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Recent Advances in Farm Planning in Europe and North America *

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I. *Introductory remarks*

The decade from the early–or mid–1950's to the mid–1960's can be characterized by the rapid expansion of use of mathematical methods, especially of linear programming and its modifications, around the globe. Thousands of applications were carried out dealing with farm organizational and/or technological problems. The increasing availability of computing facilities stimulated these efforts and greatly contributed to the adoption of the 'new' farm planning methods which are now well established tools of the profession.

The standard planning methods have been developed to rather sophisticated levels of abstraction. A critical review from the standpoint of utilization in practical farming, however, reveals a less optimistic picture. It may be argued that success in the field of research is a necessary prerequisite for progress on the applied level; it may also be said that advances in theory and methodology evidenced in the past decade may brighten the future prospects for better practical applications for farm firms.

In this sense we shall analyze the development to review theoretical and methodological development of the recent past and then turn to possible future directions in the field of farm planning.

II. *Main lines of recent advances*

The review of accomplishments in the field of farm planning and closely connected disciplines reveals advances in three recognizable areas of activity involving both theoretical and applied research:

(1) Better planning techniques,
(2) Better conceptions of the planning process(es), and
(3) New concepts of the firm.

These directions of development are interrelated and, to a certain degree, sequential steps in the search for effective and relevant farm planning procedures. They can be described as follows:

* The author is indebted to Professor W. JOHNSTON, Dept. of Agric. Econ., University of California, Davis/Cal., currently visiting professor at Hohenheim for offering his thoughts and for the linguistic revision of manuscript.

1. *Better planning techniques*[1]

The farm planner seeks to develop good farm plans in a normative sense and strives to produce farm plans which improve upon existing plans. Undoubtedly, the availability of Linear Programming (L.P.) and related techniques contributed to the attainment of these goals. The linear production model became the most common and almost universal procedure for solving optimizing problems in farm planning. Although the standard model was rather generally applicable and the computing facilities expanded rapidly many problems remain. The most critical are those related to

(a) the supply of data (data problem)
(b) the organization of the preparatory work and the planning work itself (routine application problem)
(c) the description of the real world decision-making environment in the computational model (isomorphism problem).

Since the value of the plans produced i.e., the qualitative result of farm planning work depends greatly upon improvements in these three critical problem areas, considerable effort has been directed to these areas in recent years in order to overcome or at least to lower obstacles to better farm plans.

1.1 *Advances in data supply*

Problems associated with the supply of data have been treated rather thoroughly in a previous paper[2]. It should be noted that the initial and nearly exclusive interest in models and calculation procedures of earlier years has been balanced by putting more and more emphasis on collecting data in the more recent past. As a consequence farm planners in many developed countries now have available rather sizable and detailed data catalogues for ready use in investigations and applied research. Inspite of this remarkable progress it cannot be said yet that the data problem is solved either in its qualitative or in its quantitive aspects. Additional efforts are needed in the future to improve the conditions for effective use of modern farm planning techniques. An innovation which may be successful is represented by a project soon to be undertaken in the Federal Republic of Germany, which will consist of a central 'data bank' for technological farm data and market information. This facility will provide for access to planning data via telecommunication from any location within the nation.

Such an organization of data supply may be appropriate for a country with a highly decentralized family-farm structure. In countries with large farm units one may rely much more on internal farm data, particularly where in a planned economy prices paid and eventually also amounts of goods to be sold are fixed independently from the market and in advance. Here the data collecting and processing devices will be part of the farm bookkeeping and

1 An excellent review of recent advances was given by G. WEINSCHENCK in Recent development of quantitative analysis on the microlevel; paper presented at the Internat. Seminar on Economic Models and Quantitative Methods for Decisions and Planning in Agriculture, Keszthely, Hungary, June 1968

2 REISCH, E. M., Proven tools for micro planning and decisions. Paper presented at the International Seminar (cit. above), Keszthely, Hungary, 1968

recording system. Beyond that, in socialist countries, the information system of an individual farm may be integrated into a complex macro-economic information system as an essential part of the national planning and directing system[3].

It can be visualized that modern recording and storing techniques will permit the possibility of arriving at an economical form of a data collecting system in the future. This is possible regardless of the social system involved. But we must keep in mind that even the most sophisticated data processing system can only supply historical data. It cannot by itself predict future events and economic conditions. Here we shall always have to deal with uncertainty, which in a changing world has to be attacked with other means. Modified L.P. methods such as parametric programming or programming discretely with variations in prices and/or resources, have been used to evaluate the influence of imprecise or uncertain data on farm plans (sensitivity analysis), but even the availability of better data will not solve our problems very far beyond simple linear programming results if the decision-making process is not changed. That means the advances in terms of better data supply are necessary but not sufficient conditions for advances in farm planning.

1.2 *Advances in planning routine work*

The rather slow adoption of planning techniques using computers by extension people is not only a matter of access to computers but also due to the fact, that the preparatory work is high and seems rather complicated for people coming in contact with computers for the first time. Moreover 'the software needs of extension are more demanding than corresponding needs for research'[3a]. Especially the widely practiced use of 'multipurpose programs' as linear programming, network techniques etc. with rather flexible and non-specific input and output forms have initiated developments which can be characterized by three main areas:

(a) the development of data input generators
(b) the development of report writers
(c) the development of master programs combining different basic planning methods.

The development of data input generators makes use of data banks and tries to avoid the cumbersome work of data preparation for a specific planning technique. This is a necessary step since many programs used in planning farms are not specifically developed for the purpose and therefore the big bulk of data needed normally has to be supplied for every single case. Likewise the output of information is rather unreadable to an extension man or even a farmer. Therefore the development of report writers as additions to established planning techniques have the function of making the output self-explanatory.

3 For more details see: Autorenkollektive, Operationsforschung in der sozialistischen Landwirtschaft und Nehrungsgüterindustrie, Berlin 1969

3a CANDLER, W., BOEHLJE, M. and SAATHOFF, R., Software for Extension, Agricultural Economics Discussion Paper No. 14, Department of Agricultural Economics, Purdue University, Lafayette, Indiana (USA), 1969

Efforts in the direction of the discussed developments are recognized as valuable and are undertaken at several places[3b].

The development of master programs combining different planning methods may at the same time solve the problem of data input generation and report writing, and generally is a step in developing software specifically adapted for farm planning problems. A trend can be recognized towards increased use of such techniques and is a natural outgrowth of the development process within the profession of farm management research and extension.

1.3 *Advances in constructing more realistic models*

The relevance of isomorphism depends highly upon the 'philosophy' of planning. If one accepts–as it was and may still be with farm economists–that the farm planning procedure renders an optimal solution which is identical with the optimal plan to be followed, then isomorphism is the most important pre-condition for a good plan (given accurate data). The planning process starts with choosing and defining activities thought of as being relevant alternatives. Then the capacities and other conditions are specified, thus setting up the calculational matrix. The matrix must contain in a comprehensive way all relevant technological, economic, and other effective coefficients and restraints. The resultant solution is understandably dependent upon the quantity and quality of those coefficients. Alternatives not included cannot be considered in the planning procedure.

