THE SYSTEMS APPROACH -- RESEARCH OR RESEARCH MANAGEMENT*

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INTRODUCTION

The purpose of this paper is to discuss the management of larger multidisciplinary research projects in the existing agricultural experiment station framework. Through a recounting of changes occurring in agriculture and their implications for research, the need for research management is established.

Next, systems analysis is introduced as a means for organizing the quantity and variety of resources involved in large multidisciplinary research projects. After a discussion of the requirements for engaging in systems analysis, suggestions are made for organizing research through the systems analysis approach. An example, with diagrams, is used to help clarify the discussion and to strengthen the argument that systems analysis constitutes a potentially productive tool -- both for primary research and for research management.

A Changing Agriculture

We first attempted to develop agriculture in this country by classroom instruction. This failed because our information base was too small. Only after adding research as an additional input was the productivity of the American farmer significantly increased. The evolution that has occurred in agriculture was not miraculous, nor did it just happen. It was a simple cause-and-effect relationship. The cause was the great investments we made in manpower and capital; the effect is the dividends we are reaping.

No single act of legislation did more for agricultural development in the United States than did the Hatch Act. It not only provided funds for research, but also sparked the organizational structure and program developments in our colleges of agriculture and agricultural experiment stations. Throughout the country, our colleges developed academic departments to fit the research activities, and the recurrent federal funds prompted significant investments of state resources for agricultural research.

Our research emphasis up until the 1950's was largely production oriented and the academic structure of the experiment stations reflected this. Even so, our discipline-oriented departments have been extremely useful administrative units. They have given organizational image to the disciplines and have met the early production needs of agriculture. However, too often we built fences around our departments to protect their territorial integrity and there resulted, to a point of loss, attempts to be academically and scientifically self-sufficient. We emphasized the diversity among the living systems rather than the similarities.

American agriculture has entered a new era. In the past few years we have moved from a period of surpluses of food and fiber products and a position of over-capacity in production with attendant depressed prices to a period of shortages, of increased prices, and exhortations to achieve maximum production from the resources allocated to agriculture in this country. International, rather than just national, events and forces are affecting American agriculture. The agricultural sector of the United States is being called upon to satisfy the ever-increasing demand for high protein foods in the developing nations around the world. Not only has the need for food and fiber products increased world-wide, but the ability of people in other nations to pay for such products has

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increased. These pressures upon, or opportunities for, American agriculture, depending upon one's point of view, have been further compounded by the natural catastrophes that have been hitting farmers simultaneously all over the world. Accommodation of the vagaries of weather has long plagued agricultural production. But, the simultaneous appearance of drought or flooding in many of the important farming regions of the world has brought both governments and consumers to the realization that an abundance of food and fiber products at bargain prices cannot be taken for granted.

The increasing demand for American agricultural products world-wide and the importance of the contribution of agricultural exports to this country's balance of payments position indicate that American agriculture must now put forth a strong effort to produce the quantities of food and fiber required to satisfy these demands. These increased demands are going to have to be met by an agricultural production system in which resources are organized and structured and decisions are made differently than has been the case in the past. This conclusion gives recognition to the fact that, rather than being simply a "way of life," farming today is a business – a much more complicated and imprecise business than most people realize.

This new era in agriculture is also accompanied by an increased awareness by society of the necessity for maintaining an ecological balance and minimizing undesirable environmental effects of expanded agricultural production. Increased production of food and fiber must be accomplished without undue detrimental effects upon the environment.

Role of the Experiment Station in a Changing Agriculture

The need for research and educational programs to provide information to agricultural producers was recognized by Congress many years ago. Since the inception of the land grant college-agricultural experiment station-extension service system, we have had continuous accumulation of research information concerned with the problems of agriculture. However, as new techniques evolve and new technology is adopted, the requirements for information change – becoming increasingly more complex:

> Since World War II the problems of efficient public administration of agricultural research resources have increased rapidly in size and complexity. Each year the agricultural sector seems to have more rather than fewer researchable problems. Specialization has grown rapidly and this has increased the need for program planning and coordination. The general explosion of knowledge and the proliferation of funding sources have increased the possible scope or range in the mix of station research activities [5].

