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ABSTRACT

The Management and Information System for Occupational Education (MISOE) is best described as a process which links man as a manager of a complex social service with information which describes important aspects of that social service. More specifically, the scope of MISOE includes: (1) those decisions which determine the social goals to be attained by occupational education, (2) those decisions which determine the relative amount of occupational education to be provided for citizens of Massachusetts, and (3) those decisions which determine the occupational capabilities to be provided, as well as the instructional programs designed to help individual human beings attain such occupational skills and abilities. Major sections of this document present a discussion of the integrated decision-making process of MISOE, the information component, and a forecasting example at the overall agency level. In discussing the information component, reference is made to a simulation model and to a feedback loop. A related document is available as VT 016 944 in this issue. (JS)

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OCCASIONAL PAPER #6

MISOE IN MOTION

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The express purpose of Occasional Paper #6 is to provide a clear picture of the dynamic aspects of MISOE. This paper flows from Occasional Paper #5, which provided a definitional basis for the operational statements contained within Occasional Paper #6. The development described in Occasional Paper #6 followed the completion of Occasional Paper #5 and will naturally cause some redefinitions of static MISOE space. Such differences represent growth, not conflict. Monograph II, to be developed during the Summer of 1972, will synthesize all Occasional Papers into a single statement of MISOE and this Occasional Paper is not to be confused with that summarizing effort.

In spite of not pretending to be a complete statement, Occasional Paper #6 is written to provide an uncluttered and straightforward description of "MISOE In Motion" as perceived at this moment in developmental time. Since its purpose is to communicate and not to confuse, the description of technical components of MISOE (currently under development) will be deferred to future Occasional Papers or to Monograph II. Occasional Paper #6 is separated into four logically distinct sections: (1) The Purpose and Scope of MISOE; (2) The Decision Makers Served By MISOE; (3) The Integrated Decision Making Process of MISOE; and (4) The Information Component of MISOE.

THE PURPOSE AND SCOPE OF MISOE

An impression of the purpose of the Management and Information System for Occupational Education (MISOE) should provide a basis for understanding and assessing the specific operational components of MISOE described in this paper. Although the scope of MISOE is a summation of the parts described in this paper, a general statement describing MISOE range should contribute to the understandability of this paper. Since scope is a function of purpose and both combine to form a framework for understanding, purpose and scope are joined in this first section.

Purpose of MISOE

MISOE is not a report, annual or otherwise. MISOE is not a survey, a search or a research. MISOE is not a state testing program for occupational education. MISOE is not a computer printout nor is it an infinite number of printouts. All this is to say that MISOE is not merely an information system, although information is an important part of MISOE.

MISOE is best described as a process which links man as a manager of a complex social service with information which describes important aspects of that social service. The purpose of the man-information connection is to offer an information feedback mechanism to man which attempts to describe the consequences of his decisions. MISOE is designed to help man the manager predict future consequences of current decisions and to provide insights and understandings of the ways elements of a social service and their outcomes effect each other. MISOE's fundamental focus is man, both man the manager and man the recipient of the services of a complex social agency. MISOE's purpose is to relate man the potential or real recipient of social services with man the determiner of social services through an information feedback system, a system which is designed to constitute an important part of current or future determinations.

The Scope of MISOE

The scope of MISOE is limited to occupational education within Massachusetts and includes all management decisions which determine the substance of occupational education. Three types of management decisions for occupational education are identified and included within the scope of MISOE: (1) those decisions which determine the social goals to be attained by occupational education; (2) those decisions which determine the relative amount of occupational education to be provided for citizens of Massachusetts; and (3) those decisions which determine the occupational capabilities to be provided as well as the instructional programs designed to help individual human beings attain such occupational skills and abilities. These management types were discussed in Occasional Paper #5, and are referred to as: (1) managers over all social agencies; (2) managers over all education; and (3) managers of occupational education. Managers of occupational education are divided into: (A) managers over all occupational education and (B) managers within specific occupational education programs. At this time MISOE is not concerned with identifying role incumbents at each management level, but only in specifying these distinct decision types for occupational education. MISOE was conceived and is being developed to serve decision types at all three levels.

