MICHAIL POLYAKOV, FRIEDRICH KUHLMANN AND BO OHLMER*

Computerization of Farm Management Decision Aids

INTRODUCTION

The aim of this paper is to discuss some main principles of computerization of farm management decision aids. Since the authors have different backgrounds, represent different economic and social systems and different scientific schools which result in stressing different aspects of computerization, the goal was to develop and outline general principles and approaches for the development and implementation of these kinds of decision aids valid for any country and farming system. The paper is the result of discussions on the problem the authors had during their stay at Michigan State University in 1978–79.

Agricultural researchers are producing new information and knowledge at an increasing rate, which means new production alternatives and techniques that farmers have to consider. The farm growth is continuously resulting in increasing capital investment and bigger operations, so the farmer's management work requires more details and data, and a mistake will have greater consequences. Production links are becoming more complex, farms are getting involved in deepening processes of specialization, co-operation, co-ordination and integration. However, farmers' comprehensive capacity and managerial time is limited. Some managerial tasks may be too complex and difficult for a farmer to solve, and others can be more effectively solved with the aid of new facilities or even outside the farm.

Many universities, research institutions, and private firms have developed and are developing different computerized farm management tools. Some of them represent what we now call Computerized Farm Management Information Systems (CFMIS). Much work is being done with the help of these systems, but much more still needs to be done.[1,2,4,5,7,10]

* The authors wish to express their appreciation to Glenn L. Johnson, Stephen B. Harsh and David L. Watt for their fruitful suggestions and critical comments provided during the drafting of this paper.

METHODS TO HELP FARMERS IN DECISION-MAKING

Computerization of farm management decision aids is based upon the fact that a farm is a controlled continuous and dynamic system having its own specific goals and principles of operation, utilizing certain methods to achieve given goals, and fulfilling a set of functions. The recent two decades of theoretical studies and experiments with different computer-supported farm management tools have given us a rather sound basis for defining farmers' needs, for modelling managerial processes, for designing information systems, as well as for their implementation.[7,6,11]

Since most of the systems now existing to help the farmer with his managerial tasks are developed according to the different methods of extension and advice, let us first take a short look at those approaches. This will facilitate the definition of the contents and the boundaries of a general farm management information system.

Aside from changing the farmer's environment by political means so that his managerial tasks are easier to fulfill, e.g. by fixing product prices, there are commonly four methods of improving the farmer's ability to perform his managerial tasks more efficiently in a given environment.[10]

The first kind of help is to provide the farmer with information about relevant data (e.g. available facilities and services), about problem situations, and about analysis and planning methods. This kind of help utilizes written material and broadcasting. It is directed to many farms.

The second kind of help is to increase the farmer's knowledge and managerial skills so he will be able to perform the management task by himself. This means education about the situation (problem), relevant information, analysis and planning methods, available facilities, and available service. Each activity within this kind of help is directed to a group of farmers.

A third kind of help is face-to-face service, i.e., an extension or commercial agent helps the farmer in doing a part or all of the management tasks.

The fourth kind of help is to provide facilities which the farmer can use by himself and then be able to perform the management task. Each of these facilities is used by a single farmer, although the facilities can be mass-produced.

These different ways of helping farmers with management do not, however, exclude each other. On the contrary, it is even desirable to offer farmers many alternatives within each kind of help.

The computer can be used in each of the four kinds of help. With the aid of a computer, it is possible to use a more detailed description of the reality and to consider more of the relevant factors in the analysis of the situation and in the determination of the best prescription. How advantageous this is eventually depends upon the possibilities available to execute the prescriptions, and upon how much better the production results will be compared to the additional cost of using the computer. In some situations the use of a computer may also result in lower costs for fulfilling a particular managerial task, e.g. in accounting where a lot of data has to be treated.

But in the process of developing computer based means to help the farmer with his managerial tasks, it became more and more obvious that using the computer alone does not solve all the problems. At the same time the tasks of data gathering, data transmission, and of model maintenance had to be taken into account. It is, therefore, now necessary to consider, and first of all to define, the whole system of computer supported farm management in a more comprehensive way. This definition will be the next step of our investigation.

