ECONOMICS OF PLANNING

THEORY AND PRACTICE OF CENTRALLY PLANNED ECONOMIES AND THEIR RELATIONS WITH MARKET ECONOMIES

CONTENTS

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A general descriptive model of planning processes[1]

J. Kornai
Institute of Economics,
Hungarian Academy of Sciences

1. THREE PHILOSOPHIES OF PLANNING

Before discussing *mathematical* planning, we have to deal with some problems of planning *in general*, irrespective of whether it is done by mathematical or non-mathematical techniques.

What is planning? What is the relation between the plan, as a product of human intelligence, and the real economic world? In the debates we may find three very characteristic views, three "philosophies" of planning. They are usually not stated in an explicit form; so we cannot quote from written papers or books. They are, however, expressed in oral discussions. In addition, they are reflected in the general point of view, in the "spirit" of different planning exercises. The authors of papers describing their models and computations usually do not indicate their "philosophy", but nevertheless it has an influence on their approach and on the methodology of their work.

Sometimes the three philosophies do not appear in a clear-cut form, but are rather vague and often mixed up with each other. For the sake of theoretical analysis, it seems more efficient to describe them in their purest, "distilled" fashion.

(i) *The fatalistic philosophy of planning*. The future of a country is determined by its historically given initial situation, and by generally valid "objective" historical tendencies, trends, and laws.

The economic policy of the government, conscious human decision-making, has only a limited impact. Perhaps a revolutionary change –

[1] The paper is based on a report, prepared for the First Seminar on Mathematical Methods and Computer Techniques, organized in Varna (Bulgaria) by the United Nations Economic Commission for Europe in co-operation with the Government of the P. R. of Bulgaria.

turning from capitalism to socialism, or from a colonial to an independent status – may have a more significant influence. The general conditions given, there is no more space for relevant shifts in the path of future development.

If this philosophy is true, then planning is practically equivalent with forecasting. We have to discover the "objectively given" trends; describe them and accept them as plans of our future activity.

The ideological background for this philosophy is in some cases a one-sided misinterpretation of Marxian historical materialism, the overrating of the deterministic side, and the underrating of the freedom in human action.

In some cases, the planner, following fatalistic views, is simply a prisoner of his own planning techniques. E.g. he is working with long time series, and discovers that a trend line fits extremely well to the statistical data. He infers that the trend expresses a very rigid law and there is no chance to deviate from this trend in the future. The truth is, that all historical laws, tendencies and trends in the behaviour of economic systems over time are *stochastic* regularities with greater or smaller dispersions. The deviations from the mean are at least partly explained by the quality of decision-making: whether they are more or less clever, or more or less intelligent.

Sometimes the planner uses a model where there is no substitution between the activities (e.g. a static Leontief-model). He is inclined to identify his model with the reality and forgets that the lack of substitution is an abstraction for the sake of simplicity, and not an attribute of reality. In a real system we have the possibility of choice between substitutive activities.

The *work* of these economists can be well used in planning. Long-run trends, or models without substitution can give important insights in a number of economic problems. We should use their results – but we must not accept their philosophy.

(ii) *Planning: a special case of conventional decision theory.* The usual framework of decision theory, operation research and mathematical programming is the following:

The decision-maker is faced with the possibility of different activities. A bundle of these activities is called a programme or a plan. There is a given set of feasible plans, and a given criterion of choice; a complete preference ordering over the set of feasible alternatives. The solution of the problem is the following: the decision-maker should choose that plan which satisfies the feasibility constraints and which is preferred to any other feasible plan.

Planning on a national level is nothing else but a special use of this framework. To elaborate an economy-wide plan is identical with the mathematical solution of an optimizing problem of a constrained minimum or maximum problem. We should describe all natural, technical and social constraints characterizing the given situation, and maximize a social welfare function over this set of feasible plans. The maximand should express the interests of the society, or at least the planners' or the government's preferences.

We could list a long catalogue of countries from every part of the world where mathematical planning is based on this philosophy. These planners usually received good training in decision theory, mathematical programming, and operation research – and now regard their job as a simple "application" of this knowledge to planning.

The follower of this philosophy thinks that the decision-maker has a well-defined and consistent preference ordering over all feasible alternatives, in advance, *a priori*, before the planning process. He should know exactly whether he prefers plan P to plan Q, or whether he is indifferent in the choice between these two alternatives, although he was never really confronted with *these* alternatives in the past; since the last time when he had to decide, he made a choice between alternatives G and H. In the real world the wishes, desires and goals of the political decision-makers are not quite clear or well-defined *before* the beginning of the planning process.