So we can agree with MENGES[4] that the pre-decisions are the relevant parts of the planning procedure while the calculation itself is a mechanical mathematical process and of a secondary order of importance. On the basis of the above mentioned philosophy of planning, the main structural weaknesses of standard L.P. should be cited. They are:

(1) with regard to production processes, the assumptions of linearity in production and objective functions and perfect divisibility for factors and products;

(2) with regard to the environment of the farm firm, the assumptions of perfect knowledge and independent prices; and

(3) with regard to the fact of time being a relevant factor, the static approach to farm development and adjustment problems.

3b Without trying to be complete a few examples are listed:
Anonym, Proceedings, Top Farmer Workshop, Cooperative, Extension Service, Purdue University, Lafayette, Indiana (USA), August 1968
BAKER, C. B., The History Evolution of Planning and Decision Models, Paper presented at the Seminar on Economic Models and Quantitative Methods for Decision and Planning in Agriculture, Keszthely, Hungary, June 1968
RIEBE, K., Die Betriebsoptimierung in ihrer Rüchwirkung auf Buchführung und Betriebsstatistik, in: Quantitative Methoden in den Wirtschafts–und Sozialwissenschaften des Landbaues, Schriften der Gesellschaft für Wirtschafts–und Sozialwissenschaften des Landbaues, Bd. 4, Müchen 1967

4 MENGES, G., Vorentscheidungen, in: Operations Research–Verfahren (R. Henn, ed.) Meisenheim 1965.

1.3.1 *Dealing with non-linearity*

Considerable efforts have been made to handle nonlinearity in L.P. models. Nonlinear *production functions* can be approximated by linear functions. There arise no problems if they are characterized by decreasing marginal returns or increasing marginal cost. Therefore, convex programming is widely used and can be considered a proven tool in handling these types of problems in farm planning.

The same degree of success is not as true for concave programming, i.e. dealing with increasing marginal return or decreasing marginal cost. In recent years some approaches have been suggested which seem to be of practical relevance as they handle concave production functions and cost economies without too much additional work.[5] One way is to approach a nonlinear production function by an interactive programming procedure using systematically varied coefficients. The optimal solution is found after a sequence of calculations when input coefficient and level of production coincide with the values of the real function. In another approach the relevant functions are broken down into segments with different slopes and the logical sequence of selection in the calculation procedure is ensured by additional transfer activities which have to be integer, either 0 or 1.

A third type of model examines the problem over the range of production levels of interest to the investigation, again by a concave programming procedure which establishes an estimated minimum and maximum point on the nonlinear production function. For these two points the activities x_i^1 and x_i^2 are defined on an average value basis. The additional equation

$$x_i^1 + x_i^2 = 1$$

where $x_i^1 \geqq 0; \; x_i^2 \geqq 0$

replaces the devices for solving the sequence problem and enforces the combination of the two extreme processes between the levels $x_i^1 = 1$, where $x_i^2 = 0$, and $x_i^2 = 1$, where $x_i^1 = 0$. In dealing with nonlinear *objective functions* a number of calculation procedures have been developed, but so far the applications in agriculture haven't been more than academic experiments[6]. There is little hope for practical usefulness of these more powerful

5 For a discussion of the procedures suggested by KÖHNE, ZAPF et al. see: KEHRBERG, E. W. and REISCH, E., Wirtschaftslehre der landw. Produktion, 2 ed., München 1969. For an elegant computational procedure see: ENGEL, B. and KLARDNEY, G., Der nichtlineare Ansatz bei der landw. Betriebsplanung mit MPS/360 (Separate Programmierung), in: LP–Brief Nr.3, March 1969, Landesanstalt für Anpassung der Landwirtschaft, Stuttgart-Donaueschingen.

6 KÜNZI, H. P. and KRELLE, W., Nichtlineare Programmierung, Berlin–Göttingen–Heidelberg 1962.
SEUSTER, H., Programmierung mit nichtlinearer Zielfunktion, in: Quantitative Methoden in den Wirtschafts-und Sozialwissenschaften des Landbaues (E. REISCH, ed.) vol. 4, p. 121–143, 1967.
ABADIE, J. (Ed.), Nonlinear Programming, North-Holland Publ. Comp. Amsterdam, 1967.
KÜNZI, H. P., Zum heutigen Stand der nichtlinearen Optimierungstheorie, in: Unternehmensforschung, vol. 12, p.1ff, 1968.

models' in the near future, since they require relatively large computer capacities.

1.3.2 *Dealing with integer variables*

The divisibility of factors and products cause difficulties in many cases of farm planning. In an informal way they can be overcome by calculating a series of alternative solutions with the factors and/or products given integer levels often arbitrarily chosen.

Besides that pragmatic procedure some formal methods exist which can be used for solving planning problems with some or all variables integer. More or less they represent a modification of the simplex method, as new conditions are introduced which satisfy the integer requirements. Depending on the way the integer conditions are introduced in the model three methods can be distinguished

(1) The Cutting Plane Method by GOMORY[7]. This procedure reduces an initial noninteger optimum solution to an integer one by additional constraints. Since there is no criteria for the sequence of selection of rows to generate a new constraint it can be very cumbersome to arrive at the integer optimum solution.

(2) The Branch and Bound Method developed by LITTLE et. al.,[8]. This procedure also begins with a non-integer optimum solution. If that does not fulfil the integer conditions for the x_1, all feasible integer solutions are enumerated in a sequence of calculations for all possible integer values of x_1. Thus a 'tree' of integer solution is computed. LAND and DOIG[9] suggested that only the subset of the decision tree in which the optimal solution is situated needs to be enumerated and thus the computational load is lessened considerably.

(3) Another Branch and Bound method starts with an integer non-optimal solution for a certain level of a first variable, say x_1, setting the other variables with integer condition either at zero or at a relatively low level. Then from this basis the optimum calculation continues with the first variable decreased to the next possible lower level and another integer variable increased up to the highest possible level and so on. If not subject to special restrictions, the number of calculations can be very high, but this method seems well adapted particularly, for technical problems. Although this is not a straight forward mathematical procedure it has the advantage of practica-

7 GOMORY, R. E., All-integer programming algorithm, in: MUTH, J. F. and THOMPSON, G. L. (Eds.) Industrial Scheduling, Englewood Cliffs, pp. 193–206, 1963. GOMORY, R. E., An Algorithm for integer solutions to linear programs, in: GRAVES, R. L. and WOLFE, Ph. (Eds.) Recent advance in mathematical programming, New York 1963.

8 LITTLE, J. D. S., MURTY, K. G., SWEENEY, D. W. and CAROLINE, K., An algorithm for the travelling salesman problem, in: Operations Research, vol. 11, pp. 972–989, 1963.

9 LAND, A. H. and DOIG, A. G., An automatic method of solving discrete programming problems, in: Econometrica, vol. 28, pp. 497–520, 1960.

bility since one can start with an estimated optimal level of the integer variables. In this sense it has some similarity with the RHS method by MARUYAMA and FULLER[10] and the simulation techniques which will be discussed later.