COMPUTERIZED FARM MANAGEMENT INFORMATION SYSTEM ORGANIZATION

The most appropriate way to define a complex system like the one under consideration here is to apply the now well established systems methodology.[8] In particular, to define the system it is necessary to give the definition of the exact boundaries, system structure, and characteristics of internal and external links. The changing of the links and modes of operation gives us a certain spectrum of possible alternatives. The latter allows us to judge about possibilities of the complete or partial solutions of particular managerial problems.

Analysing a defined system, one should include here all the components of the CFMIS as far as one intends to utilize the corresponding technical and personal facilities.

In spite of the fact that the considered system is intended to be used by farmers, the CFMIS is regarded as an external system having its own problems, goals, structures, etc. Those problems do exist, for example, related to the so-called "delivery system", or to the low rate of CFMIS acceptance by farmers, or to the gap between technical levels of existing operational CFMIS and others that are technically feasible now and in the immediate future.

An information system represents "not only (1) a data system, but also (2) the analytical and other capabilities necessary to interpret data, and (3) the decision maker as well. . . . An information system is the total process by which knowledge is generated and brought to bear on social decisions – public and private. It is social information processing with which we are concerned as social scientists and statisticians. The design of the information system establishes the nature of the relationship between the decision maker, the information on which decisions are based, the analytical process which transforms data into information, and the design and collection of data. . . . When the phenomenon that is being represented changes rapidly . . . the conceptual base of the information system must be redesigned frequently to keep up with the changes in reality being represented and the problems being studied. If the rate of change is high enough, the need for conceptual redesign becomes nearly continuous. This is the fundamental problem in the design of information for agriculture".[7]

Having analysed different types of systems, developed in different countries, and processes of research, design, implementation, and usage, we have come to the conclusion that any CFMIS should be considered as consisting of two main blocks:

(1) operational, and
(2) "system development facilities"

The first block can also be subdivided into

(a) on-farm computer "self-service" facilities, and
(b) "delivery system" (see Figure 1)

As an organizational structure, the CFMIS can be either an on-farm, or off-farm or mail-in, or mixed system, or a computer network depending upon the location and number of central processors, and the type of means for data transmitting.

Institutions involved in any kind of activity related to the CFMIS form a high level organizational structure having personnel, hardware, software, data and documentation its low level structural components. The role of institutions is very important as far as no activity in research, design, implementation, supervision and usage of any CFMIS takes place anywhere but within these institutions. They establish goals, provide necessary means for the CFMIS creation, development and maintenance. These institutions are characterized by their content and include farms, research units, extension services, computer companies, communication agencies, private firms, etc. The institutions use their experience and capability to fulfill different functions in a problem-solving process.

There can be named at least four functional areas of activity: research, design, implementation, and supervision and evaluation of the CFMIS. Depending upon the level of consideration, these areas can also be subdivided in groups of functions or stages of management. As far as problems both farm management and computerized information systems have been linked together, some specific groups of farm management functions have the same meanings and importance for the whole CFMIS, and they take place in the development or exploitation of the system. Projecting and forecasting, planning and programming, accounting, analysis and operative control are needed to properly organize and supervise the system creation and usage. At the same time these functions are the farm management functions; therefore in given context they are related to corresponding models.

Other functions are more specific, for example, data gathering, coding, preparation, transmitting, processing, storing, and retrieval. This group of functions is needed to organize the process of converting data into information. Functions of surveying, development, selection, modeling, programming, testing, training and education, and evaluation are main functions of the CFMIS creation, whereas consulting, service, up-dating, interacting, performance, administration and evaluation represent the main functions of the system usage.

Personnel distributed among institutions execute functions mentioned above. Personnel include people of different specialities and skills, users, developers, producers, service people and so on. They are farmers, economists, programmers, extension personnel, etc. In respect of the CFMIS, all of them have certain duties and responsibilities and deal with hardware, software, data and documentation related to the CFMIS.