Complexities of Agricultural Production

Management of the farm business, because of the biological processes involved, requires that decisions be made at times when the outcomes or the implications of such decisions will be highly uncertain to the farmer. A considerable time lag may exist between decisions to produce a crop and the harvesting and marketing of that crop. Weather conditions, insect and disease infestations, prices of inputs, product, and competing products, and other variables are subject to change.

In addition to these uncertainties, the farm manager must possess technical knowledge regarding the production of the particular crop or combination of crop and livestock activities in which he will be engaged. All aspects of crop production – including selection of equipment; land preparation; timing of land preparation activities to suit the needs of his particular soil; incorporation of fertilizers; choice of pre-emergence chemicals, selection of crop varieties; determination of planting dates; selection of the proper cultivating, herbicide, and insecticide programs; proper harvest times, and marketing – reflect areas in which the farm manager requires decision information. While many farms are becoming quite specialized, most farmers must be technically competent in the production of multiple crops, perhaps involving different soil types, different machinery, different chemicals, different production techniques, and different methods of marketing. Those farmers who also produce livestock have a considerably longer planning horizon, since the biological production period for livestock is sufficiently long to require substantial changing of plans before the planned production is realized.

Implications for Research

In order for our research establishment to effectively serve the new era in agriculture, we must embark upon a new era in agricultural research and research management. The past contributions are recognized and well documented of agricultural researchers to the development of the most efficient agricultural production system the world has ever known. These contributions have been the result largely of the individual initiative and individual accomplishments of researchers operating in a rather loosely organized and, in most instances, uncoordinated environment. Research has largely been directed toward the solution of a particular problem in isolation from all other problems and interrelationships and has not been designed to reflect the impact of such research upon the total production system. The complexities of the problems of today's agriculture and the magnitude of the demands being placed upon research resources are such that the problems may not be solved and these demands met by using the former organizations and approaches to agricultural research. Research problems must be defined and attacked within the context of their relationship to the total farm organization and production system. Tomorrow's research must be designed, managed and conducted in such a way as to best satisfy the information needs of tomorrow's farmer and the public.

RESEARCH MANAGEMENT

The Need for Research Management

Providing assistance to the farmer with his decision-making problems will require research that is broader in scope than that which individual disciplines are capable of visualizing and investigating. Thus, researchers from several disciplines should work together in a coordinated effort so that the research results obtained will contribute to the solution of the broadly stated problem. The organization and functioning of such a team is a research management problem.

Research management, in the broadest sense, involves the allocation of scarce, valuable research resources to problem areas in which the solutions will have the greatest expected benefits relative to cost.

Paulsen and Kaldor [5] summarize one philosophy and the related criterion as follows:

> If research is viewed as a social investment, the criterion for selecting specific research investment is the greatest social return possible for total investment funds available. The criterion is implemented by estimating the expected rate of return for resources to be used in each alternative and selecting enough of those research investment alternatives with the most favorable benefits relative to cost to utilize the available budget.

They also note that the improvement of social return on research depends very heavily on the creativity shown by individual scientists in suggesting high priority research alternatives. Although this point will not be pursued here, it should become apparent later how the approach suggested could assist in facilitating this contribution by individual scientists.

The Problem of Research Management

The fact that much information has been provided in the past does not diminish the responsibility of the state agricultural experiment stations to continue to develop new and better ways of producing agricultural products. The ever-present questions are: (1) how can the needed information be determined at the lowest cost and in the most practicable manner? (2) how can the resources of the experiment station be utilized most efficiently? and (3) what information needs are most pressing? To bring the questions closer to home, how can one experiment station director organize the resources of 15 or more departments and a number of affiliated branch experiment stations to determine what questions need to be answered and to insure that the priority questions are examined and necessary information provided?

It is becoming increasingly difficult for society, its representatives, and agricultural research administrators to identify the most valuable allocation of research resources. Can the system analysis approach assist in alleviating this problem?

Use of Systems Analysis for Management of Experiment Station Research

A *system* is a regularly interacting or interdependent group of items forming a unified whole. This definition allows the specification of the system at many levels (a point to be stressed later). To the agronomist, a part of a plant may be a system – or a plant with its interactions with insects, disease, environment, etc., may constitute a meaningful system. Likewise, an economist may view the national economy as a system – or he may focus on the cotton economy as a system – or he may concentrate on a typical acre of cotton with its agronomic, economic, human, and other interactions as a system.