MISOE is essentially a state management and information system. MISOE is being structured to treat the state wide impact of occupational education on state wide goals in a way that provides an empirical basis for state wide decisions about relationships among the elements of occupational education programs, the people served and the outcomes attained. To conclude that such a system does not serve the needs of local communities is to assume that state goals are unrelated to local needs. Typically, state goals are described in terms of differential local impacts or needs. For example, a state goal to reduce unemployment to 5 per cent among twenty to twenty-five year old youth triggers vastly different needs across communities in Massachusetts. Although MISOE will provide local communities with information which describes the degree to which they are meeting state goals, it does not substitute for a local educational management system which is singularly responsive to unique local needs. However, MISOE is purposefully designed to provide for an exemplary structure for local education information systems and considerable information which will be supportive of such systems. Further, MISOE is developed so that local educational information systems can be connected to a state wide system such that local communities can easily replicate MISOE findings or use state wide information as bench marks for comparison. This is not to imply that MISOE is conceived as a structure to standardize instruction or educational goals simply because its fundamental scope is state wide management. Provisions for diversity are a basic part of MISOE structure and have been thoroughly discussed in previous papers (see particularly Monograph I). Occasional Paper #6 is concerned with the substance of MISOE, which should make apparent MISOE's fit into a flexible and responsive state wide educational system.

A summarizing statement of purpose and scope might be that the Management and Information System for Occupational Education is intended to assist man in managing occupational education for Massachusetts by providing an information support system which describes the results of past decisions in a way that allows him to systematically estimate the future consequences of current decisions based on past results, prior to committing resources to actions designed to achieve specific goals.

THE DECISION TYPES SUPPORTED BY MISOE

The purpose of this section is to specify the decision types to be supported by MISOE and to suggest a formal decision making process. A later section of this Occasional Paper will relate decision types to specific information types within the formal decision making process. Put another way, Occasional Paper #6 is being developed to describe the dynamic aspects of MISOE in terms of the decision makers to be served. As previously stated, role incumbents will not be assigned to decision types in Occasional Paper #6, although in some instances they will be suggested. Frequently, role incumbents are not restricted to one decision type.

No distinction is made between policy making and policy execution at each management level, i.e., <u>over all social agencies</u>, <u>over all education</u> and <u>within occupational education</u>. MISOE assumes that all management behavior is made up of both goal determination and attainment. It should be noted that Occasional Paper #6 initiates an additional decision making level, <u>over all education</u>. This level was not separately described in Occasional Paper #5, but included within "educational space". However, since MISOE does conceive of a range of decisions which determine the mix of occupational and non-occupational education as being separate from the range of decisions which stipulate occupational capabilities and programs, an <u>over all education</u> decision type is distinguished from within occupational education decisions.

<u>Type I - Over All Social Agencies</u>. Type I decisions can be classified by three categories: (1) Setting specific societal goals, based on an

assessment of societal values and value related realities; (2) raising and allocating resources across governmental and proprietary agencies to impact on the specified societal goals; and (3) evaluating the performance of agencies in terms of their individual impacts on specified societal goals. Put another way, decision makers over all agencies are responsible to determine the least cost mix among competing governmental and proprietary agencies to achieve specific societal goals. MISOE conceives of Type I decision makers as the state legislature, a group responsive and responsible to the citizens of Massachusetts. To over all agency decision makers, occupational education is one of several alternatives available to attain specified societal goals.

MISOE considers Type I decision makers an essential part of the integrated decision making process for occupational education in Massachusetts. Not to include Type I decisions in an educational management and information system is to render that social service non-responsive to societal needs.

Type 2 - Over All Education. Type 2 decision types can be classified by the same three general categories described in Type I: (1) Setting specific educational goals, based on prescribed societal goals; (2) allocating resources across competing educational programs (secondary-post-secondary, academic-occupational, etc.) most likely to impact on these educational goals; and (3) evaluating the impact of specific educational programs in terms of specified societal goals. Put another way, decision makers over all education are responsible to determine the least cost mix among competing educational programs to achieve specific societal goals.

Type 2 decision makers are an essential element of the integrated occupational education decision making process. They are responsible for assigning both human and capital resources to occupational education. They are also responsible to over all agency decision makers for the total impact of education on societal goals. Not to include Type 2 decision makers in MISOE would be to exclude occupational education from a rational relationship between Type 1 and Type 2 decision makers.

Type 3 - Within Occupational Education. Type 3 decision types can be classified as: (A) over all occupational education and (B) within specific occupational education programs. Both over and within occupational education decision types fall into the same categories as Type 1 and 2 decisions, i.e., (1) setting goals; (2) allocating resources; and (3) evaluating impacts.

Decision types over all occupational education programs basically assign goals as well as human and capital resources to specific occupational programs at the secondary, post-secondary or adult level. Put another way, managers over all occupational education programs are responsible to establish and maintain the least cost occupational program mix to achieve specific societal goals.