The hardware is the equipment including communication facilities. General components of the hardware are a processor, memory, I/0 devices and channels, mass storage, data preparation devices, means of communication and, in some cases, measuring and controlling devices.

Different kinds of hardware can be distinguished according to their costs and performance. Micro- and minicomputers can be used either as self-contained computers or as terminals to a maxicomputer. It is also possible to use terminals with a minicomputer.

The system software consists of three main types of programmes – a) system programmes and/or operating system, b) data base management programmes (system), and c) user's programmes. The degree of the software development and, therefore the capability of the CFMIS to solve complex problems, is defined by the system software supplied with hardware, and the power of the system development facilities.

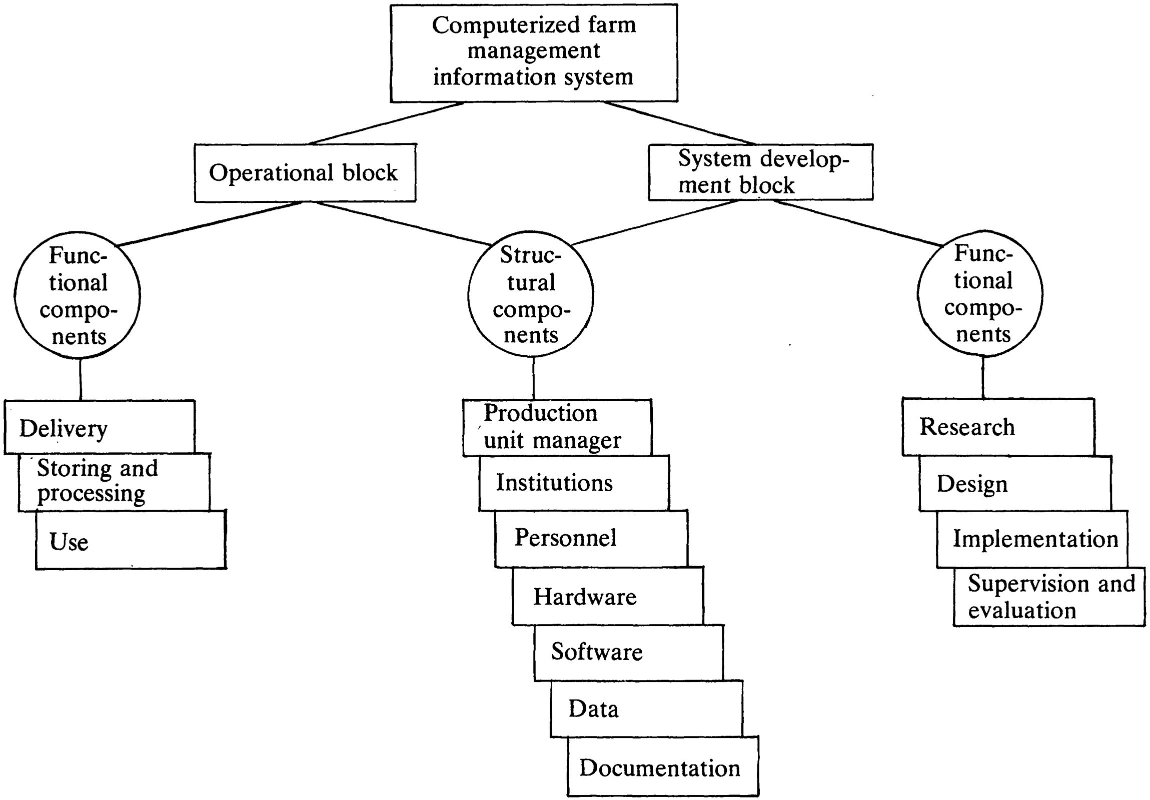
User's programmes developed by personnel should be considered and classified in accordance with corresponding models serving to solve practical problems. This classification is based first of all on the following characteristics a) functions, b) subject area of activity, c) time, d) methodology, e) mode, f) type, and g) level; therefore it has several dimensions.