1.3.3 *Dealing with risk and uncertainty*

We all know that the assumption of perfect knowledge with respect to production techniques, resources and planning environment is unrealistic. The planning situation following KNIGHT's[11] distinction of risk and uncertainty can be characterized as (a) a situation with a measurable non-certainty, and (b) a situation with a non-measurable non-certainty respectively.

TINTNER and others[12] have shown that risk situations can be handled by quadratic (stochastic or risk) programming. Since the total net revenue from the farm plans can be described by an objective probability function, the optimal solution is defined as the organization which satisfies given income goal with the minimum of variance.

In the case of non-measurable non-certainty, a subjective probability function is introduced[13] or several game strategies can be applied[14].

All the procedures mentioned so far cause much preparatory and computational work and are very demanding with respect to their data needs. However, an approach suggested by RENBORG[15] appears to be very promising. That approach separates the determination of optimal solutions from the problem of variance and choice of strategy. 'Stable elements' provide a 'skeleton' for rational decisions by the fact that they are repeatedly included in the optimum. 'Unstable elements' are activities and levels which are only under certain numerical constellations in the optimum plan. The more they prevail the weaker is an optimum plan as a foundation for realization in practice.

A similar approach was recently published by EVERS[16]. He separates the matrix of technical coefficients into determined and into stochastic parts, and

10 MARUYAMA, Y. and FULLER, E. I., Alternative Solution procedures for mixed integer programming problems, in: Journ. of Farm Econ., Proced; issue, vol. 46, Dec. 1964.

11 KNIGHT, F. H., Risk, uncertainty and profit, Boston, 1921.

12 TINTNER, G. Stochastic linear programming with application to agriculture, in: Sec. symposium in linear programming, Proceeding 1, 1955.
FREUND, R. J., The introduction of risk into a linear programming model, Diss. Raleigh, 1955.
McFARQUHAR, M. M., Rational decision-making and risk in farm planning, in: Journ. of Agric. Econ., vol. 14, No. 4, 1961.

13 SCHNEEWEIB, H., Entscheidungskriterien bei Risiko, Berlin–Heidelberg–New York, 1967, pp. 28 ff.

14 It may be sufficient only to mention the criteria suggested by WALD, HURWICZ, SAVAGE–NIEHANS, LAPLACE, BAYES, HODGES–LEHMANN and HANF.

15 RENBORG, U., Studies on the planning environment of the agricultural firm, Uppsala, 1962.

16 EVERS, W. H., A new model for stochastic linear programming, in: Management Science, vol. 13, No.9, pp. 680-693, 1967.

considers the related costs, charged for infeasibility in the stochastic part, weighted with the probability of its occurence.

This approach takes into account–in contrast to the above mentioned stochastic programming–that a variance bringing forth a decrease in profit or increase in factor input shows other consequences than a variance resulting in higher profits or less factor input; the latter may cause a loss of possible profit but no infeasibility.

1.3.4 *Dealing with time as a factor*

The static nature of the standard L.P.–models is another point of serious criticism. Decisions are made for a certain planning horizon or for a number of production periods. Yet, there has been rather little progress in developing planning models which effectively reflect the non-static real world. At present the two alternative procedures for handling farm planning problems with time dimensions are

(1) transforming the dynamic problem into a static one and solving it by variable resource programming, or

(2) stating the dynamic problem as a dynamic-linear programming problem and solving it by a multiperiod model considering all periods simultaneously.

The static approach under (1) is based on the fact that in farm planning dynamic problems are capital and investment problems. It is, therefore, possible to derive the production program as the expansion path of the farm firm with an increasing amount of capital available. The amount of capital needed for the realization of the next investment step and the amount of capital saved per year simply determines the length of the period from step to step.

Certainly this procedure is not very elegant from a mathematical point of view, but from a practical one it has the comparative advantage of being able to handle the problem of integer variables, important in many cases of farm growth and planning over time. Unfortunately since this approach is a static one, it cannot handle increasing yields or changing factor or product prices which lead to changes in the net returns per unit of activity.

Such situations have to be handled by the multiperiod approach (2) in a dynamic-linear model. Here, the single production periods also are considered static, but they are linked by activities which transfer real investments, internally-generated capital and costs of borrowed capital from period t to t+1 and so on. Capital growth, investment and financing can be treated with separate activities and considered simultaneously with other model specifications. Since all periods are included in one matrix, the returns per period may or may not change during the time under consideration. The main weakness of that dynamic-linear model is its assumption of infinite divisibility which we have already discussed above. The required expansion to integer multiperiod programming models causes a rapid rise of the computational load and practical utilization of such models often force the model builder to accept a trade–off in the form of simplifying his previous model.

An interesting step in this direction may be the procedure suggested by

WEINSCHENCK[17] in which in a first stage a sequence of feasible optimum solutions with regard to different capital or other factor input levels is parametrically computed and each of these solutions is taken as one activity for formulating a new dynamic problem.

Since many production factors will remain stable over the time period under consideration, only capital (or the other changed factors) have to be included in the second optimizing model. The model may therefore stay rather small and remain within reasonable computing limits.

1.3.5 *Dealing with space*

Within an individual agricultural firm the question where to produce a certain product has lost its importance because of technical and technological progress. With high speed transportation equipment, improved all-weather roads and modern production techniques, a space problem exists only in very big farms—and even here there may be other more restrictive factors like variable soil and water conditions which warrant more attention than spatial problems facing the firm.

An explicit consideration of transportation costs is necessary if one seeks the optimal size of the firm or the optimal location of agricultural processing industries. Both problems may be solved with models with cost minimizing objective functions, such as the transportation model. But there are several other models for dealing with spatial problems[18]. Analogical to dealing with time we can also apply a multispatial L.P.—model with activities connecting the production areas of a farm firm and charging the transportation costs including opportunity costs for restricted transportation capacities.

1.3.6 *Summary*

With regard to isomorphism of optimizing models it must be said that in recent years the main problems have been adequately recognized and dealt with in many publications. The various approaches to different problems have been summarized briefly. Nevertheless, varying degrees of present day methods and models still suffer from lack of realism which restricts their effectiveness in treating many types of individual farm planning problems e.g. problems of uncertainty and dynamic processes. The merits of the present tools exist almost entirely in the field of teaching and scientific work. Making plans for individual farms calls for a revision of the philosophy of planning.

17 WEINSCHENCK, G., op cit., pp. 27–30.

18 see f. i. STOLLSTEIMER, J. F., A working model for plant number and locations, in: Journ. of Farm Econ., vol. 45, pp.631-645, 1963.
KING, A. and LOGAN, S. H., Optimum location, number and size of processing plants with raw product and final product shipments, in: Journ. of Farm Econ., vol. 46, pp. 94-108, 1964.
POLOPOLUS, L., Optimum plant numbers and location for multiple product processing, in: Journ. of Farm Econ., vol.47, pp. 287-295, 1965.

2. *Better conceptions of the planning process(es)*[19]

The end result of early efforts to use mathematical programming models was generally an optimal plan resulting from successfully applying a prescribed algorithm to a 'more-or-less' realistic model. Our experience has now convinced us of the difficulty of attaining realism.