Continuing the description of philosophy (ii), the planner's task is to compute the optimal plan. When that is done, then according to the view described here, everybody will be happy to accept it, and after acceptance, to fulfil it quite exactly.

Unfortunately, the real world is not so simple. There are always *conflicts* between groups, strata and classes of the society. The plan attracting one of the groups or classes is usually disliked by another group or class.

Philosophy (ii) is a modern variant of the XVIII century "enlightment"; with an over-optimistic hope in the power of strict rationality. It would be quite sufficient to explain to the people what is the best way to develop the economy, then we get their understanding and all will follow the rational central planners. Alas the world is not the place of happy harmony.

(iii) *Planning: a process of cognition and compromise*. Planning is an instrument of cognition. The main purposes of planning are the *collection and careful evaluation of information* about the future. It helps in understanding our own desires, wishes, goals; and helps to confront them with the realities. It is a framework for the *exchange of information* and the co-ordination of otherwise independent activities. Since the activities of all participants of the economic system are mutually interdependent, planning is a device to understand the interdependencies and to *reconcile the conflicting interests*.

Most of the practical planners, sometimes unconsciously, follow the third philosophy. They do not think about their work in the form of theoretical statements, but they know from their experience, that a plan is neither a manifestation of blind fate, nor the victory of perfect human knowledge. Planning is an imperfect, yet very important instrument of exploring the future and of reconciling the activities of the social organizations.

The third philosophy is going to gain more and more influence in the theory of planning as well.[1] The author accepts that philosophy and tries to elaborate it in more detail in the forthcoming sections.[2]

2. FROM THE FIRST ASPIRATIONS TO THE DECISION

The elaboration of a medium- or long-run plan (for short, of a plan) is usually a long process requiring sometimes 2–3 full years. It is not enough to concentrate our attention only to the very last minute, to the time of decision-making and the final approval of the plan. It is useful to consider the whole process of plan-elaboration.

For the sake of easier graphical visualizing, let us assume, that the five-year plan has only two main indicators. In practice, of course, the number of main plan indicators can be pretty large. For example, these two indicators are the rate of growth of Gross National Product and of consumption.

If we would accept philosophy (ii), the planning decision problem could be described in the form of *Figure 1*.

F is the set of feasible plans, P_1, P_2... are indifference curves representing the decision-maker's preference ordering. The optimal plan is a*, since this is the plan assuring the highest social utility and the highest welfare among all feasible plans. Accepting any plan below the indifference curve P_3 would be inefficient, and above P_3 would be infeasible.

[1] See e.g. Tinbergen–Bos [14], Porwit [11], Helényi [4], Kindleberger [5] and Eckaus [3]

[2] See for a more detailed exposition the author's books: *Mathematical Planning of Structural Decisions* [6], Ch. 27, and *Anti-Equilibrium* [7], Chs. 8, 12 and 23.

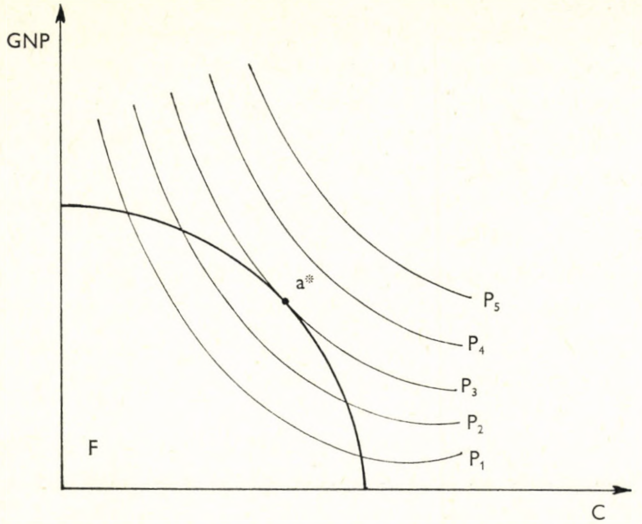

Figure 1.

Experience shows that this is not a realistic description of planning. Instead of that, we shall introduce some new concepts. They serve, at the present moment, as a *descriptive* theory of planning. We do not say that the following process is the best method of planning. We do hope, however, that it is an appropriate framework to describe any kind of real planning procedures.

The main concepts are shown in *Figure 2.*

The planning process begins at time $\underline{t}$ and terminates at time $\bar{t}$. The interval $[\underline{t}, \bar{t}]$, called *plan-elaboration period,* can be 2–3 years in the case of five-year planning.