The performance efficiency of any CFMIS depends on the model structures and the flexibility of the models to a particular situation adjustments. Considering models as the reflection of reality, we should design them in such a manner as to provide the most effective way of application.

Modern farming is characterized by the processes of deepening specialization, therefore farms are now becoming simpler to model, and corresponding models are simpler to generalize and to structure. On the other hand, more and more farms are getting involved in different types of co-operation and integration. Farms are receiving more alternatives in selecting means of production, advanced technologies and services. All these make some models have broader boundaries and include more components and links.

The first group of classification characteristics include forecasting, projecting and planning, analysis, accounting and operative control. The second group is connected with agricultural inputs and outputs – resources, crop and livestock production, and also with marketing, tax management, inventories and cash flows. All these tasks can be either permanent or connected with some specific problem which has to be

FIG. 1 Example of organization of a computerized farm management information system



solved only once. In other words, there can be distinguished two options in the CFMIS usage requiring different modes of operation and resulting in the necessity to consider separately routine management tasks known both to a developer and to a user, and problems either existing (current) or projected. It is closely connected with the adaptive capabilities of the CFMIS to adjustments playing a very important role in some systems development.[15]

For repetitive tasks, a long-term programme for creating some type of CFMIS can easily be developed. Something can also be done for tasks related to projected problems but quite little for those of current problems. The nature of current problems frequently does not coincide with the nature of a corresponding repetitive task; therefore to solve any current problem means modifying existing models in order to meet the requirements of a unique situation.

Major models which are now in practice are the ones for repetitive tasks. They cannot easily be adjusted to solve problems of a different nature. Only a few "all-farm" models allow this (6a); for others, it is necessary to incorporate many models into a system, or even to develop new ones to evaluate possible effects.

In designing the CFMIS models structure, there exist at least two ways – to follow the stages of management or the spheres of managerial activity. The second one seems to be much easier to follow, corresponding model packages are more understandable to farmers. It is also easier to develop and implement them.

But this way does not fully account for possible changes in the structure and process of management. The managerial improvement in agriculture including goals, principles, functions and methods, which results in the structure and process of management could bring the need for a substantial part of the CFMIS and be redone. The first way of constructing the CFMIS is, therefore, to ensure more flexibility for any further adjustments of the computing complex to future changes. Also, the structure of models of an integrated functional package is independent in the sense of interaction of the separate packages.

In classification, one dimension may be larger and more complete models of reality versus smaller and simpler models, depending upon the number of dependent variables. In the simpler models there are more independent variables and the programme is run several times with different values of relevant independent variables. The simpler models require less storage capacity and are usually easier to use because of less input data.[10]

Another dimension may be optimization versus simulation models. (We include the budget approach to simulation models.) In optimization models decision-rules, i.e., normative elements, are included, while the user normally interacts with the simulation models and provides the normative elements manually. If many normative elements are involved in a decision process, it may be difficult to find a relevant optimization model. This may be the case in long and medium range management, where most of the resources are variable, and the solution will have great influence on the structure of the farm and the situation of the farm family. In these cases a simulation model will be more generally accepted. In short run management on the enterprise level, optimization models will be easier to accept, e.g., feed planning.

A third dimension may be interactive versus batch operation. The interactive execution is advantageous especially in combination with simulation models or simpler models where the programmes are run several times. The user wants to solve the task without interruptions, and when he still is acquainted with the problem. When dealing with an interactive system more realistic and effective results can be obtained in many cases, even more effective than some optimization models can give us. But it depends on both the heuristic ability of a user and the degree of the interactive programme sophistication.

Data in the CFMIS can be represented by records, data sources, codes and data banks. This component of the CFMIS is linked with a) institutions by possession and usage, b) personnel by development, usage and up-dating, c) hardware by special equipment for data gathering, transmitting and usage, d) software by data base management programmes, and e) documentation by the description of data organization and manipulation.