Decision types within occupational education programs determine the specific, end program occupational capabilities most likely to achieve stipulated societal goals, as well as the instructional process mix or program for specified ranges of student types most likely to support occupational capability attainment. To the within occupational education decision maker, the product is the number and occupational capability configuration of the program completors. Put another way, the within occupational education decision maker is responsible to determine the least cost occupational education instructional process for specified student types to achieve specific occupational capabilities. He is also responsible for determining occupational education objectives within a program which are most likely to accomplish societal goals.

Type 3 management decisions are of fundamental importance to MISOE. This is not to suggest that MISOE is a narrow process that fails to deal with the comprehensive nature of the occupational education decision making process, but to simply state that the information basis for many of the decisions concerning occupational eduation result from Type 3 decisions. MISOE will structure a substantial part of the information resulting from Type 3 decisions such that it can "feedback" into Type I and Type 2 decisions.

THE INTEGRATED DECISION MAKING PROCESS OF MISOE

Since MISOE classifies decisions for occupational education by three distinct types and assumes that important constraints for occupational education are established at each level, a decision making process which integrates decision making behavior across types into a coordinated activity is fundamental to the purpose of MISOE. Such an integrated decision making process would dictate that the goals of Type I decisions are reflected in the goals and objectives of Type 2 and 3 decisions. Examples of this integrated decision making process were offered in Occasional Paper #5 and will be restated below.

As previously discussed, economists tend to describe efficiency as either achieving specified goals at least cost or maximizing production with fixed resources. This dual notion of efficiency is important to the integrated decision making process of MISOE. In general, superordinate agencies, when dealing with subordinate agencies, are concerned with achieving the least cost solution to stated goals, so that limited resources can be applied to other needs. For example, the legislature distributes its funds on a "least cost" efficiency basis to competing social service agencies. However, when they report to their superordinates, the citizenry of Massachusetts, they present a "maximization" efficiency picture. Similarly, managers of over all occupational education at the same time seek a "least cost" efficiency analysis from within specific occupational education program managers and present a "maximizing" efficiency picture to managers who make Type I and 2 decisions. The integrated decision making process of MISOE, is structured, in part, to "maximize" this reality in its own behalf.

If MISOE were being initiated in a new society on the first day of its existence, the implementation of an integrated decision making process over all three decision types might be fairly uncomplicated. Societal goals could precede the establishment of social agencies and their objectives. In light of short and long term societal goals, social service agencies could regularly present proposals describing expected impacts and costs to over social agency managers for their particular agency and resources could be distributed accordingly. However, Massachusetts is an old and complex society. A traditional decision making process for occupational education has been traditionally established. Althouth the existing process is generally patterned on an integrated basis, the decision type connections are frequently disjointed. Further, well established vested interest groups exist within all decision types in Massachusetts society and existing relationships among competing social agencies and societal goals are often fuzzy. Two reasons seem to account for the state of affairs, and they are: (1) social agencies tend to exist independent of goals and (2) over social agency decisions are seldomly explicit. These patterns are well established in Massachusetts and it is simply naive to hope that all of a sudden a new societal decision making process will spring into existence. This is not to say, however, that an integrated decision making process and related information system cannot be initiated by one societal sub-agency, like occupational education. It is to suggest that such a process must consider realities and evolve accordingly. Little progress can be expected in improving man's ability to manage society in the absence of experimentation. MISOE is clearly designed as an alternative to the traditional management process for occupational education. If it is to support improved performance on the part of social agencies and serve as a model for all education, MISOE must be implemented in a way that is responsive to the reality of current practice and perception.

Both a "least cost" and "maximizing" integrated decision making process will be simultaneously implemented by MISOE in a way that can be exclusively maintained by the Division of Occupational Education or expanded to include participation by management role incumbents at the over education or over social agency management levels. Such a strategy is required, as MISOE has little influence beyond occupational education.

In practice this will mean that the "least cost" decision making process will be structured such that the impact of occupational education will be evolved and described in relation to explicit societal goals. During the early stages of implementation these societal goals might be fairly narrow, reflecting limited participation on the part of over social agency management. Similarly, very little "least cost" decision making is expected at the over education management level. However, MISOE will provide a structure so that not only can "least cost" decision making behavior occur over all occupational education and within specific occupational education programs, but in a way that offers an exemplary mechanism such that occupational education managers can display their "least cost" occupational education decisions within an integrated, multi-level framework. Such a provision is designed to encourage participation on the part of role incumbents who are responsible for Type I and 2 decisions in an integrated decision making process for occupational education.