If this satisfactorily describes a system, what is systems analysis and what is its purpose? *Systems analysis* can be defined as a coordinated set of procedures which addresses the fundamental issue in management – that is, specifying how men, money, and materials should be combined to achieve a larger purpose. At its simplest, it could be a quantitative study of the possible ways to achieve certain goals or to use certain resources. A good systems analysis, at whatever level it is done, is one that carefully identifies the important issues and alternatives and relates the several costs and benefits of each project in a way that is meaningful to the persons responsible for approving a program [1, pp. 1-2].

The terms models, systems, systems analysis, modeling, simulation, systems modeling, system simulation, operations research and others, are currently in vogue. They are new to many, are therefore fashionable, and are receiving considerable attention. The fact that attention is being given to these terms is not bad – *if* they are being appraised for their usefulness in terms of providing the means for comprehensive analyses of problems. On the other hand, if their attraction is simply "newness", their potential usefulness may be overrated and result in misdirected research effort.

REQUIREMENTS FOR SYSTEMS ANALYSIS

If it is to be useful, systems analysis requires some particular expertise. The capability for modeling complex systems requires knowledge of the system and an orderly and logical mind. Converting the conceptual model to a quantitative model requires training in mathematics, statistics, and optimization techniques. Transforming the mathematical model to a computer-operational model necessitates familiarity with an appropriate computer language. Implementation of the model depends on adequate computer facilities. And, verification and interpretation call for a little (or much) of subject matter knowledge, economics, mathematics, and logic.

"Systems analysis seeks to integrate the power of advanced quantitative analysis and the conceptual richness of economic theory into systems design and evaluation. In this way it hopes to provide larger opportunities for the skillful designer and manager to exercise his judgment and understanding of substantive problems. The computer-based methods inherent in systems analysis reduce the computational burdens on the (user) and provide him with the freedom to exercise his creative abilities in a more sophisticated and incisive way" [1].

SUGGESTED ORGANIZATION FOR AGRICULTURAL RESEARCH

Management can be an essential contributor to the success of an experiment station. The complexity and size of the modern experiment station, the magnitude of its capital investment, and the speed of technological change require a much greater utilization of managerial resources than in less hurried times of the recent past. In any event, capital investment and raw material input held constant, management is the element that most affects the researcher's productivity.

Group activity requires organization. Organization is the pattern of ways in which large numbers of people, too many to have intimate face-to-face contact with all others, and who are engaged in a complex task, relate themselves to each other in a conscious systematic establishment and attempt to accomplish mutually agreed objectives [6].

Large multidisciplinary research projects require a project manager or small group of coordinators to function as a linking pin [5] to couple the individual scientist, departments, and in some cases, universities together. The project manager must also encourage and be responsive to frank, candid, and instructional feedback.

However, the most important role of the project manager lies in providing comprehensive prior planning. Such planning contributes to attainment of project objectives in the following ways:

1. Directly expresses goals, thereby providing a basis for measurement, evaluation and control of research resources;
2. Provides a framework for decision-making and increases the chances that subsidiary plans and decisions at all levels will interface and will not conflict;
3. Explicitly lists value judgments and assumptions;
4. Is a means for improved communication and motivation, and
5. Provides the potential for spotting problems in advance and encouraging solutions.

The project manager, in essence, must develop an inexpensive simulation of the future, thereby providing for a comprehensive systems review to establish important internal and external variables and to build the rough form of the system.

One of the stickiest problems facing the project manager is the selection of a proper time span for planning. If the time span is too long, it may involve unnecessary expense and time without contribution to research achievements, and also places an unnecessary burden on management. On the other hand, if the time span is too short, the important problems facing the organization may not be recognized or identified early enough to permit the desired action. There is no scientific formula for determining appropriate time spans. Nevertheless, there are some factors which should be considered when making such decisions. Among them are the following:

1. The organization's resources. Planning takes time and money; the longer the time span and the more detailed planning becomes, the more expensive it will be.
2. The nature and complexity of programs. Agencies dealing with familiar programs in accepted areas of responsibility may find a

shorter planning span more workable. The reverse is often true when agencies are involved in unusual problems requiring innovative analysis and the building of public support through justification of expenditures whose impact may not be immediately apparent. When programs are large, many, varied, and interrelated, a longer time period may be useful simply to provide the time and means for better coordination and control.