Finally, the CFMIS documentation developed or being developed also relates to other structural components of the system, and its content is defined by the content and function of corresponding components.

A very important feature of the system, is the so called "delivery system".[12] It has several components. Major components are marketing and the provision of introductory information about how to use the equipment and the available software; maintenance, especially of the software; an organization (institution) providing extension or commercial agents; personnel for input and output processing (i.e., coding and transforming data from one media to another), and an organization (institution) for operating the central maxicomputer.

Some computerized methods need simpler delivery systems with less of the above components than others. Skill and interest of the involved agents are important factors.[3] In computerized methods not involving agents, the skill of the user, i.e., the farmer, has, of course, the same importance, while the interest of the farmer had to be present in both cases.

The delivery system has to be considered already in the development of the computerized tools, so the hardware and software will suit the available delivery system.[10]

CFMIS DEFINITION AND STAGES OF CREATION

With this in mind, the CFMIS can now be defined as a man-and-computer organizational structure directed towards accomplishing farm management tasks through data gathering, transmitting, storage and processing and converting data into information to facilitate the farmers' decision making processes and having facilities for its further development, implementation and maintenance.

The main task of the CFMIS is to provide the best ways of rational resource utilization (labour, land, capital investment, water, energy, etc.) in the process of agricultural production, processing and marketing in accordance with farmers' goals by the means of farm management improvement based on modern economic mathematical methods, computer techniques and means of communication.

In our definition we stress the fact that any CFMIS possesses facilities for its future development. It is connected with the unique feature of this system to add a new quality to it by developing more sophisticated programmes and data bases to solve practical tasks and problems, to be an educational tool improving farmers' managerial skills and enriching their abilities. On the other hand, "if agricultural information is to be accurate and reliable, the capacity for redesign must be a normal internal function of the information system".[1]

In fact, and as a rule, such a development never stops, although it is mainly related to the software, data and documentation because of its relative simplicity. It is more costly to change hardware, and it is much more difficult to modify and organize a new organizational structure.

The CFMIS follows three stages in its development. The creation of the CFMIS should be started with preliminary surveys of the existing system of management, farmers' needs for computerized farm management decision aids, and theoretical investigations in the field of agricultural economics, farm management and technical disciplines. The goal is to define problems, and outline possible solutions, to structure tasks, to study sources and flows of information, to develop testing methods and models, and system requirements and recommendations as well.

In the stage of designing, the CFMIS type and mode are determined, the hardware is also selected, software, data system and documentation are developed and tested. Based on research methods, the evaluation of the expected performance efficiency has to be provided.

At the same time, some work on implementation can take place. Here, personnel education and training, hardware purchasing or renting, data transmitting and processing organization has to be done.

To build up a complex system such as CFMIS requires a lot of resources. These resources are as a rule limited; therefore it is impossible to create it in a full volume at once. Rapid computer technology and means of communication improvements strictly influence the structure and process of data services that are to be designed or modified.[4] That is why it is necessary to have system development facilities in a row with the CFMIS supervision as an administrative functional component providing measures on the operational system maintenance and development by interacting institutions.

Different operational CFMIS have different components and elements, modes of operation, types of computers, and forms of organization. Ohlmer and Nott (1979) have studied four main alternative combinations of these components for different computerized methods (systems). The methods have been characterized mainly by the type of hardware utilized, namely (1) on-farm use of programmable hand calculators; (2) on-farm use of micro or minicomputers; (3) on-farm use by an agent with or without remote processing, and (4) mail-in systems with a maxicomputer.

The methods are numbered in reverse order of their development. Mail-in has been used the longest; programmable hand calculators are the newest. For delivering effective management aid to farmers, Method 3 seems to have the most potential. The delivery system provides expert consultants and interpretation of output as needed. The computer processing is immediate if the hardware is operating. Many software packages already developed for Method 4 can be made accessible to Method 3 with minimal effort. Some problems can be observed with rural area telephone lines and access to the computer during certain hours of the day. For smaller problems, and for automated production control, minicomputers and Method 2 would be noticeably more reliable. Land grant universities and farmer organizations may need to review their role in creating a delivery system for Method 2. In the future all four methods are expected to exist, each serving farmers in the situations where they are cost effective.