Not only will MISOE provide a process such that occupational educational managers at all levels can estimate the likely impact of "least cost" alternatives to stated goals in future time, but it will also provide a process by which they can estimate future "maximization" outcomes for levels of fixed funding for each decision type. Such a decision making option is crucial in that it allows subordinate agencies an opportunity to determine and describe additional outcomes <u>attained</u> or <u>attainable</u> beyond those specified by superordinate decision makers. This "maximization" decision making function will be included for all three decision types and will be available for across decision type role playing by managers of occupational education. Also, historical information will be arrayed and fed back to decision makers for all three decision types which describes the "least cost" outcomes of occupational education in light of specific goals as well as the additional benefits attained. In summary, MISOE will provide a process to probe future time outcomes of current decisions for all decision types on both a "least cost" and "maximization" basis, as well as a description of such past achievements.

The next section displays MISOE information types in relation to the decision types described above. Referencing information to decisions should make clear the multi-level feedback process of MISOE. The information section also presents examples of the multi-level simulation component of MISOE which should present a fairly representative statement of MISOE. Given MISOE's purpose, it is essential to consider MISOE as a multi-level decision making information feedback system. It is important to understand that when MISOE is operational, decisions for all decision types will be supported by information which describes pertinent historical aspects of occupational education for each decision type as well as models which allow an estimation of future outcomes for current decisions at each level. The integrated decision making process of MISOE allows managers at each level an opportunity to consider the comprehensiveness of occupational education. Further, MISOE allows the comprehensiveness of occupational education to be revealed to decision makers at each level.

Before specifying the particular information types of MISOE such that they can be referenced to explicit decision types, a brief presentation of the formal decision making process of MISOE will be offered. An assessment of MISOE's formal decision making process should include a consideration of MISOE's implementation strategy. Although limited participation is anticipated on the part of role incumbents responsible for Type I and 2 decisions, MISOE's information component will be structured by decision type, independent of participation. As previously suggested, MISOE will allow role playing by <u>occupational education</u> management for all three decision types. It is anticipated that such a strategy will contribute to broader perspective and improved decision making on the part of occupational education management. Such a structure also provides for an increasingly better estimate of the impact of occupational education on the well being of Massachusetts and should support managers of occupational education in presenting both a "maximizing" and "least cost" efficiency description of occupational education.

MISOE's implementation strategy is designed to entice increased participation on the part of Type I and 2 decision makers over time and MISOE stands ready to be responsive to such a development. Essentially, the implementation strategy is important to the future of MISOE. It prevents the development of a "closed" management and information system for a social service agency intimately bound up with important aspects of the larger society and at the same time offers a broad-based management information system for state wide occupational education management.

The Formal Decision Making Process of MISOE

The formal decision making process for MISOE assumes that management at each level has access to information which describes past realities and relationships and has developed simulation models for time future to estimate probable results of current decisions. Such man-information interactions will be available for all decision types. Further, the integrated decision making process must encourage "maximization" as well as "least cost" communication among all decision types in the management hierarchy for occupational education.

The formal, integrated decision making process of MISOE could be described as follows:

1. Over social agency managers -
   - A) Determine short and long term societal goals. Goals are explicitly stated and overtly linked to values.
   - B) Determine the state of conditions which contribute to goal accomplishment.
   - C) Solicit information from social agencies which describe their efficiency (both "least cost" and "maximizing") in contributing to the attainment of these goals.

D) Determine the "least cost" agency mix to attain an array of short and long term societal goals. (The simulation model is used at this point).

E) Allocate funds to agencies to impact on societal goals on a "least cost" basis. (Funding availability sets constraints on range of goal achievement and is part of step D.

F) Annually review cost/impact posture of participating agencies.

It is important to view this as an annual process and equally important to understand that the two-way communication between Type I decision makers and Type 2 and 3 decision makers is essential, i.e., agencies must be encouraged to not only react to goals in a "least cost" way, but to <u>boldly</u> assert the "maximization" potential of their particular agency.

II. Over All Education

A) In light of explicit societal goals from <u>over all society</u> managers, over all education managers develop a plan designed to attain the "least cost" impact on specific societal goals, as well as one which describes the "maximum" expected impact of that agency on specific societal goals. Maximization descriptions are not necessarily restricted to explicit, hierarchically determined goals.

B) To develop and manage educational programs (occupational-academic, secondary-post-secondary, etc.) designed to "maximize" impact. It is important to note that programs are typically operated on a "maximization" basis, within the boundaries of specific goals, although social agencies usually survive because of "least cost" efficiency. MISOE supports this reality.