3. Immediacy of demand for results. The lead time required to obtain the desired results is obviously a critical factor.
4. The program environment. Both the need for planning and the time span required are conditioned by the program environment: the stability or lack of stability of technological factors, the nature of political decision and support, the degree of dependence among economic activity, and the man-power constraints [3].

The key to successful completion of larger multidisciplinary research projects lies in a comprehensive and systematic approach to prior planning. There appears to be no short cut to this stage of the research project. It is hard and painstaking work. A careful literature review will always be required. The approach to be taken must be transferred from a conceptual plan somewhere in the research manager's mind to an operational plan on paper which is understandable by all researchers and administrators involved in the project. Some sort of network analysis seems to be most appropriate for this task. However, it must be realized that no single network can be constructed in sufficient detail for most of the larger multidisciplinary research projects. Consequently, the project manager needs to develop the skill for constructing networks or flow diagrams at various strata. Some networks will be extremely aggregated while others may be quite detailed.

For example, when discussing or presenting the proposal to representatives of a funding agency or higher level administrators (such as the director of the experiment station) a macro presentation may be best. When the proposal is presented to the heads of the departments whose personnel will be involved, additional detail will be required. And, finally, when the contribution of the individual researcher is discussed, extreme detail (a time-dated work plan) is mandatory. Naturally, the project manager cannot develop a detailed plan for all researchers involved in a large project. He must encourage the individual scientist to perform the task. However, he can and should review and modify the plans of the individual scientist. Planning at this level is the most detailed and should include an analysis of the individual scientist's complete research program. For example, many experiment station researchers are assigned to more than one research project. Only by detailed planning can a sound judgment be made as to whether the individual is over-committed, or whether he can be expected to perform his tasks in the time allocated, etc.

AN EXAMPLE

Consider the following example for development of a farm simulator at Mississippi State. Figure 1 is aggregated or macro in nature. It indicates that the various crop models such as corn, cotton, and soybeans must be combined with insect, disease, and weed models along with weather and soil models to form a meaningful farm simulator. While this conceptualization is by no means complete, it does focus upon the decisions that farmers must make, and it provides some indication of the complex interactions involved and the research effort that will be required. Such a conceptual and theoretical framework for the organization, operation and functioning of the various disciplines must be provided if maximum benefits are to be achieved. In Figure 1 the cotton growth model shows up as only one line. However, moving from the macro- to the micro-network analysis concept, Figure 2 details the cotton growth model. Similarly, insect models in Figure 1 are simply noted insect model 1, 2, ...N, whereas Figure 3 is a network of insect pest management research activities in more detail. Finally, Figure 4 even more thoroughly outlines insect pests peculiar to cotton.