Linking elements of structural or functional components into a CFMIS, it is possible to evaluate alternatives in the process of analysis or synthesis while dealing with any problem of the CFMIS, on the basis of the systems methodology it is also possible not only to develop structural or functional components, but to design a comprehensive programme for implementing a particular system.

TYPICAL DECISIONS AND SITUATIONS

In recent years, many models have been developed to solve the very same problems. The number of these models is rapidly growing in spite of the fact that their modification is not significant. Major parts of the models do not need to be redone, but this is done because it is sometimes difficult to build in a new module into existing models.

In some countries, this problem is beginning to be solved with the help of so-called "typical decisions" modules standardized enough to be used in making up models of any complexity and configuration. Special requirements have to be developed for these modules libraries and be used by developers and model-builders. Typical decisions cover models (model modules), hardware (typical hardware packages for farms, county offices, etc.), software (applied programme packages), documentation (typical operating instructions), etc. They represent a flexible and economical tool in the design and adoption of a particular CFMIS.

FARM SYSTEMS INTEGRATION

With computer technology developments, more and more alternatives are becoming feasible. Much is expected to be done in combining functions of automatic devices with functions of the CFMIS into an integrated CFMIS (ICFMIS).

Utilizing the idea of "distributed processing" for controlling technological processes on the farm, and simultaneously feeding the central computer with rectified data for further processing, it is possible to create an effective ICFMIS. An effect of any CFMIS is mainly created in production. So, to be effective, the CFMIS should be linked with production processes as closely as possible. Experiments with dairy farm automation on the basis of ICFMIS have confirmed this statement.[9]

On the other hand, farm management information systems should be linked with other information systems also employed for the agricultural sector, e.g. Pest Management Systems. Such a consideration requires much more effort and in some countries they are being made in the design and implementation of agricultural computing networks. There the farm level of management is considered to be the lowest level in a hierarchical structure.[11]

CONCLUSION

The CFMIS performance efficiency depends on the degree of correspondence and fitness of its components. These components should be equally effective and developed, and they should provide the way for future improvements.

Many questions in the CFMIS creation are still open. Some of them are the result of the uncertainty which takes place in any attempt at modelling reality. In this respect, any CFMIS can be considered as a model of farm management organized on a new scientific and technical basis. Impressive figures of user numbers or computer runs witness only to the need for computerization of farm management decision aids; but they do not reflect that what is done is what ought to be done. Absence of reliable methods for CFMIS analysis and synthesis creates problems needed to be solved. At the same time, great variety of models, available software for farm management, and hardware used within differently organized CFMIS can give us what is necessary to develop descriptive models of CFMIS, analyse their problems, and outline possible way of synthesis.

REFERENCES

[1] Bonnen, J.T. "Assessment of the Current Agricultural Data Base: An Information System Approach", *A Survey of Agricultural Economics Literature*, Vol. 2, University of Minnesota Press, Minneapolis 1977, pp.386–407.

[2] Chapman, C.A., Infanger, C.L., Robbins, L.W. and Debertin, D.L. "Computers,

Information and Community Development: A Review of State Extension Programmes", *Taking Computers to the Community: Prospects and Perspectives*, (ed.) Carol A. Chapman et al., Kentucky Coop. Extension Service, 1978.

[3] Harsh, S.B., Black, J.R. "The Michigan Computerized Forward Planning System", Agricultural Economics Misc. 1971–72, Dept of Agricultural Economics, Michigan State University, 1971.

[4] Harsh, S.B. "The Developing Technology of Computerized Information Systems", *Amer. J. Agr. Econ.* 60 (1978): 908–912.

[5] Infanger, C.L., Robbins, L.W. and Debertin, D.L. "Interfacing Research and Extension in Information Delivery Systems", *Amer. J. Ag. Econ.* 60 (1978): 915–920.