The planning environment governed by risk and uncertainty calls for individual decisions based on varying subjective attitudes of decision-makers among alternative plans. Furthermore experience from numerous applications of L.P.–models have shown that in most cases 'the optimum' forms an almost flat-top rather than a peak, with little difference in economic result. But the range of flat-top alternatives often implies considerable differences in necessary farm organization. Finally, it has been recognized that maximizing profits, even when including some 'side-conditions', is a poor description of the rather complex structure of farmer's goals. Plans satisfying given aspiration or satisfaction levels may be of higher importance for decisions than profit maximizing optimum plans.

It was the recognition of these facts which decreased interest in *the* optimum solution and led to heightened interest in processes and structure. Even with L.P.–Models it has become a standard procedure to calculate several plans under various assumptions in order to provide a basis for the choice of the 'best plan' for the individual farm decision-maker. So the final plan chosen for realization was not the simple result of a mathematical model with built-in technological and economic pre-decisions, but included an actual decision-making process following the calculations as a second stage.

The whole planning process now is conceived as a multi-stage operation consisting of (1) formulating the problem and goals, (2) setting up a suitable calculation procedure, (3) supplying the data, (4) providing an information field by relevant calculations, and (5) defining the plan in a formal or informal decision-making process.

The main progress in this concept of planning is the recognition of the fact that arriving at an optimal plan for a certain farm situation (including the farmer) is a problem of getting relevant information to facilitate rational decision-making. Any procedure which leads to reliable information about result from possible constellations and actions is likely to be acceptable, no matter whether optimizing methods are used. The choice should be guided by effectiveness.

On this basis a certain trend to a broader use of other than optimizing models can be expected in the future particularly since recent experiences have shown that alternative calculation procedures, such as, simulation techniques are more capable of handling some problems which cause serious difficulties in applying L.P.–procedures–e.g., problems of nonlinearity,

19 This section is influenced by the papers of E. O. HEADY, L. REISEGG, U. RENBORG, L. TWEETEN and J. de VEER presented at the International Seminar, Keszthely, Hungary, June 1968.

stochastic and integer variables, consideration of time, space and trends, planning in an uncertain environment and with imperfect knowledge.

In general, the two basic models, analytic mathematical programming and computational systems, need not exclude each other; each has specific advantages and disadvantages[20].

For the present time the L.P.–models appear to be much more readily applicable since they are adaptable to a broad spectrum of problems and a wide variety of computer programs is readily available.

The alternative procedures identified below are generally designed for problems which are more specific in nature. They are, therefore, more capable in solving specific types of problems. Unfortunately, library programs are not generally available so in many cases the user will have to do the programming himself. But this situation will improve and lower the barrier to these procedures.

2.1 *Alternative calculation methods*

Although the list of alternative calculation methods should include procedures like inventory models, replacement models net work techniques and queuing models, and inspite of these specific models have their merits we shall restrict ourselves to simulation techniques because it is assumed they will claim for the most attention in the future[21].

Simulation means carrying out computational experiments to study the behaviour of a system under varying conditions, i.e. numerical constellations.

The single experiments are done with a constant model structure[22]. As a qualitative condition the 'experimental system' must be capable of answering the question: What is the result if . . . ? Realism is not a specific criterion per se[23], but the environment must be defined. The main pre-investment for simulation technique, therefore, is an intelligent design of the system.

It should be mentioned that simulation can be carried out not only with different mathematical models, but also with different conceptual backgrounds. If the total number of feasible numerical constellations is computed the optimal solution must be included. The problem of that *combinatoric*

20 Some authors believe in the combination of the two techniques being of particular effectiveness, because in a first step f.i. simulation may provide a broad decision background and in a second step an optimizing model may guide the decision to the optimum solution.

21 A list of recent work is presented by JOHNSSON, B. and EISGRUBER, L. M. in: Annotated bibliography on simulation in business management. Dept. of Agric. Econ., Purdue University, Lafayette, June 1969.
A comprehensive presentation of simulation technique and its application may be found in: Operationsforschung in der sozialistischen Landwirtschaft und Nahrungsgüterindustrie, Autorenkollektiv, Berlin, 1969.

22 In this sense parametric programming and similar procedures are not simulation since structural coefficients are changed rather than independent variables in a sequence of single calculations.

23 FRIEDMAN, M., The methodology of positive economics, in: Essays in positive economics. Chicago, 1953. Note taken from Cyert R. M. and March J. G., A behavorial theory of the firm, Englewood Cliffs, 1963.

simulation is the rapidly increasing calculational load[24]. It can be lowered by a 'wide-meshed' selection over ranges of levels in the first run and a close-meshed second run for the relevent region (partial-combinatoric simulation).

Statistical simulation is a more powerful device to reduce the number of calculations. Randomly chosen numerical values and knowledge of their distribution functions are required. On that basis a restricted number of calculations is carried out, but sufficient enough from the standpoint of statistical theory to make sure that the sample demarcates the boundary of the near-optimum (line of efficient) plans. The best-known procedure of statistical simulation is the Monte-Carlo-Technique.

If one includes in that system of simulation a formal or informal learning process, using the first run experiments as a starting basis for improving the system and proceeds in this way towards an intermediate goal, while always being open for accepting new information and imposing new decisions, one reaches a *heuristic simulation*. It is the most ambitious type of simulation technique; but also the most adequate one for the new concept of the planning and decision-making process described previously.

Applications of simulation techniques are not very many yet, but they appear sufficient to show their potential[25]. Much work still will be needed in the future to develop more general and usable models for the different types of farm problems. Otherwise the time spent for programming its own 'experimental system' will badly hinder a broader utilization. A simulation program written by British colleagues already claims to be rather general for various farm problems. It has been used successfully in various countries[26].

24 The number of combinations $= \prod_{j=1}^{n} m_j$ where n_j stands for the variables and m_j for the levels of the variables; n=6 and m=10 result in 1 mill. combinations.

25 See JOHNSSON, B. and EISGRUBER, L. M., op. cit, in addition: EISGRUBER, L. M. and HESSELBACH, J., Möglichkeiten und Grenzen von Unternehmensplanspielen und Betriebssimulationen in der landw. Betriebslehre und Forschung, in: Agrarwirtschaft, vol. 13, pp. 88-93, 1964.
LINDGREN, I. and CARLSON, M., Företagsekonomisk planering med Monte-Carlo-Method, in: Erhvervsökonomik Tidsskrift, vol.30, pp.61–89, 1966.
MÜLLER, W., Technik und Leistungsfähigkeit betriebswirtschaftlicher Simulationsstudien, in: Zeitschrift für Betriebswirtschaft, vol. 38, pp. 605–620, 1968.
STRYG, P. E., Application of the Monte-Carlo-Method and linear programming in farm planning, in: Roy. Vet. and Agric. College Yearbook, pp. 195–217. 1967.
THOMPSON, S. C., An approach to Monte-Carlo-Programming, Misc. Study No 3, Reading Univ., Dept. of Agric., 1967.
THOMPSON, S. C., Investment in a weaner unit, in: Farm buildings digest, Summer 1969.