C) Annually review the impacts and costs of the product of education on both a "least cost" and "maximization" basis and report these results to managers <u>over all social agencies</u>.

This is an annual process, and two-way communication between Type 2 decision makers and Types 1 and 3 decision makers is essential, of course.

III. Occupational Education

A) Over All Occupational Education

The decision making process for this decision type is the same as for Type 2, except that it is restricted to programs of occupational education, i.e., they present to over all education management a plan which describes occupational education programs which have a "least cost" impact on explicit societal goals, as well as a plan for "maximizing" impacts. The maximization plan is not necessarily restricted to stated goals, but represents "out reach". It is both reasonable and desirable to expect subordinate agencies to present a persuasive picture of extra benefits likely to be attained with additional expenditures. Similar to <u>over all</u> education managers, Level IIIA managers develop and operate programs and annually report on impacts of these programs and the cost of that impact to managers <u>over all education</u>.

B) Managers Within Occupational Education.

In view of specified societal goals, Level IIIB managers present to Level IIIA managers a plan describing the "least cost" impact of specific occupational education programs on explicit societal goals, as well as the "maximum" likely impact of each specific program on goals annually developed by <u>over social agency</u> managers. A report on the "maximization" impact of specific programs on societal goals need not be restricted to hierarchically developed societal goals. These plans must account for varying student types, and explicitly describe the instructional process designed to achieve the product, i.e., the end program occupational capabilities, by program and capability. This plan also includes a description of the "least cost" and "maximization" relationships between the product of a specific program and the impact on particular societal goals. Like managers at Levels II and IIIA, managers at this level operate specific programs, and annually report descriptions of process-product and product-impact relationships, including costs, to managers over all occupational education.

A logical conclusion to this section and introduction to the next section is to simply state that each decision type is dependent on an integrated information system, one which allows managers at each level to account for reality and relationships at that level, as well as one which makes possible an estimation of future outcomes for current decisions by decision type. Such an information support system is an obvious requirement to the decision making process herein described. The following section will specify MISOE's supportive information system, referencing information to decision types.

INFORMATION COMPONENT OF MISOE

This section of Occasional Paper #6 is presented to provide a clear picture of the information component of MISOE. It will stipulate all of the information types to be developed by MISOE and reference each information type to decision types described above. All MISOE information types have been previously described (see Monograph I, Occasional Papers #1 and #5, Planning Chart #1) and it is not the intention of Occasional Paper #6 to redefine MISOE data types. Rather, Occasional Paper #6 will simply review the previously stated information distinctions as currently conceived in a summarizing way that might offer new insights to MISOE's information component. This section will treat relationships between information types and decision making types when attempting to forecast probable future outcomes of current decisions, after a fairly thorough review of relationships between decision and information types.

Information Types of MISOE

MISOE staff has expended substantial developmental effort on the specification of a model to describe the structure of the entity it seeks to serve and has designed its information types in a way consistent with this model. The so-called IPPI model of occupational education differentiates information types as describing inputs to occupational education, human and capital; the process of occupational education; the product of occupational education; and the impact of occupational education on explicitly stated societal goals. Types of decisions have also been carefully specified in relationship to the

IPPI model. Monograph I stipulated that decisions can either be considered as definitional, i.e., determining the quantity and quality comprising each model element or distributive, i.e., allocating inputs to specific process alternatives for the attainment of prescribed product and impact goals. Further, occupational education decision types have been carefully described by hierarchical level in a way that connects occupational education to the larger society it serves, i.e., over all society, over all education and within occupational education. Also, MISOE information has been described as either descriptive or defining IPPI elements or analytical, i.e., estimating relationships among IPPI elements. Obviously, those responsible for MISOE believe that the technical development of the components of a management information system follows such specifications if such a system is to become an important support mechanism for the management process. Given specification, technical development can proceed in a systematic way which allows both developers and managers to be served by MISOE to understand the relationship between parts of the system under development and the system as a whole. To move directly into development of parts of the whole system without specifying the total system is to run the risk of confusing the parts with the whole, and deny both developers and managers enough information to assess a system part "under development" in the context of the whole. Too frequently, management information systems which charge into a technical development posture before an intensive model and specification experience result in historical information libraries which only infrequently modify management behavior.

Simply stated, this section will connect already specified components in a way which seeks to define the totality of MISOE, i.e., it attempts to connect all decision and information types. Although the information types have been previously specified, they will be briefly reviewed so that the reader can conceptualize MISOE totality without having to refer to previous publications. MISOE information types, however, have been quite thoroughly described in earlier papers which can be referred to for greater detail.