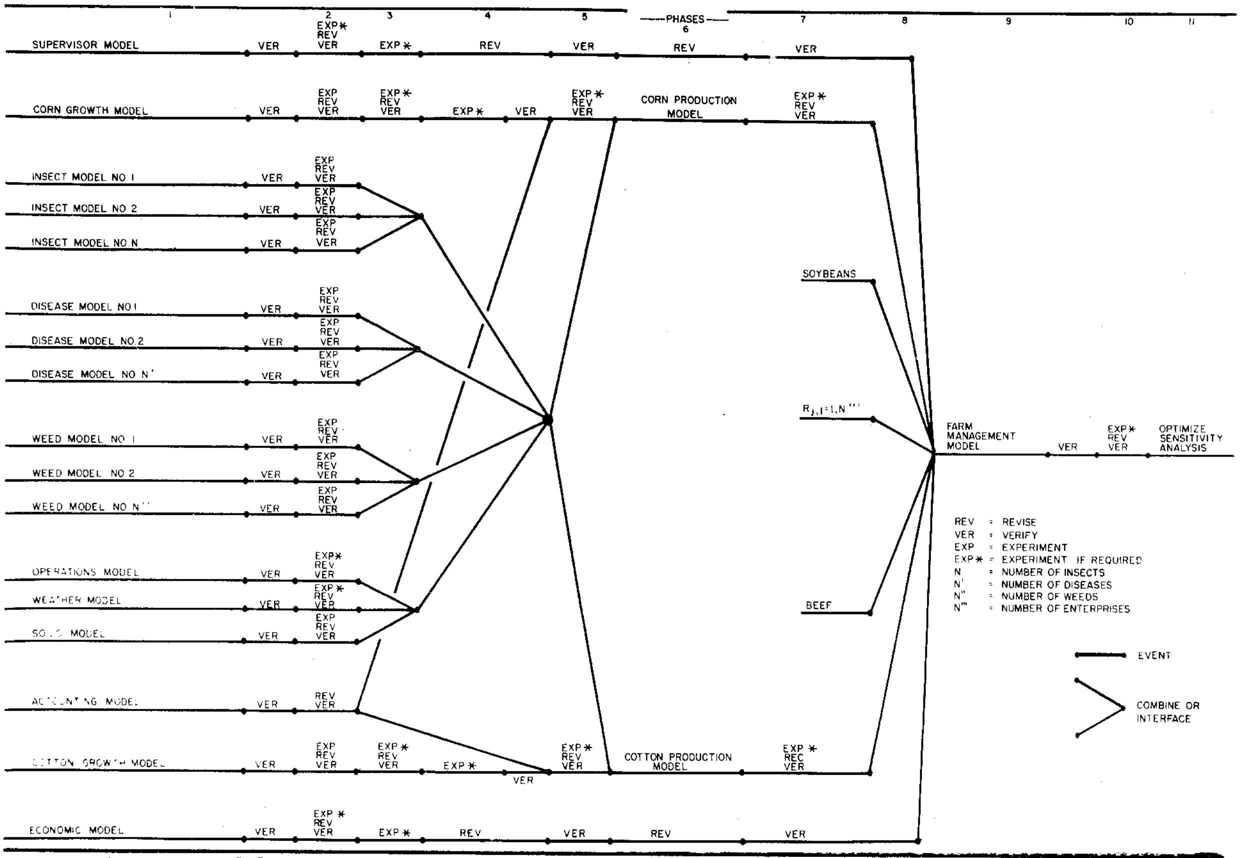
If these networks, or flow charts, are developed from the macro to micro or in reverse, and the research manager and the primary research manager and the primary researcher both understand the research objectives, the research has a higher probability of success. It is recommended that some type of network analysis cover the entire research project from some point similar to Figure 1 (or even more aggregated) all the way to a detailed, time-dated network analysis of all experimentation (whether field or laboratory), and that the network analysis clearly indicate expected times for completion of research and reporting of results.

EVALUATION OF THE SYSTEMS APPROACH

The advantages of using some type of systems analysis as a research management tool are that it:

1. Provides a clear indication of who is responsible for each project activity –

Figure 1. EXAMPLES OF SYSTEMS ANALYSIS AS A RESEARCH TOOL TO SIMULATE A FARM MANAGEMENT-PRODUCTION SYSTEM.*



*Source: [7]