The point a is the *aspiration level*[1] of the political *decision-maker*. (This can be the government, the inner cabinet, the leading body of a ruling party or coalition, etc.) It is a point in the *plan indicator space*. (In our over-simplified example it is a 2-dimensional vector-space of our two main indicators GNP and C.) The aspiration level expresses the decision-makers' wishes, desires and targets at the beginning of the plan-elaboration period at $\underline{t}$. It is not a maximand, nor an objective function, but a target expressed by numbers (in our example, a vector of 2 components). Perhaps in some cases it is not one single number for each indicator, but rather a range, a given interval (e.g., GNP growth rate

[1] The concept of "aspiration level" was introduced at first in mathematical psychology by K. Lewin. (See [9].)

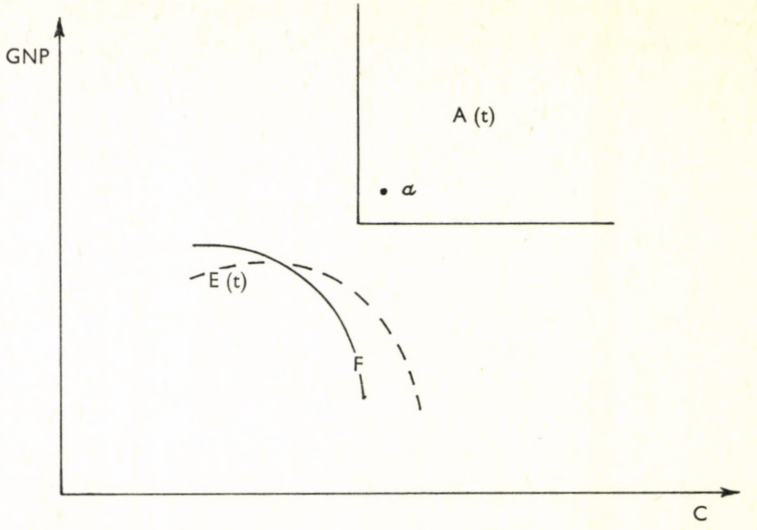

Figure 2.

should be 5–6 per cent and consumption growth rate should be 3–4 per cent).

The decision-maker, indicating its aspiration level, believes that a is feasible. This is, however, only a tentative, preliminary belief subjected to further tests.

During the plan-elaboration period we have to deal with two sets of plan alternatives (both in the plan indicator space). $E(t)$ is the set of *explored* plan alternatives. It is changing over time during the period $[\underline{t}, \bar{t}]$, following the exploration of feasibilities. The explored set is a subjective image of the really feasible set. If planning was done on a high professional level by well advanced techniques, then it is a good image; if planning was poor and primitive, then the image is unreliable. There are usually feasible but yet unexplored alternatives (in Figure 2 the field between the continuous and dotted line, on the right hand side $F-E(t)$.) At the same time, there may be plan alternatives which the planners believe to be feasible, but actually they cannot be fulfilled (in Figure 2 the field between the continuous and dotted line, on the left hand side: $E(t)-F$.) The better the planning process is, the smaller the differences between sets $E(t)$ and F.

Figure 2 shows a case where the aspiration level is outside the feasible and explored sets. This means that the political decision-makers are over-optimistic and unrealistically ambitious. This often happens in planning, but sometimes we may find the opposite phenomena, a is deeply inside $E(t)$ (i.e. politicians and decision-makers were too cautious). Exploration can convince them that the economy is able to satisfy higher requirements.

Figure 2 describes a situation where the set of explored alternatives is connected. The exploration (and especially exploration by primitive planning techniques) sometimes leads to much less exhausting findings. Thus, the planners only compute some discrete points. (We return to this point later.)

We also have a second important set, $A(t)$, the set of *acceptable* alternatives.[1] The boundaries of this set are usually upper or lower limits revealing the conditions of acceptance by the political decision-makers. "We cannot accept a plan with less than 2 per cent growth rate of consumption pro annum," or similar statements can be regarded as bounds of acceptance. They express the *political* evaluation of the situation by the highest decision-making bodies and their judgments about the main politically important targets of the plan. The aspiration level is, of course, necessary in $A(t)$ at the beginning of the elaboration.

In order to find a non-empty intersection, the elaboration of a plan is a mutual adjustment process between $E(t)$ *and* $A(t)$. The properties of this adjustment process are characteristics of the particular planning framework of a country at a given time. In some cases, at the beginning, there is no intersection, the alternatives explored by the planning-technicians are not acceptable for the politicians. Therefore, either the planner has to find new alternatives, or the politician must be content with less ambitious targets, and revise his acceptance bounds; or both.

It sometimes happens, rather exceptionally, that the planners are less careful and honest. They report such proposals, which they do not regard as surely feasible, as explored alternatives only to please the politicians.