MISOE information will be either collected on a census (all schools offering occupational education programs at all levels) or sample (by program over school types, levels and geographical subdivisions) basis for each IPPI data type. As described in Occasional Papers #1 and #5, descriptive census data will include:

1. Input - Anticipated and real expenditures, enrollments and completors for occupational education for all programs at all levels.
2. Process - Minimum description of some process elements, i.e., staff, facilities, equipment.
3. Product - Annual description of specific occupational capabilities (behavioral objectives) by program (at beginning of school year).
4. Impact - None (if accepted by federal government).

Analytical census data will only describe expenditures by program, by enrollment and by program completor. Census data is expensive to maintain, but can be expanded upon demand. It is designed to provide necessary information for fiscal accountability at the least cost burden to the local community. It is further designed to provide a management tool for the Division of Occupational Education which offers knowledge of each operating occupational education program (cost, specific behavioral objective, enrollment - number of completors) in a way that bridges gross census information to sophisticated sample information.

MISOE's sample data will be collected by MISOE staff and is designed to present a detailed picture of occupational education in Massachusetts. The sample will be over the entire state, and will be stratified by program over school type and level. Data will be generalizable not only to school type and level, but urban, suburban and rural Massachusetts. The sample will also be stratified over the six regional offices of the Department of Education in Massachusetts to facilitate regional management of statewide education. Further, the secondary and post-secondary level sample will include students who pursue competing educational programs. Such information will allow analysis of the comparative effectiveness of occupational education and other program alternatives. Occupational education data will be maintained such that within occupational education program comparisons are possible. At the secondary level, the comparison groups will include students enrolled in general and academic programs, and at the post secondary level, students pursuing non-vocational programs. It should be noted that comparisons of relative impacts and costs of occupational education across levels, i.e., secondary, post-secondary, and adult is also possible.

MISOE's descriptive sample information is as follows:

1. Input - a thorough description of student types served by occupational education and total expenditures for occupational education. Also a similar description of student characteristics in competing programs, by level, including expenditures.

2. Process - a detailed description of the occupational education process, by program. Other than labeling by competing program type, for example, general or academic, and keeping a record of total expenditures by enrollment and completor as well as program length, no process information will be maintained for comparison groups.

3. Product - For the sample of occupational education completors, product data will include: (1) achievement by objective, by program; (2) number of completors by program; and (3) general academic achievement. For the non-occupational education sample, only gross product data will be collected, i.e., numbers of completors and general academic achievement.

4. Impact - Impact information will be the same for students pursuing both occupational and non-occupational education alternatives. This information will carefully describe the post-program behavior of program completors (including dropouts), and will be collected on a 1, 3, 5, 10, 20 year basis. Two important points need to be made about impact data and they are:

    a) It will begin as cross-sectional and become longitudinal over time. Therefore, until sufficient time has passed such that the very same students upon whom impact information is determined in fact experience specific programs and achieve particular objectives, all impact related data rests on a gross estimation of previous experiences.

b) The total determination of the contribution of education to the achievement of societal goals rests on impact information.

To summarize analytical data types of MISOE so that they can be referenced to decision making types requires an understanding of MISOE sample data connectiveness. All MISOE data is connected by students. This means that information describing each IPPI element can be connected to any other element. For example, information describing the impact of students on a particular societal goal can be connected to particular occupational capabilities attained, which in turn can be connected to specific instructional alternatives, and finally to specific student types. Given this connectiveness, two analytical data types are sufficient for the purposes of this section, i.e., referencing IPPI information types to decision types and makers.

1. Product-Process Information. This analytical information type describes relationships between achievement (product) and specific instructional components. For occupational education product, reference can be made to specific capabilities and program elements, but for non-occupational education product, i.e., general educational achievement, connections can be made only on a gross level. Since the cost of occupational education is described on a capability (behavioral objective), within program basis, product cost data is considered a subset of product-process information. Such information describes the cost involved, by product objective, within program. Since data is connected by student type, process-product data not only differentiates for various instructional alternatives but for different student types.

2. Product-Impact Data - The second analytical data type describes

the relationships among: (1) occupational education and non-occupational education in terms of impact on specific societal goals; (2) among different occupational education programs in terms of impact on specific societal goals; (3) within specific occupational educational programs and impact in terms of explicitly stated societal goals. Given the connectiveness of MISOE data, product-impact information supports judgments about the relative effectiveness of occupational education. Since MISOE provides information about program costs and estimates impacts in terms of dollar values, cost impact estimates of competing educational programs on societal goals will be provided by MISOE.