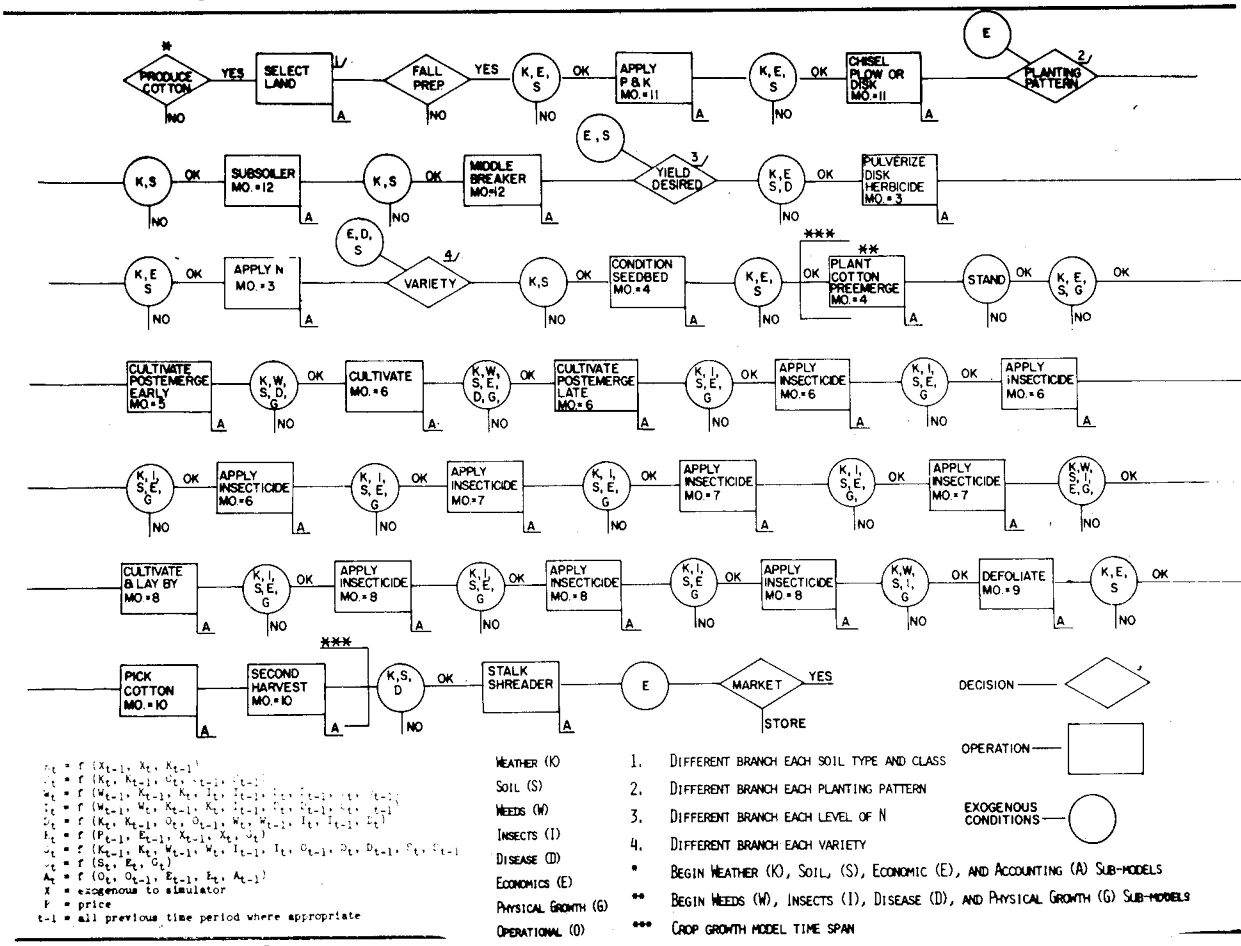
designates responsibility -- and spotlights exceptional as well as poor performance;

2. Reduces probability of overlooking a key activity which might delay subsequent activities,
3. Improves logic of planning (ascertains whether activities are in proper sequence);
4. Encourages people to meet schedules -- their mistakes become obvious to all concerned;
5. Improves utilization of key resources;
6. Allows "management by exception" – reduces time demands on key management personnel – after comprehensive prior planning, management time is spent only on trouble spots; and
7. Provides the project manager with a detailed overview of the project. In multidisciplinary research the project manager often works outside his area of specialization. Systems analysis which requires the project manager to "write it down" can be extremely beneficial.

The advantages of using systems analysis as a primary research tool include:

1. Requiring specification of a conceptual model of the system being analyzed and a detailing of the existing state of knowledge with respect to the modifiable relationships within the system. As a result, relationships about which sufficient information exists for the assumptions of the model will be identified. More importantly, relationships in which information is inaccurate or nonexistent and in which additional research is needed also will become evident. This is especially true if a crude model can be developed early in the project;
2. Bringing relevant issues and pertinent factors into the open. Without the systems approach, decisions are often compromised by lack of complete information;
3. Providing for better direction for the individual researcher;
4. Providing a basis for the establishment of research priorities by allowing the "testing" of alternative courses of action before they are adopted [2];
5. Measuring relevance of research;

Figure 2. TYPICAL CROP PRODUCTION FLOW CHART FOR COTTON.*



*Source: [4]

6. Allowing greater insight into entire systems;
7. Using it to screen experiments, and
8. Forcing the researcher to organize his research effort.