26 DONALDSEN, G. F. and WEBSTER, J. G. P., A simulation approach to the selection and combination of farm enterprises, Reprint No 387, Wye College, London, Dept. of Agric. Econ.
DONALDSEN, G. F. and WEBSTER, J. G. P., An operating procedure for simulation farm planning, Wye College, London, Dept. of Agric. Econ., 1968.
THOMPSON, S. C., A Monte-Carlo-Programme for resource allocation problems. Univ. of Reading, Dept. of Agric., 1969.
SEUSTER, H., Simulation landw. Betriebsorganisationen, in: Agrarwirtschaft, vol. 18, pp. 263-271, 1969.
STUART, O., Farm planning by using a Monte-Carlo-Method, preliminary study report, Univers. of Stellenbosch, S. A., Dept. of Agric. Econ., Dec. 1969.

2.2 *Better understanding of the role of planning*

As shown above the conception of the planning process has been revised and extended beyond its former scope. The purpose of planning now is understood to guide decisions and actions in a firm. The plan selected, by decision-makers, is the result of this guidance concretized in a program of actions and a schedule of steps to be taken as they attempt to achieve their goals.

A plan always covers a certain period in the continuous flow of events. Therefore, time expressed in terms of a planning horizon becomes an important factor, since expectations and forecasts rather than facts guide the decisions and plans. Even goals may shift over time. Uncertainty will increasingly affect the situation as longer periods are taken into consideration.

Introducing the concept of relevant and irrelevant future events may help to handle such situations. One should concentrate one's interest and decisions to plans for the nearest subperiod (defined in length by relevant future events) and exclude irrelevant future events which are of little or no influence on the first period's actions.

This apparently sophisticated distinction once more shows the 'flowing' character of planning. As one proceedes from one period to the next, future events come closer, irrelevant events become relevant, once vague expectations become more concrete forecasts, the planning horizon has to be continuously extented, and the planning process is repeated with better information.

There still remains one additional obstacle to the effective fulfillment of the revised concept of planning: the formulation of the entrepreneur's goals. It is commonly agreed on that profit maximization is not a sufficient definition of it. Substitutes like maximization of utility, survival of the firm and similar circumscriptions are not satisfying either[27]. In planning one should define quantitatively and qualitatively the aspiration levels of different goals and their relationships to each other. They can be measured in terms of acceptability, satisfaction of maximization, thus considering that depending upon the individual attitude, the planning may be guided by rather different objective functions under the same technical and economic conditions. Given the problems above, it is still maintained that simulation techniques may promise more usefulness in solving farm planning problems than the analytic-mathematical tools.

3. *New concepts of the firm*[28]

Recent changes in farm size and organization require a review of the farm model commonly used for farm planning. The traditional family farm with no

27 For a discussion of applying 'lexico-grapic utility functions' see: DEAN, G. W., Growth of a Firm, paper presented at a seminar, N. Carolina State Univ., Febr. 1967, and LOGAN, S. G., A conceptual framework for analyzing economies of vertical integration, in: Journ. of Farm. Econ. vol. 51, pp.834-848, 1969.

28 In this section some ideas are taken from U. RENBORG, Problems and objectives in planning at the farm micro level. Paper presented at the International Seminar, Keszthely, HUNGARY, 1968.

or little hired labor employed and with the ownership of substantial parts of the resources represents the typical entrepreneur of economic theory. It is one-man management. Therefore, within the farm no organizational and communicational problems exist, and no conflicts or partial strategies are encountered among subunits of the firm.

The family farm characterized above is the ideal field of application for planning procedures derived from classical economic theory. It can well be expected that the gap between the plan suggested and actions taken will be rather small if the farm situation is adequately described in the planning model and the objective(s) are properly included.

However, large farms are increasing in number in many parts of the world and neoclassical theory may not be adequate to successfully cope with diverse problems of larger farming units. Management of the firm becomes increasingly separated from production activities as farm size increases beyond that of family farms. The structure and system of management comes closer to that of modern business firms in industry. Further, such firms may not respond to changing prices, capacities and technologies by changing the quantity produced as it is assumed in classical theory, underlying mathematical programming, and maximizing net returns to fixed factors may not be an adequate goal to them.

3.1 *The behavioral firm model*

A model of how firms, conceived as an organization, act and react has been developed by MARCH and SIMON[29]. Following them CYERT and MARCH[30] presented a consistent 'behavioral theory of the firm', dealing with the operation of large multi-product firms under uncertainty in an imperfect market. The 'backbone' of this theory consists of sets of variables affecting the organizational goals and expectations and choice of organizational structure. The success of such an organizational firm depends upon (1) the solution of conflicts between goals held by various members of the organization, (2) the avoidance of uncertainty by avoiding planning where plans depend on predictions of uncertain events and replacing that by a 'heuristic' device, (3) the intensity of search for good alternatives, and (4) the continuity of the learning process. The basic structure of the planning process in the behavioral firm model can be pictured in form of a computer program showing the dynamic flow of information, action and reaction which continuously accompanies the production activities of the firm[31].

3.2 *The cybernetic firm model*

Another firm model developed by WIENER[32] is the 'controlled system of production', using cybernetics as the principle framework.

29 MARCH, J. G. and SIMON, H. A., Organization, New York, 1958.

30 CYERT, R. A. and MARCH, J. G., A behavorial theory of the firm. Englewood Cliffs, 1963.

31 RENBORG, U., op. cit. p. 7.

32 WIENER, N., Cybernetics, or Control and communication in the animal and the machine, 1948.

Although this concept is more suitable to technical problems it can be applied for the management area as well. The model assumes the existence of a multitude of controlled subsystems on the same and on different hierarchic management levels. They are connected by a flow of information between the subsystems and as such form an integer information and controlling system. The subsystems are capable of being adjusted as additional information is acquired.

As shown in another paper the whole management of a firm can be understood as a cybernetic operation[33]. In this view farm planning becomes a multi-level informational and controlling system which produces and controls a system of subplans over various future time spans, these depending on the various levels of decisions, governed by the guidelines of top level strategies.

Within the hierarchy of management levels those decisions made at the highest level of farm planning would include the long run planning of overall objectives and guidelines, priorities and game strategies against market trends, institutional and technological developments and similar events. These plans are perspective plans over 10 or more years. Inspite of a high degree of uncertainty, management cannot escape the necessity of making such plans for guiding future actions. It is in this field where modern management science is about to replace the historical 'art of management' by responding to new types of information which assists in rational decisions. The advances as to the conception of planning and the changing structure of farm firms point to that direction.

As the second level, planning and decisions for an intermediate period of a few years are carried out. It is at this level where the 'top plans' are converted into 'practical plans' for realization and the problems of resource allocation and short run investments have to be solved.

As the resources used are of various ages and since there probably exists some flexibility in production, the intermediate term plans will be subject to control and eventually change from one production period to the other. Thus on this level the type of a 'rolling plan' will be practised rather than a once set program.

At the third level among the hierarchy of management levels, the single production period is planned, organized and controlled. Minimum cost calculations, net work planning and similar methods may be applied as well as simple budgeting. The decisions to be made on that level are numerous, and sometimes very little idle time is left for procuring the information needed for rational decisions. Therefore, efforts are undertaken to avoid such situations by (1) installing an effective information system connecting the firm's subunits and levels for keeping the decision makers well informed, (2) developing 'optimal' working routines to be followed without specific planning and without regarding the disturbing factors creating a stochastic situation, and (3) setting up a controlling system (net work plan, replacement plan, inventory plan etc.) ensuring correction of deficiencies in the related subunits in an optimal way.