A third data type is not fundamental to MISOE, but needs to be mentioned. Such information estimates the status of societal elements both pre and post impact. Although educational impact data provides an estimate of the impact of education on specific societal goals it does not describe the previous status or over all change of societal goals. Obviously, information which only describes the impact of education on societal goals, does not assess the total impact of all other factors or the over time change in status of a societal goal, except grossly, by subtraction. This information is hereby labeled <u>total impact information</u> and will be referred to in the next section. Total impact information is beyond the scope of MISOE.

In summary of this brief outline of MISOE data types, a general statement of the characteristics of the information types and decision making seems appropriate. A bare bones description of decision making involves the selection of an alternative(s) action(s) to accomplish goal(s). Involved in the process is an assessment of the relationship of alternative actions and goal attainment.* Decisions occur now or during time present (let k = time present)

*Opportunity costs of alternative actions constitute a part of this process, of course.

and goals are achieved in time future (let L = time future).

MISOE descriptive information describes the status or level of IPPI elements in time past (let J = time past). For example, product information describes the capabilities attained by program, input data describes the characteristics of students or funding levels which have occurred. For the decision maker, MISOE descriptive information stipulates the current status of IPPI elements up to K time. It also describes trends of status changes at sub J times, up to K time. It is important to understand that decisions are made at K time, which is by definition, after J time. Decisions are made in current K time, always subsequent to the time elements described by IPPI information. Decisions, therefore, are actions which seek to change or maintain the status or level of IPPI elements at L time by changing relationships between these elements during KL time.

MISOE analytical information attempts to describe the relationships between IPPI elements during JK time (not including K time). These relationships are usually described as probabilities of causation of one element on another, relationships between two or more elements which may or may not be causal, or a variance of one element accounted for by other known elements.

Taken together, MISOE's descriptive and analytical data provides the decision maker an estimate of the current status of IPPI elements at J time, trend information of changes by element status during J time intervals, and causal and "suspected" causal relations among elements during JK time (not including K). The purpose of this information (in addition to straightforward accountability) is to feed into the decision making process an empirical basis for predicting the consequences of alternative actions, as well as describing the current state of affairs. Information for prediction usually takes the following form: Given these conditions, this action is likely (a probability statement) to cause that result. The extent of similarities at J and L time is to be determined by the decision maker, although J time descriptive and analytical information will carefully describe the conditions surrounding all information such that generalizability from J time to L time can be based on all that is known. (Occasional Paper #7 deals with the research design of MISOE. The above statement is merely suggestive of MISOE information characteristics to be considered when connecting information and decision types).

The following section simply ties decision types previously described to information types. The final section of Occasional Paper #6 presents an important MISOE forecasting tool to support managers at all levels in estimating and understanding the general nature of future consequences in L time of decisions at K time, through modeling and simulation.

<u>MISOE Information and Decision Types</u>

<u>Over All Agency</u> decision types include both definitional and distributive determinations. They define societal values and societal goals, as well as impact goals for social agencies. Further, they distribute inputs, both human and capital, over social service agencies. All this has been well described in Occasional Paper #5 and in an earlier section of this paper.

MISOE will not provide all the information required for this decision type in its initial conception, although such data can be easily added to the system when available. The information types required by this decision type will be presented by the order in which they occur in a typical decision making process.

1. Information estimating the values of Massachusetts society are basic to goal setting for society. MISOE will not provide such information for decision makers.

2. Information which describes the current status or level of value-related societal conditions are essential to this level of decision making. MISOE will include some soeietal status information, but not very much. Societal status information is also important in estimating total change in society over time, as well as providing a basis for assessing the comparative impacts of various social agencies on the goal related elements. MISOE will attempt to include United States Census data (inexpensively available on tape) and some information from Statistical Abstracts of the United States. However, most total societal status information is beyond the scope of MISOE at this time.*

3. Information which describes the comparative impact of occupational education on stated societal goals for this decision type is described as product impact data. This data type has been previously described as cost-impact data, but given the connectability of MISOE information will be described here as product-impact data. Product-impact data is connected in the sample to inputs, so such information includes a description of the characteristics of the people who were served by the societal agency, in this case occupational and non-occupational education. For this discussion, therefore, product-impact data includes a description of the impact costs of various