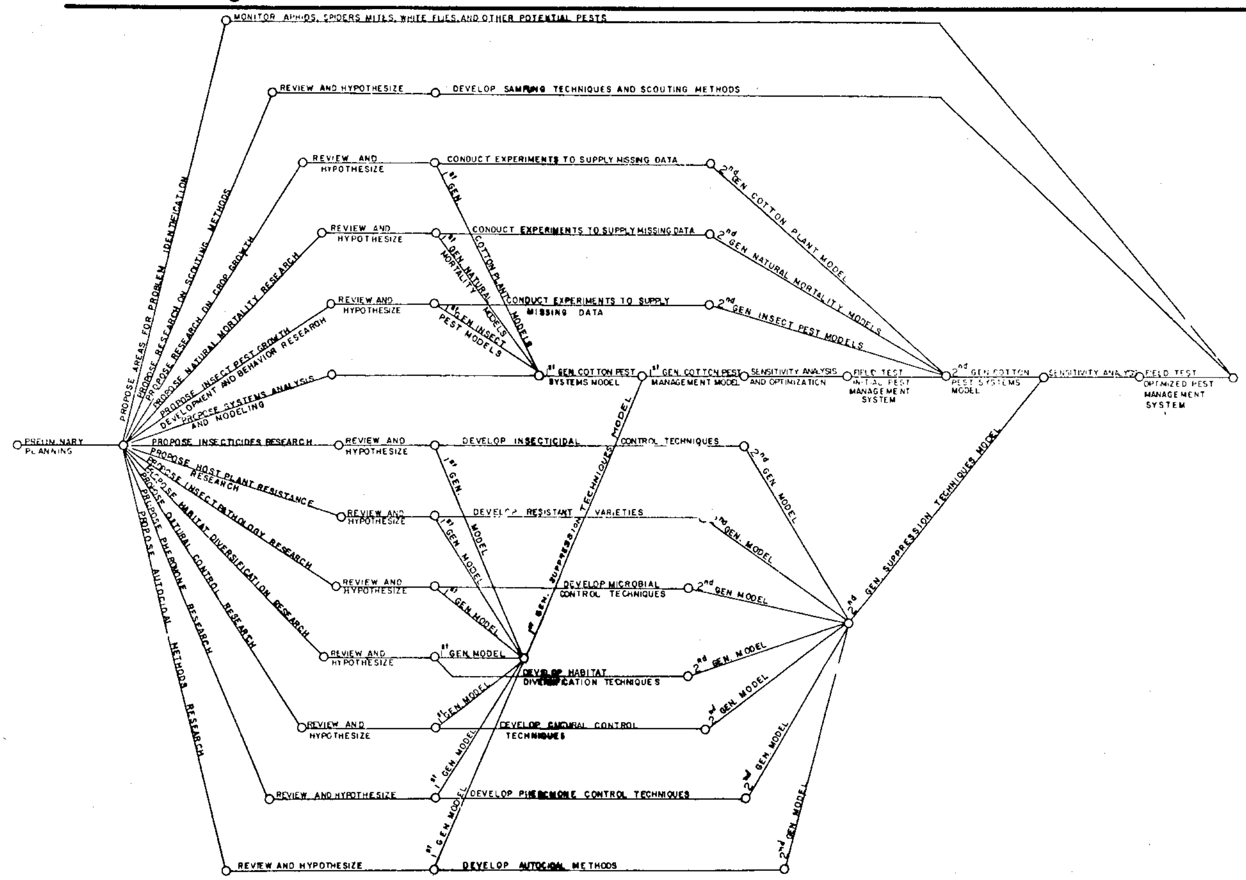
A disadvantage is that the individual scientist may begin to feel like an administrator instead of a researcher. He may learn to enjoy pure conceptualizing and performing analysis in general and forget to do his actual research. Another possible disadvantage is that systems research is structured. There may be a threat to what some professionals refer to as "academic freedom." However, if the experiment stations are to merit public esteem, we must continue to identify and solve the *real* problems in agriculture, rural development, and human welfare. Many of these problems are complex problems and require a multidisciplinary approach. That, of necessity, means that we must cross departmental lines within the experiment station. We must utilize the team approach for the identification and solution of problems. The development of an interdisciplinary or team-approach attitude by scientists in the different departments is mandatory in order to have effective interdisciplinary research programs.

