannot be considered stable over longer periods of time. What can be desired and what ought to become possible depends of what is desired. Goals and welfare functions are no independent entities. They are in close mutual interaction with the decision space. Value systems are malleable within wide ranges (as e.g., the "creation of demand" for consumption goods through advertising).

In face of the uncertainties of "alternative futures" it is hopeless to attempt the design of rigid decision models which produce strategies over longer courses of time by considering very many variables. These attempts at constructing well-balanced goal functions and developing very many alternatives depending upon one's own course of actions in order to determine the "optimal course of action" are futile. (Such an optimal strategy would prescribe the courses of actions to be carried out dependent upon all possible intervening events.)

It proves to be more meaningful to generalize the problem of decision and to consider the organization and the aptness of decision-making

systems: how to design an organization which can operate under those uncertainties of innovation and political change? Here decision theory becomes closely connected to systems research, mentioned above. Instead of those "natural" goal functions, now, entities like "stability", "ultra-stability", "adaptability" become objective variables. Instead of taking a certain decision-making system and value system as given, the aptness of the system for fulfilling its tasks is investigated:

> Which feedbacks to the object systems are necessary? Which data about the object system are needed with which degree of precision?
>
> Which organization is appropriate for processing these data?
>
> Which value systems are consistent and free of contradiction?
>
> Which value systems guarantee a chance for "adaptation" and therefore "survival"?
>
> Which "innovation policy", that means, which policy for extending the decision space is appropriate in the face of unknown "futures"?

To give a few examples for this type of problems: it would be useless to design an educational system today which is based on a prediction of the demand for electrical engineers, biochemists, and so on, in the year 2000. In face of large changes of demand, which may be expected as a result of unknown developments, an optimization under this point of view would soon be falsified. Instead, one should have educational facilities which can adapt themselves to such changes of demand. Or, in the United States, the government is sponsoring research projects in which it is investigated which attitudes and value systems the population of the U.S.A. would have to adapt in order to improve political and economic stability. Into these considerations deep-rooted attitudes like those

towards death have to be included. "Survival" is not sufficient as a long-term motto. In this context belongs the program to increase the "economic awareness" of the citizens of the United States. This is attempted, for example, by experiments with carefully worked-out television courses about economics designed to improve the insight into the mechanics of economic processes, resulting, hopefully, in a decrease in the proneness to crises. This is motivated by the belief that economic crises to a large degree are the result of "wrong" reactions of the individuals, which produce snowball effects. It is further believed that widely-spread knowledge of these relationships and their consequences could moderate or even dissolve the determinateness of such crises which otherwise have almost the inevitability of a natural law.

Another example indicates that governing a large nation requires a high capacity for decision-making; i.e., a great number of decisions have to be made per time unit with as short a delay as possible between the cause of the decision and the response. A great number of receptors is incessantly feeding messages into the decision-making system. In the U.S.A., for several problem areas, the processing of the data stream into manageable and relevant decision messages has been mechanized to a high degree. This data transmission system and the data processing system together provide the required speed of reaction, thereby securing sufficient and stable decision capability. In addition, these systems have to be secured against failure and destruction in order to reduce the probability of their failure. To this end the most refined devices and provisions have been developed which consider even events like the psychic failure of the President. Another group of research projects deals with the stabilization of a governmental structure against catastrophes by mistakes

of the political organization. These projects inquire into which governmental organization and which constitution are compatible with basic political convictions and which nonetheless guarantee high stability.