We may also meet the reverse case when there is a large excessive intersection of $E(t)$ and $A(t)$. (See *Figure 3*.) This indicates that the political decision-makers were too cautious and can raise the requirements.

The change of $E(t)$ and $A(t)$ is partly a *mutual* adjustment process. In addition, it depends also on recent *information* perceived by the planners, or by the higher authorities or political decision-makers (e.g. the last statistical data, reporting on the results in the previous period,

[1] The concept of acceptable alternatives is related to H. Simon's ideas about the "satisfactory" behavior of decision-makers. (See [12] and [13].)

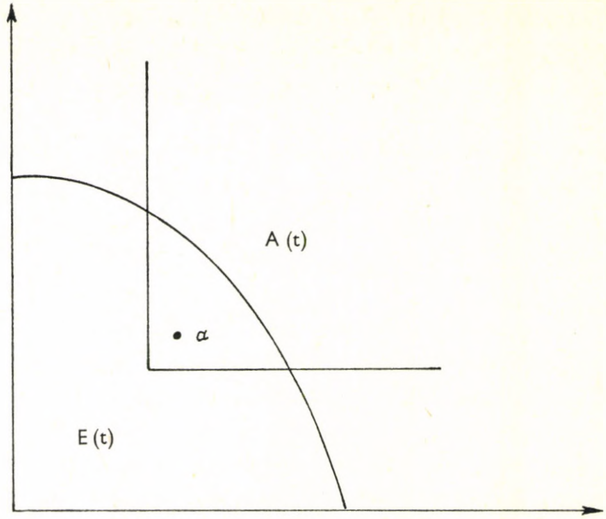

Figure 3.

new knowledge gathered on future technologies, news about the domestic and international political situation, etc.)

When is the plan elaboration process terminated? When the plan became "optimal"? No, the realistic answer is much simpler. The final decision is done when it cannot be postponed any longer. In the good case, this should sometimes be before the beginning of the plan's fulfilment period. It happens, however, that the plan elaboration is finished only later; the plan is ultimately approved when the implementation of the same is already in progress.

After the moment of termination, there must be – by definition – a non-empty intersection of the explored and of the acceptable set. We call it the *eligible* set and denote it by $G(t)$. (See *Figure 4.*)

$$G(t) = E(t) \cap A(t)$$

Only the elements of set $G(t)$ at the time $t = \bar{t}$ are eligible for choice by the decision-maker.

The experience shows that the choice over this set is random. The essence of plan elaboration is to find a non-empty intersection of $E(t)$, and to narrow down this intersection. Compared with the great intellectual effort for this sake, the interest in the choice within the eligible set $G(t)$, is not too great.

This does not mean that any element of the eligible set has equal

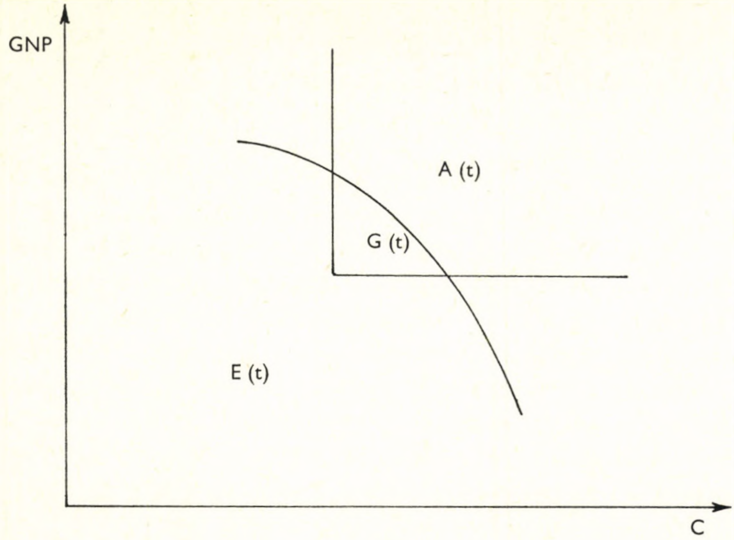

Figure 4.

chance for being chosen. There may prevail some stochastic regularity; a *decision distribution* ξ (H), which determines the probability of the decision falling into the given H subset of the set $G(t)$. For example, it is more likely that alternatives which are closer to the aspiration level will be ultimately accepted than alternatives that are far away from the original aspirations.