CONCLUSIONS

Systems analysis is not easy. It is hard work but will make the researcher more productive per unit of time. It also will assist the research manager in coming to grips with the totality of the research project. Finally, systems analysis changes from project to project or even from subproject to subproject – it is never the same. In large multidisciplinary research projects, the first role of systems analysis is usually one of research management. As one moves into the productive stage of the project, the role of systems analysis changes from research management to primary or pure research. Systems analysis is not the usual research tool – it is a concept. It can be anything or everything that is useful in attacking a research problem.

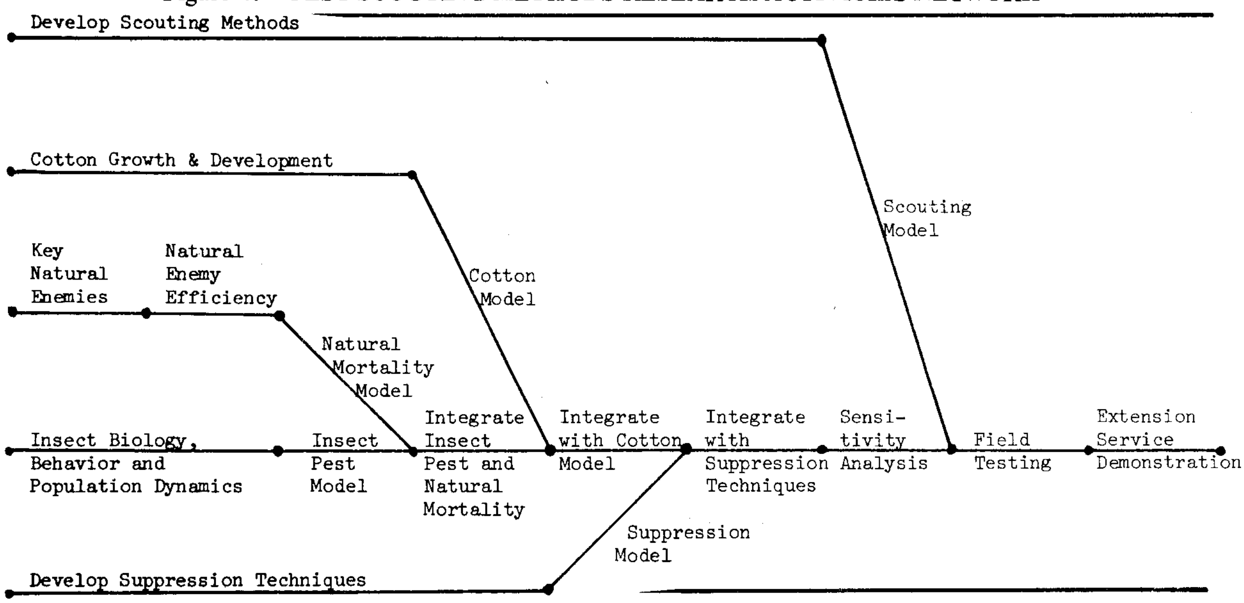
In conclusion one might say that the systems approach simply means that one is doing a thorough and comprehensive job of attacking the problem.

Figure 3. INSECT PEST MANAGEMENT RESEARCH ACTIVITIES NETWORK*



*Source Unpublished material, Drs. F. A. Harris and L. G. Brown, associate professor of entomology and assistant professor of industrial engineering, respectively, Mississippi State University.

Figure 4. PEST SCOUTING METHODS RESEARCH ACTIVITIES NETWORK*



*Source: Unpublished materials, Drs. F. A. Harris and L. G. Brown, associate professor of entomology and assistant professor of industrial engineering, respectively, Mississippi State University.

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