33 REISCH, E. M., Proven tools . . . , paper presented at the International Seminar, Keszthely, Hungary, 1968.

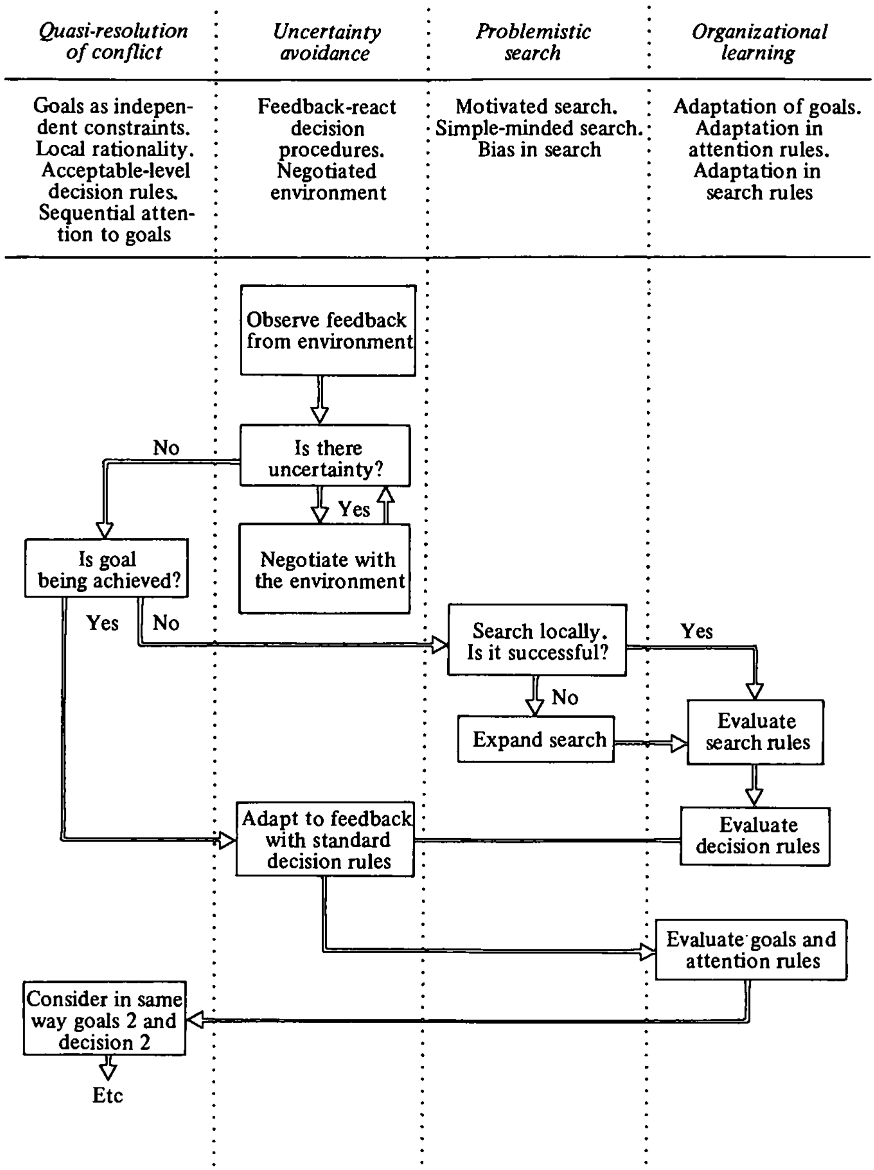

Figure 1 Basic structure of the decision making process in the behavioral firm model. (See Section 3.1)

Taken from: CYERT, R.M. and MARCH, J.G., *A Behavioral Theory of the Firm*, Englewood Cliffs 1963, p. 126

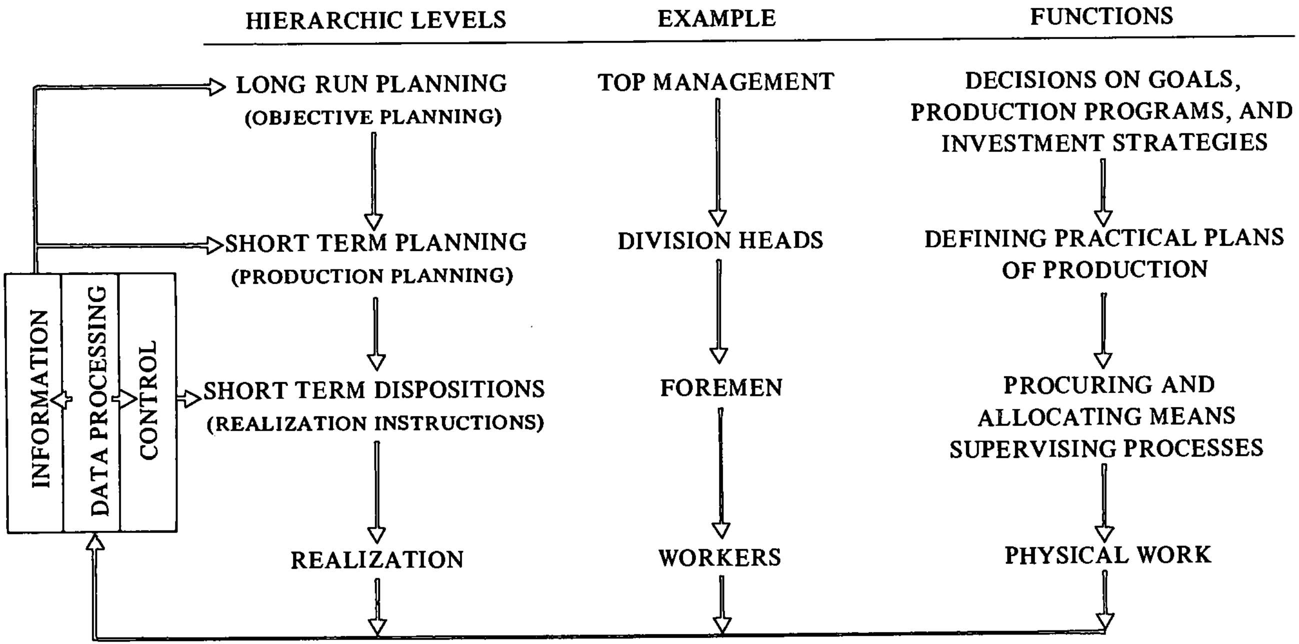

Figure 2 Kybernetic System of Management
(See Section 3.2)

III *Summary*

Within the prevailing philosophy and practice of farm planning three areas of advances are defined and discussed:

(a) advances in the data problem—establishing of data banks;
(b) advances in the routine work of planning-input data generators, report writers and master programs combining different planning methods;
(c) advances in constructing more realistic models—refinement of known planning methods (handling non-linearity, integer variables, risk and uncertainty).