In summary, the *characteristics* of a planning process are period $[\underline{t}, \bar{t}]$, the processes forming $E(t)$ and $A(t)$ and the distribution ξ (H). If we want to describe different planning processes, we have to describe these characteristics. What are the regularities of establishing aspiration levels? How do they depend on further performance, on the imitation of other countries, and on the ambitions of politicians? What are the techniques used for exploration, for information gathering on new alternatives and for the feasibility of a plan? What kind of mutual adaptation is carried out between exploration and acceptance? What are the stochastic regularities for the ultimate choice? These and similar questions should be raised for a realistic descriptive theory of planning.

3. THE ROLE OF MATHEMATICAL PLANNING

We must consider the role of mathematical planning in the context of a realistic description of planning in general (as briefly indicated in Section 2 of this paper).

1. *Exploration process.* Using non-mathematical techniques in the formation of set $E(t)$, the planners can find only a few disjoint points and a small number of alternative national plans. Sometimes the result is still more modest, the planning office elaborates only a single proposal without alternatives. By applying formal models we are able to compute a large number of complete plan variants and alternative plan proposals.

Non-mathematical "traditional" planning reconciles the first preliminary plan estimates and figures elaborated independently at the beginning by different planning agencies in a series of meetings and negotiations. The final plan is based on this kind of "collective guesswork". In contrast, a formal model carries out the reconciliation and the co-ordination of different partial plan figures systematically and rigorously by solving a large simultaneous equation system.

At the same time it would not be justified to overrate the achievements of mathematical methods in the exploration process. Each formal model, neglecting many complexities, is a simplified image of the real economy. The mere fact that a plan computed by a formal model does satisfy all constraints of the model, does not guarantee a complete feasibility in reality, since we usually accept strong assumptions in model-building and we sometimes work with inexact data, etc.

2. *Acceptability.* Mathematical planning should help the political decision-maker in understanding his own goals and wishes by confronting the different conflicting goals with each other and considering their relative importance. Important results of a *sequence* of mathematical planning computations are different "trade-off" schedules or in graphical form, "trade-off" curves. Let us return to our simple example. The mathematical planner can easily compute a series of plans with different combinations of *GNP* and consumption growth rate. The result can be presented in a curve, as in *Figure 5,* or in a table like this:

	GNP *Growth Rate*	Consumption *Growth Rate*
Plan No. 1	7%	2.0%
Plan No. 2	6%	2.4%
Plan No. 3	5%	2.7%
Plan No. 4	4%	3.0%

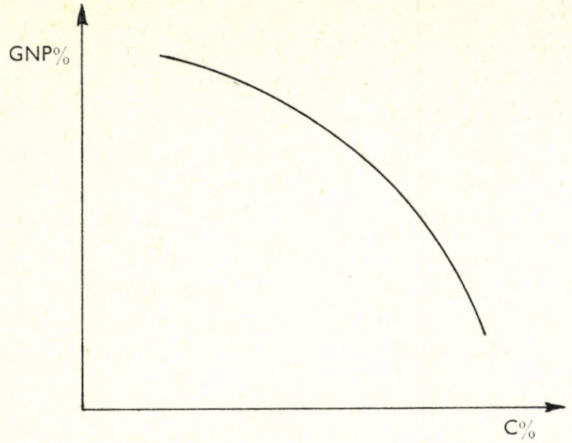

Figure 5.

In practice, there are not only two main plan indicators, but more, 10–20–30. The elaboration of a large number of plan-variants which differ in the different combinations of the 10–20–30 main indicators can help to understand the rather complicated interrelations between the political targets. At the beginning of the planning process the general attitude of political decision-makers is usually the following: they would like to see very high levels of *all* main indicators; high growth rate of *GNP,* but also high consumption and high terminal capital stock; very good balance of payment, etc.

After careful analysis of the variants, the decision-maker will understand that each economic political aim has opportunity costs. For higher consumption, e.g. he must "pay a price" in worse balance of payment – and he gets figures expressing this "price", and this "opportunity cost", the decrease of the positive balance of payment as the counterpart of the increase in consumption.

As mentioned briefly in Section 1, explaining the three philosophies of planning: the decision-maker does not have a preference ordering over all feasible alternatives in advance. *He is going to understand his own preferences, and the relative importance of different conflicting goals, only by experience with practical alternatives presented by the planners.* Mathematical planning is a very powerful method in this kind of learning process.