[6] Johnson, G.L., Halter, A.N., Jensen, H.R. and Thomas, D. (eds) "A Study of Managerial Processes of Midwestern Farmers", Ames, Iowa 1961.

[6a] Kuhlmann, Friederich, "The Farm Firm Simulator SIMPLAN and Its Application to Research, Extension and Decision Making" Ag. Econ. Staff Paper 79–24, Michigan State University, East Lansing, Mi. 1979.

[7] LaDue, E.L. "Impact of Alternative Remote Access Computer Systems on Extension Programmes". *Amer. J. Agr. Econ.* 60 (1978): 135–138.

[8] Manetsch, Thomas G. and Gerald L. Park, *System Analysis and Simulation with Applications to Economic and Social Systems*, Part 1 and Part 2, 3rd edition, E. Lansing, Michigan, August 1977, Chapter 2.

[9] Minister, P. "Into the Computer-Controlled-Wide Blue Yonder", *Dairy Farmer*, February 1978.

[10] Ohlmer, B. and Nott, S. "The Need and Design of Computerized Farm Management Tools." Ag. Econ. Report No. 353, Michigan State University, 1979.

[11] Polyakov, M.A. "The Automated Control System for the Management of Agriculture (ACSMA): Creation Problems and Future Developments". A Seminar Paper, Dept. of Electrical Engr. and Systems Science, Michigan State University, East Lansing, Michigan 1978.

[12] Pugh, C.L. "Farm Management Information Systems – A Practical Approach", Farm Management, Vol. 3, No. 5, Spring 1977.

[13] Schmidt, J.R. "Documentation of EDP Programmes for Extension". Paper presented at the North Central Farm Management Extension Workshop, Michigan State University, May 1973.

[14] Thompson, S.C., "Central Computing Facilities for Information Systems", Draft for *Agricultural Information Systems*, 1978.

[15] Thompson, T.L., Kendrick, J.G. and Stark, A.L. "AGNET – A Management Tool for Agriculture", ASAE Paper No. 78-5001, St. Joseph, Michigan.

DISCUSSION OPENING – TED NELSON

The authors have given us a comprehenisve taxonomy of Computerized Farm Management Information Systems and the large number of combinations of equipment, software and delivery methods available to build CFMIS.

I fully endorse the addition of a delivery component parallel to the structural and design blocks in Figure 1. It seems to me that we need to consider three questions about the application of these systems at the farm level and this seems naturally to follow the presentation.

1 Are the concepts and models used understood by the farmer? If not, the best hardware and software can be expected to fail, until such time as the user has been taught (with or without the aid of computers).

2 Who is to accept the responsibility for developing computer-use skills

by field agents and farmers? (Agricultural economists do not teach basic mathematics or reading but may have to teach a few hours of computing skills to farmers for the use of calculators and micro-computers to be successful).

3 How can we provide useful software for hardware currently available, with cheaper and better hardware becoming available so often, which will displace the hardware (and probably software) of each yesteryear?

GENERAL DISCUSSION – RAPPORTEUR: LEONARD KYLE

The general discussion was comprised of the following questions regarding (1) measurement of benefits of computers to farmers; (2) whether programmes are designed to reflect the way professionals or farmers think; (3) the usefulness of various types of computer and in particular micro-computers; and (4) the cost of farm advisers and their training.

In reply, the authors felt that (1) was difficult because more tasks would be done in less time and farmers would also increase their managerial input in other areas. Regarding (2), the system had to be designed with farmers in mind if it were of a kind where they had access. In other cases some compromise was possible. Under (3) the most immediate use was that of financial control. Larger and more complicated computers can be used for planning and decision making. Within their limitations, micro-computers can be similarly used. It was felt that (4) represented the major item of cost, by comparison with which the cost of the computer was of minor significance.

Participants in the discussion included Keith Butterworth, Stephen B. Harsh, Stephen C. Thompson, A. Hartmann and John C. Duncan-Watt.