Finally another type of approach ought to be mentioned because of its long-range impact. It is the area of innovation planning. As discussed above, rigid planning on the long range is mainly frustrated by the permanent change of technical possibilities. This change is mainly due to research and development. Therefore, any long-range planning has to consider the programming of these activites. It could almost be postulated that long-range planning is equivalent with innovation planning. This does not mean that invention and discovery could be predetermined. But research activities can be carried on with different intensity on this or that area, and it can be organized in different ways. Already the fact that research resources have to be allocated to the different areas of research, that new research institutions are founded all the time, that there are science policies, and that research contracts are commissioned -- all mean that decisions with long-range effects are made all the time. Awareness of the long-range character of these effects is not everywhere sufficiently developed. Germany is a case in point. Not only what will be the case tomorrow, is essentially influenced by today's innovation policy. That part of decision theory, dealing with these types of decisions, has been named "R & D planning". In this area -- again mainly in the United States -- in the last ten years a great number of results has been obtained which relate to questions of appropriate project selection, of educational planning, of the scientific organization of labor, research and development budgeting and so on. Of course, in the United States also many an organizational failure and many a false decision in research and development

has been made. But the awareness of the long-range importance of these activities, of the influence of the organizational form of science, and the insight into the linkage of these activities with political decisions is far developed. It has become apparent that every political decision which is not only technical cannot be derived from the proclaimed classical historicist ideals: each serious political strategy has to consider the variability of conceptual possibilities. Into which direction this change will develop and with what intensity is the object of today's decisions about innovation planning in a competitive situation.

XI. The last paragraph could lead to the suspicion that the "final" traditional objectives have sneaked in again through the back door. For, what does "good adaptability" mean except that certain "important" variables remain within "desired" boundaries, where the question of desirability has of course to be answered in terms of given and accepted value systems? This objection can be rebutted. This objection presupposes that the determination and the change of value standards is arbitrary. This, however, is not the case. In spite of all the "makeability" (machbarkeit) the existing norm systems represent modifiable but not arbitrarily changeable entities. The above-mentioned difficulties of interpersonal comparison of values in actuality bypassed processes of bargaining. Nowhere in the pluralistic social structures of modern societies is omnipotence concentrated; and if this were the case, nobody could exploit this power because of insufficient decision capability. These social processes take care that no decision can be made on the basis of an arbitrary decision space. Power structure, habits, rules and "fantasy capacity" determine the boundaries of makeability, and

reduce arbitrariness. Here lies the most important potential role of decision theory. It can help to determine the game boards and to formulate the rules in terms of which the field of conflict is defined. It could become a means to clarify the issues of conflicts, but also to cultivate these conflicts. The battle for ideological constructs could be replaced by a discussion about the second decimal place. It could help to suggest the replacement of atavistic fights by debate. The chess player who gives up a game because of insight could become a prototype. If a game has been recognized as being not very promising it doesn't have to be played at all. To carry out the struggle for existence with atavistic means has become too costly for all involved. Decision theory is one expression of the insight that unworthwhile conflicts should not be carried out at all. If one so wishes, the motivating attitude for this kind of behavior could be called rational. Among American decision theorists the word "friendensspiel" (peace game) has become a jargon term, a word of the English language, which has been formed in analogy to the German word "kriegsspiel" (war game). This designates the sandbox games of army general-staffs used to simulate the "serious case", say, of war. Peace games simulate peace. Decision research could help to make peace a serious case.

Summary of Hypotheses

1. Since the Second World War there is an increasing number of tasks for science which violate the proclaimed principles of the ideology of science.
2. Since then there are "meta-scientific" approaches which do not only permit to do 'research on research' but also investigate the discrepancies between science and its application.

3. These sciences can be understood as aiming at a "general theory of action". The main emphasis thus far can be subsumed under the headings of 'systems research' and 'decision theory'.
4. Decision as a scientific object has reverse effects on the concept of science.
5. Decision theory can be carried out from two points of view: that of an external observer and that of a participant.
6. It is characteristic for a conscious decision that it dissolves the problem of decision.
7. One methodological trick for analyzing decision processes consists in pretending that the act of decision would have to be carried out by a machine. In some cases this can even be realized.
8. Defining the goal and the scales of value produces unsettled methodical difficulties.
9. Traditional maxims of actions are insufficient in face of long-range and far-reaching decision tasks. Instead, goals like 'stability' or 'adaptability' become relevant. In this connection, research and development as determinants of long-range planning play a predominant role.
10. The problems of determining goals are resolved by bargaining processes. It is a task of decision theory to cultivate these bargaining processes.