3. *Efficiency.* Mathematical techniques may improve the efficiency of the plan. Let us consider *Figure 6.*

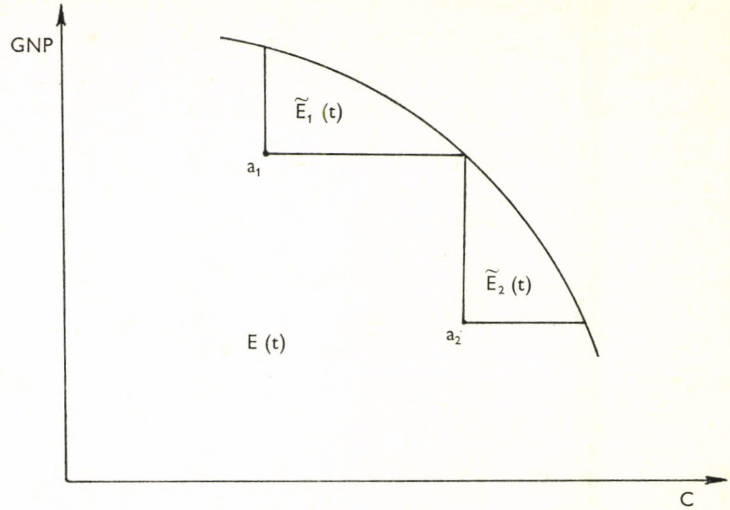

Figure 6.

Let us assume that at time t, ($\underline{t} < t \leq \bar{t}$), in the plan-elaboration period, the non-mathematical planners are only able to prepare two complete plan proposals: $E(t) = \{a_1(t),\ a_2(t)\}$. With mathematical techniques, we are able to compute a connected set $\tilde{E}(t)$, with infinite number of elements, i. e. of explored plan alternatives. There are two subsets $\tilde{E}_1$ and $\tilde{E}_2$ in $\tilde{E}$ where we have an infinite number of elements, each of them *dominating* a_1 and a_2 respectively. They assure both more *GNP* and more consumption than the original a_1 and a_2 non-mathematical plan proposals. The mathematical planner ought not to give a strict, unambiguous proposal to the decision-maker suggesting one single point. He should simply propose to choose only a point on the boundary, not any inner point of $\tilde{E}(t)$. These are the efficient points. To any inner point you may find many efficient points on the boundary which are more advantageous in respect of both indicators.

The reader may observe, speaking about mathematical planning, that we avoid the term "optimality". Using mathematical programming methods, the programme computed is of course "optimal" in the mathematical sense, it is a constrained maximum or minimum solution of a given mathematical extremum problem. This optimality, however, is a *relative* one, valid only under given simplifying assumptions, regarding definite political targets and expressed in the constraints and in the objective function of the model. In a series of computations we determine

10 or 50 "optimal" plans, each of them is *relatively* optimal. The significance of mathematical planning is not the search for "optimality", which is only the blue-bird of economic theory, but the exploration of feasibilities; the explanation of interdependencies between conflicting goals; and the improvement in efficiency.

4. COMPLEXITY

The operation of an economic system is immensely complex. Human intelligence can only approximate this complexity when elaborating plans. Let us consider three different aspects of mathematical planning all concerning the complexity of the economic system.

1. *The concentration of information.* To describe the activities in an economic system in great detail, we need several hundred or several thousand variables in the model. We cannot expect, however, that the political decision-makers, e.g. the cabinet of a country, should analyze tables with several thousand rows and columns. This would be impossible, independent of the intellectual standards of the highest decision-makers. Whether they are well trained economists or not, they cannot make serious decisions after reading thousands and thousands of numbers. Information must be "concentrated" and "distilled" to very limited numbers of main indicators which can be really perceived. To put it in a very simple way, all relevant decision problems should be described in 10 or 20 not too large numerical tables or diagrams. If the decision-maker was faced with such a limited amount of numbers he could concentrate his efforts on the analysis and seriously consider the political implications, and finally, he would be able to make his decision.

Mathematical planning is a "bridge" between the infinite complexity of reality and the limited perceptive capacity of political decision-makers. The linkages are described in *Figure 7.*

The *information input* of the mean rectangle, i.e. of the mathematical models, is the set of data collected for the numerical computations. The data collection (and before that, the construction of the model) implies some "filtering" of the complexity of the real world. We do not observe everything; observation, data collection and representation in the formal model is very limited compared with the infinite number of possible observations.

The information output of the mathematical models is a report presented to political decision-makers containing not more than 10 or 50 small tables. (For example, the "trade-offs" described in the previous

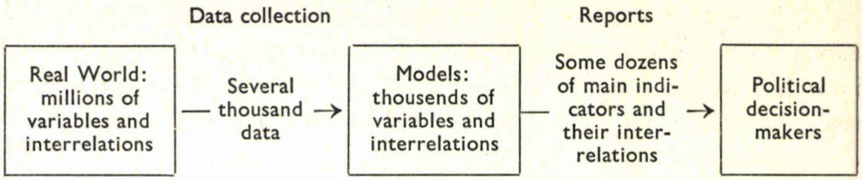

Figure 7.

section.) The output is more concentrated and more "dense" than the input. It shows only the *ultimate* consequences of the *main* decision-variables.