It has been argued that the role of creating farm plans needs a re-evaluation within the whole framework of economic decision making.

Furthermore the validity of the neoclassical concept of the theory of the firm has been critisized and two alternative concepts (behavioral theory and cybernetic theory of the firm) have been touched upon as fruitful elements of a broader concept of the farm firm

Richard Manteuffel, *Poland*

I am most grateful to Professor Reaburn for having invited me to open the discussion on Professor Reisch's paper. I have thus the opportunity to honour my teacher and master Professor Stefan Moszczenski from the Warsaw Agricultural University who in the years when I was his assistant i.e. in 1923–1926, was certainly the first in Europe and also one of the first in the world to apply mathematics to farm organization. He published in the year 1924 the first volume of a textbook devoted to the application of mathematical and statistical methods to farm organization. At that time I took part as an auxiliary in the investigations then being conducted by Professor Moszczenski in this field. This may justify the rather critical tone of my remarks, as it would be difficult to suspect me of a lack of sympathy for the econometric approach. I must agree with the author of the paper that planning methods have reached a considerable degree of sophistication but that the results obtained by means of these methods are rather mediocre. It would be difficult not to agree with statement that an intense effort to improve these methods has persisted for at least 20 years. During those years the results obtained by agriculture have been due mainly to the advances in agrobiological sciences and in the field of chemistry and the mechanization of production.

But planning on no account can be an aim in itself. Planning is taking optimal decisions based on relevant information. The information should answer the question: What can be expected if a certain decision is taken? Every procedure which helps to provide this relevant information will be good, independent of what methods were applied to obtain the information. It should be added that the more simple and understandable the procedures the better they are. Never should we apply the principle: 'Why do it so simply—if it is possible to do it in a complicated way.' I think this is what the author had in mind even if he did not express it so bluntly. The deciding factor in the effectiveness of procedures *is* the effectiveness of decisions based upon relevant information obtained through these procedures.

The author, on the base of Menges' formulations, is expressing the opinion that in planning, even when utilizing the most sophisticated methods, the most important features are the *initial* decisions. These introductory decisions are taken before starting the proper programming. The calculation as such is a secondary technical mathematical problem which must be performed by mathematicians—the farm planners need not be bothered by this technical work.

I would like to add here that in my opinion it would be much better if the planners were more engaged in setting up the essential problems and devoted more time and energy to the analysis of the steps and results of the calculation and its proper application—instead of spending themselves in creating continuously new methods—a job in which in any case they cannot compete with the mathematicians. At the same time the opposite is also true—let the mathematicians leave to the agricultural experts the preparation of parameters for the calculation, as well as the analysis of results. In both cases when trying to work in an unfamiliar domain people are always 'rediscovering America'.

The Achilles' heel of the optimal calculation is the fact that, due to their nature, the materials on which this calculation is based are already obsolete.

Data banks should in no case limit themselves to the segregation of data obtained from the farms even when this segregation is done according to the features of the farms i.e. according to the type of farming, technical level, level of intensity and degree of mechanization. Data on which the perspective planning must be based must be forward—looking, must contain the element of progress. Here again however, we encounter the danger of entering the domain of fantasy in using non-verified data.

There is a notion that data banks should rely on a system of gathering and transforming data, which in a mechanical and automatic way would convert these data so that they are useful for planning and analytical purposes.

In my country also, work has been started and is increasing in importance every year with the aim of adapting the record-keeping system of state farms to the requirements of optimal programming.

An exceedingly important problem which exists not only in western countries with family farms but also in eastern countries with a planned economy, results from the fact that the aim of farming is not single—purpose but that there are always different aims from different points of view. There is the point of view of the producer, individual or collective, and the point of view of the national economy. Efforts are made, at least in the countries with a planned economy, to achieve a full integration of aims.

Again there are complications arising because it is becoming clearer now that the aims of productive activity must not necessarily be exclusively economic. But how do we include these non-economic aims in the calculation and insert them in the optimalization model?

Professor Reisch says in his paper that when one is elaborating plans for single farms one must reconsider the planning philosophy. Of course the micro- and macroeconomic approaches to planning in agriculture are different. It seems to me that in my country we have better achievements in the field of mathematical production and investment programming for individual farms than on a macro-scale for agriculture as a whole.

It is known that optimalization plans present rather a plateau than a peak–which means that usually there are many suboptimal solutions very little differentiated between themselves in results but very greatly differing in the farm organization and production. It is considered that, in practice, it is better for the manager of the farm to have the opportunity to choose one of these suboptimal solutions which, in his opinion, is the most adequate and has the best chances of being adopted.

It seems to me that this statement is a good starting point for a positive evaluation of the simulation technique in the organization of particular farms. Simulation as I understand it, enables us to raise questions or to perform some kinds of experiments by means of the computer while maintaining the principle *ceteris paribus*, i.e. the principle which is observed in biological experiments by controlling certain variables such as fertilizer, variety or feeding. In our case we have a kind of experimental field of economic organization with this advantage that, with the application of the at random principle the occurrence of numbers of similar solutions shows which type of solution has a preponderance.

Up to now I have presented views on points in which I agree with the author of the paper. I think, nonetheless, that Professor Reisch would not be well pleased if I did not present also some doubts.

It is not clear to me what the author had in mind in saying that the optimalization methods hitherto applied have merits almost exclusively in the field of teaching and research work. If for practical purposes the results are rather mediocre–what advantages can they have in teaching? Can teaching of things which are not very useful in themselves be a useful kind of teaching?

I understand it rather in this way, that the acquaintance of practical planners with the optimalization methods gives them a broader view about the possibilities available for the farms and permits a better knowledge of relationships between branches and activities and of the influence of limitations on the results of productive activity.

The same I daresay is rather true for research work.

And now for my second doubt. As far I understood the author of the paper he says that the methods are still imperfect because they cannot give a proper program due to the fact that the aims put forward by enterprises and farmers are undergoing changes with time. But is it possible even for the best method to yield an unfailing programme of activity which would take account of changes of aims and of criteria, when the direction of these changes is unknown?

I. J. Singh, *India*

Prof. Reisch deserves our congratulations for presenting his paper on recent advances in farm planning in North America, Oceania and Western Europe.

Since he has not demonstrated the use of planning techniques of the farm firm by taking practical examples, confining the paper only to North America, Oceania and Western Europe appears to be irrelevant; and on the whole the paper is theoretical without any practical slant.

Even on theoretical grounds, the paper lacks serious methodological consideration. For example, in the first few paragraphs Prof. Reisch discusses the limitations of Linear Programming as a tool in Farm Planning. In the succeeding paragraphs the author suggests non-linear programming, dynamic programming, and simulation techniques as alternatives to overcome the limitations of Linear Programming techniques. He also suggests that on the farms where diminishing marginal productivity of resources exists, convex programming should be used in farm planning process. The implication of this statement is that the technique of convex programming is applicable on the farms where production is being carried to the second stage of the production function. However, Prof. Reisch does not suggest any other technique of farm planning for the farms who are operating in the first stage of the production function and do not possess enough resources to reach the second stage where, according to Prof. Reisch the technique of convex programming could be used in preparing the farm plans.