The literature of mathematical planning does deal in great detail with the mean rectangle, the model, and with the linkage on the left, the description of the real world by the model. It does not deal, however, with the linkage on the right, how should we transmit our results to the decision-makers. There are many problems. To begin with, we have a problem of "language" and communication. We must "translate" our results from our technical chart to the language of political decision-makers. A more serious problem is that of filtering and selection. The mathematical planner must decide what should be regarded as the *main* problem awaiting the decision of the higher political bodies, and what can be considered as a secondary problem. There are many practical experiences in this respect, since every mathematical planner has some contacts with political decision-makers. Unfortunately, this experience is not included in the literature.

Sometimes political decision-makers get lost in disaggregated data in the second-rate decision problems. There are sometimes debates in the cabinet, in the leading bodies of the parties, or in the parliament on small details where the decision should be left to the planners, or the heads of the competent organizations. The use of mathematical techniques should help in distinguishing the essential from the non-essential. *A well formulated model describes the details as a function of the main indicators*. For example, if we have a 1000-variable linear programming model, then the numerical values of the variables give us the details of the plan (the second-order decisions) as a function of the main political decision variables (employment, balance of payment, consumption, growth rate, etc.) expressed in some main figures of the constraints and of the objective function.

2. *Model-system.* It is a science-fiction idea to cover all relevant problems of an economic system in a single model. We would need a model

with millions of variables and equations representing all details of consumption, production, investment, trade, services, education, income distribution, etc. The model must have sectoral, regional and temporal breakdowns at the same time. This is, however, impossible.

Instead of having one giant model covering every segment and every aspect of the economy, we need a large variety of models. Every partial, segmental model must have a "profile" and must be specialized to one, or to some limited aspects of the economy, handling, at the same time, only in a very concise, simplified form all other aspects.

At the present moment we have, in most countries, a wild-growing development of different models, sometimes with superfluous overlapping in some areas and a lack of representation in other areas. There are, e.g. two or three five-year plan production models in the same country, but at the same time there is no model of education and manpower.

The different models are living side by side, but they are not interconnected. The next step should be to link up the different models. Instead of separate single models, we must construct a united *system of models*. In the case of a model-system the information output of model 1 is the information of model 2 and 3 . . ., and vice versa, the information output of model 2, 3, . . . is the information input of model 1. (See *Figure 8*.)[1]

We have, for example, a model for the detailed planning of foreign trade. Each country is represented by separate variables. We also have a model for production planning. In the second model we can represent

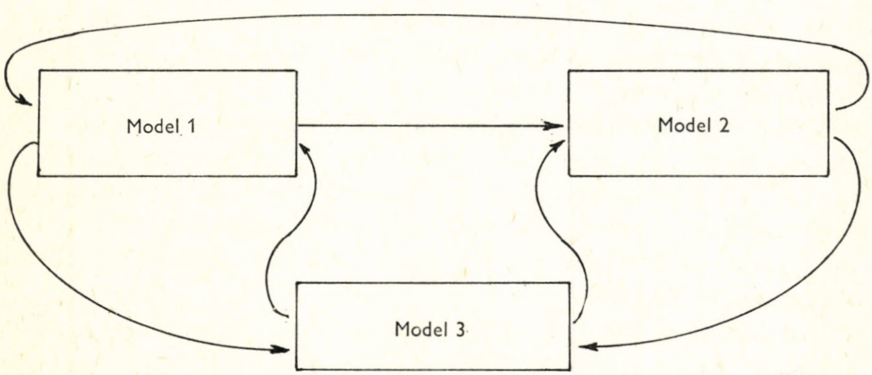

Figure 8.

[1] About the operation of model-systems see Brass–Köhler [2] (experiences in the German Democratic Republic) and Agliette–Seibel [1] (experiences in France).

foreign trade only in a more aggregated fashion, e.g. instead of a breakdown in countries in only two or three main geographical or political world-regions. At the same time, production in the second model is described in finer details than in the first foreign-trade model. The linkage between the two models may be the following:

The first model computes foreign trade plans in fine details, but the information output toward the second model is only the aggregated ultimate result on foreign trade. The aggregate foreign trade figures are treated in the second model as exogenous parameters. Similarly, the second model computes production in fine details, but the information output toward the first model is only the aggregated ultimate result on production. The aggregate production figures are treated as exogenous parameters in the first model.

Up to now there are very few attempts over the world to link up models and to join them in economy-wide model *systems*. We are faced with many difficult problems by establishing model systems. One group of difficulties arises in the classification, definitions and different nomenclatures. Another group of problems is connected with aggregation and disaggregation. Finally, there are very serious theoretical and practical difficulties of convergence. The question is whether the repeated solution of two separately operated, but by information flows interconnected models does converge to a common solution or not? And if the process is convergent, is it fast or slow? What can be done to make convergence faster?

At the present moment the literature only deals with very simple model systems, e.g. a system of linear programming models which could be solved as one single large-scale model, but it is treated like an interconnected system of smaller models. We need further research on the operation of more complex model systems linking up different types of aggregated and disaggregated models.

3. *Man-machine planning.* A complex model system cannot be operated exclusively by computers. We cannot hope that all necessary actions, such as all intermediate decisions, selections and evaluations can only be done by the computer, following a previously completely elaborated computer-routine. Mathematical planning is a joint work of computers and living human beings.

We call this joint work of computer and people "man-machine planning" (following the well-known expression, man-machine simulation). The idea is visualized in *Figure 9.*

The rectangles represent models. One or more ıigorous algorithms belong to each model and are able to give an exact solution of the prob-

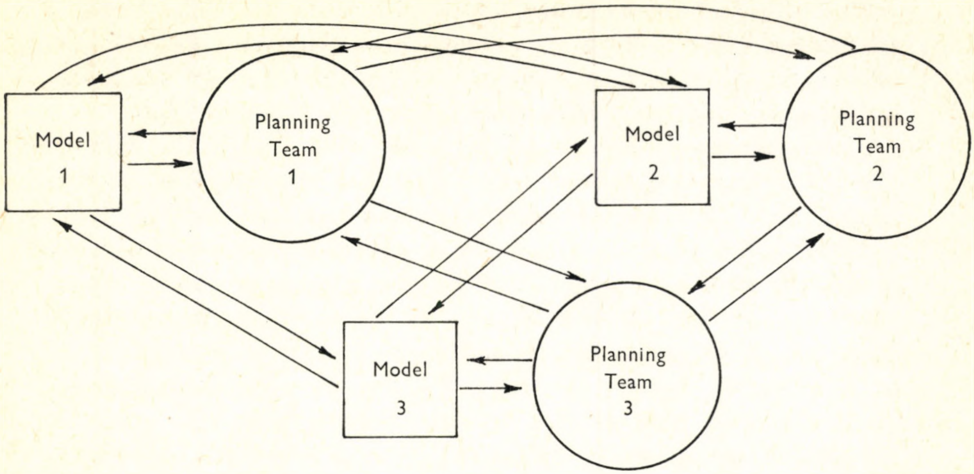

Figure 9.

lem represented by the formal model. The algorithms are described by computer routines and are fed into the computer.

The circles represent living persons (planners, economists, engineers, and political decision-makers). They perform manyfold tasks:

– They collect data. This activity is always connected with subjective judgment in preselection of data sources, eventually subjective estimation for some figures, etc.

– They build up a model. Perhaps it is not exaggerating to say that to build a model implies a combination of science and "art". The economist's intellectual abilities, his "taste" and imagination do play a role in model-construction. When different economists are faced with the same economic problem they usually represent it by different models; like painters who make different paintings from the same landscape.

– They evaluate the results. This again requires some subjective judgment. They have to decide on the forthcoming computations, must make a selection from the large number of numerical results and decide what should be transmitted to other planning groups and decision-makers, etc.

As we see in Figure 9, some rectangles are directly connected with each other. This means that the information output of model 1 flows immediately to model 2. (For example, the output appears in the form of punched cards, and these punched cards are used for the computation of model 2. Or it is filed on a magnetic tape, and the routine of model 2 calls directly from this tape.)

Some other information flows associated with this particular rectangle are directed from the rectangle to the circle, and vice versa. For example, the planning team, using a mathematical programming model, decides on further sensitivity tests after analyzing the results of the first run.

Finally, there are information flows between the circles. The different planning teams must consult with each other, negotiate about contradictory targets, and they exchange their computational results.

The literature of mathematical planning is mainly concerned with the description of the "rectangles". There is a large amount of practical experience on the operation of the "circles," but very few empirical literature. An important task for further research, is a systematic study of interactions between "rectangles" and "circles," the co-operation of machine and man in planning. Based on more empirical descriptive research, we may suggest methods for further improvement in the operation of the "circles", better "rules of thumb", more intelligent and consistent judgments, more reliable subjective estimates, etc. One part of the "circle" operations can be transformed gradually in "rectangle" operations as we discover more and more powerful mathematical methods. But we cannot neglect the improvement of the remaining part, we need normative theories for the combined machine *and man* operations.[1]

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