He talks about recent advances in farm planning, 'Recent' is a relative term. I think any technique which gives pragmatic results is 'recent'. In India we have used Linear programming and Partial Budgetting techniques in farm planning. Our tentative results show that, other things being equal, linear programming gives the same results as partial budgetting where 'real activities' are replaced by 'disposal activities' in the linear programming matrix.

T. S. Rihlik, *Poland*

I would like to make some remarks on the very interesting paper by Dr. Reisch. About the difficulties which exist in mathematical planning, I must emphasize that these difficulties exist in all methods of planning, mathematical and non-mathematical, but mathematical methods create the hope of overcoming the obstacles in the way of this method. Professor Reisch has elaborated this question. In my opinion, some of these difficulties of planning are more of a technical character than connected with the problem of uncertainty. We have special differentiation as regards what the enterprise may market, and the degree of uncertainty is thus narrowed to some degree. The same may be said as regards the intensification of production and the utilization of more sophisticated variables, as well as the deliveries of the produce to the shops. Even in our socialist enterprises, we have some problems in this respect, but we solved them coherently with the use of the plan.

We are closely connected with the social structure of the enterprise. For large scale enterprises the application of mathematical modelling is more possible and is more efficient than when dealing with small scale enterprises.

Michel Petit, *France*

Irrespective of the remarks that were made by Professor Manteuffel from Poland, I think that we have to congratulate Professor Reisch for his very explicit presentation because in this paper there is a thesis that to my mind is very interesting because it casts light on some problems of planning agricultural enterprises. I would like to add something to what has been said. We have to evaluate and to estimate the progress that has been achieved; for this we must look to what has been done. I would like to say something in relation to what remains to be done, because there remains much to be done; I will stop short at only one problem. To my mind there exists lack of knowledge of how we should guide agricultural producers in relation to technical uncertainties. There exists a great stock of literature, on the subject of farmers in relation to uncertainty, but I think that we have very little practical knowledge with which to help farmers on this matter, we know little of what they believe counts. This is a very important problem in planning because when we try to put better plans into use producers must be able to see clearly what is involved and why he is doing it; if not they will not apply technological innovations in the way we would like them to.

A. S. Kahlon, *India*

We have come to a very exciting experience of working with farm plans in the intensive agricultural districts in India and, based on our experience, I would like to make the following observations. Wherever farm planning was used as a mechanistic tool, it did not yield very useful results, but in all cases where it was used in a careful process of planning it yielded highly interesting results.

In all situations where the planning procedures were used at the intensive stage just because some of the research workers were very much enthused with sophisticated methods of programming analysis-like linear programming,–and we did not work with the farmers, we found that the results were not very encouraging. In all cases where we worked with very simple tools working much more in the direction of making improvements in the method of production and farm practices and then passed to a second and still more intensive stage of farm planning procedure, we found that we got a very highly technical kind of result which could be put into practice. Again, from our experience, we learned that in all such situations where programming techinques were used without taking into consideration high complementarity relationships, they have not worked, as a result of interdependence between the technological inputs and such activities which could not be separated out. We found that using assumptions of linearity, divisibility etc., which are normally used without taking into consideration that they are not really met in a realistic way, the results were not very encouraging. It seems to me therefore that in the context of recent technological breakthrough and in the context of highly interdependent technological inputs and activities, there is no real need for using simulation models and all such other refind techniques. We can meet the assumptions much more when we use some simple forms of analysis.

Finally, I would like to mention that in our situation where we need to handle millions of farms it is not possible to programme each individual farm situation. In all such cases we have found that simple tools of analysis are essential, what we call the 'extension workers methods', noting the departures from standard farm plans and using them to make realistic farm plans for actual farm situations. It seems to me therefore that the state of planning greatly affects which tools will be used and where and what type of data are needed to make them useful.

U. Renborg, *Sweden*

I appreciate Professor Reisch's paper very much, and I hope he does not mind if I have just one addition for his consideration. I think it is important that we develop rules of thumb of sub-optimising type for practical use, but on the other hand, I think it is important that we do not use them until we have tested them with the more sophisticated methods. I should like to see a parallel work here on sophisticated methods, and parallel with that, development of rules of thumb that have been tested with these other methods. He could have included it in his paper, and that is my addition, as work of this type is going on now. I have two reasons why it is necessary to also work with the rules of thumb. Man, the decision maker, unfortunately has not enough ability to look over the whole problem at the same time that a firm has to solve. Second, information costs money in any system This means that the cost for planning has to stand in some reasonable relationship to the value of the plans.

P. S. Ivaschenko, *U.S.S.R.*

In Professor Reisch's report, we have a very profound evaluation of the mathematical models of planning of agricultural enterprises in Western Europe and North America. We have seen and heard the great difficulties which the research workers come across, especially connected with uncertainty created by the economic laws which exist under capitalism. In socialist countries, we do not come across such difficulties on such a large scale as you come across in Western Europe. In the Soviet Union we have a well elaborated system of planning of agricultural enterprises; we have some achievements and perhaps these achievements may present interest for the farming enterprises of different countries. I would enumerate the three main directions of planning. The first is working out the prospective long-term plans of development for 5 or more years; the second, working out of one-year plans and the third, developed elaboration of operation of plans for different periods of agricultural work in the field of crop growing and for cattle breeding. The aim of all these plans of socialist agriculture enterprises is in order to create greater production of agricultural produce at less cost. In his paper Dr. Kravchenko discusses some questions of the main trends of development and economic mathematical methods of optimal planning of agricultural enterprises, and the sphere of their application. Therefore, I will not touch upon this problem. I would like only to dwell upon the question of the creation of prospective plans. In the last year we have paid especial attention to long-term planning, especially to different institutional reforms, and this activity is being fruitfully fulfilled, because in the last 15 years, in the economic sense of the Soviet Union, we have elaborated to a greater degree the question of philosophy of planning as Professor Reisch puts it, and we have performed great work in working out a system of machines for different zones of the country. We have worked out special systems of farming for special agricultural zones and regions. Moreover, great help in fruitful planning has been rendered by normative data books, and they are in full conformity with the achievements of science.

Professor Reisch *in reply*

I think that I will not use much time to answer the questions and problems that were touched upon in the discussion. To my mind the problems that were raised here are of course very important, that the application of a given method tends to rob us of some degree of certainty. In principle, the representatives that spoke here have similar problems. One speaker expressed his view that when we evaluate progress, our viewpoints coincide. This is a very important aspect of planning.

There were some questions put to me, and I would like to answer them. The first question was put in relation to the sophisticated methods which are used here. I thought that in this connection it would be senseless not to discuss various methods when we are asked to distinguish according to the spheres of use. In our sphere we can secure success only through the success in another sphere. And this is of course another stage in the process of development. On a second question, of course these methods can be applied simultaneously, but of course we must bear in mind that these methods can't be applied on an equal footing in North America and in Europe. The mathematical method of planning, can be applied in various countries, I think, but only on a certain level. Here we must also remember the so-called spheres of contact. The supply of data can be produced by electronic computers. When we really have this data at hand, we can use it or not as may be required for the work in hand.