*Although MISOE will not empirically determine societal value and status data in its first several years of implementation, such information will be estimated and included in the system to allow the exercise of total decision making at all levels to occur and as an example of total decision making in occupational education. Since limited participation on the part of legislators and over education managers is anticipated in the beginning, these determinations will be frequently arbitrary, and accordingly labeled.

occupational and non-occupational educational programs at the secondary, post-secondary and adult levels by specific student characteristic types on specified societal goals. Such information will provide for over all agency decision types a description of the so-called payoff occupational education, including comparisons with competing educational programs in terms of impact on specific societal goals. Given the "maximizing" efficiency definition in the early part of this paper, such information will not be restricted to specifically stated societal goals, as it is perfectly reasonable to expect subordinate agencies to estimate impacts beyond a narrow range specified at any one point in time. Such information will be of enormous usefulness to over all agency decision making. MISOE will generate this information for over all agency decision making. It is important to note that MISOE product-impact information will allow for comparisons among occupational education programs and between occupational and non-occupational education, but will only provide limited product-impact information for other societal agencies which impact on societal goals.

Over All Education decision types include both definitional and distributive decisions. Definitional decisions determine inputs to occupational education, both human and capital, and some aspects of educational product. Distributive decisions allocate human and capital resources to specific educational programs. Both analytical data types previously discussed are of major concern to these decision makers.

1. <u>Product-impact data</u> describes the relative impact of educational programs on societal goals, both given and non-given. This data type has been described as useful to <u>over all society decisions</u> and is equally valuable to <u>over all education decision</u> types. It forms a basis for making education's case as a social service agency by estimating "least cost" program mixes most likely to impact on specified societal goals. Further, it provides a basis for over all education managers to present the "maximum" efficiency description of education on societal goals, both given and imagined. Managers at this level are typically not interested in specific product data by program (see Occasional Paper #5), but in comparisons among major program types.

2. <u>Process-product data</u> provides for this decision type an estimation of the comparative cost of competing programs in terms of specified product. As in the case of product-impact data, these decision types usually do not require information about specific process elements or product configurations within programs.

Taken together, process-product and product-impact information provide this decision type with information which allows an estimation of the relative contribution of various educational programs to specified impacts on societal goals. Since this information is connected to input information, comparisons can include an analysis of differential results by student characteristic grouping, an important consideration for this decision type.

In addition to the analytical data types mentioned above, <u>over all education</u> decisions require status descriptions of all IPPI elements on a state-wide, regional and urban -non-urban basis, on both the sample and census basis. Such data should be characterized as summary information, not in the detail required by specific program managers. It would include a description of total impacts, total expenditures, number and type of students served by program, and a general description of programs. Trend information of IPPI elements is of interest for this decision type..

MISOE sample data will provide process-product and product-impact data required by this decision type for occupational education, including comparisons to major non-occupational education program types. Non-occupational education programs will not be described in very much detail, but the description should be sufficient to accomodate a substantial range of decisions at this level. MISOE census data should meet all requirements for status knowledge within occupational education by IPPI type for these decisions. Since MISOE is being constructed to be connected to and consistent with information of the Division of Research and Development of the Massachusetts Department of Education, decision makers at this level can call upon that information for a thorough description of the status of non-occupational education programs, as well as for analytical data of these programs. As previously mentioned, MISOE will include general educational development or achievement information for both occupational education and comparison groups within the sample. Such information should allow for comparisons between occupational and non-occupational education programs in terms of general achievement, controlled for by student characteristics. In the context of product-impact information, such data provides a basis to estimate the relative usefulness of non-occupational education product and the process which supports it. Such information will also be useful in determining relationships between occupational and non-occupational product mixes and impacts on societal goals.

Within Occupational Education decisions include both decisions within and among specific occupational education programs. Since decisions which determine the distribution of resources, both human and capital, over specific occupational education programs are dependent to a great extent on the performance of individual programs, information types for decisions within specific occupational education programs will be discussed first.

The first range of decisions within this decision type deal with determining the specific occupational capabilities which each program is designed to assist students to achieve. The basis for these definitional decisions is product-impact information.* This information includes the differential impact of program completors with varying within occupational education achievement records. (Occasional Paper #7 discusses statistical controls which allow the estimation of the relative contribution of end program achievement by occupational education program and intervening experiences between program completion and impact measure). Since this information is at the specific capability level, it allows these decision types to consider their product by specific capability.

Process-product information is equally crucial for this decision type. (It is important to continue to remember that such information is connected to specific student types). Process-product information describes relationships between various within program instructional process alternatives and specific product attainment, by student type. It is this information which allows an estimation of "least cost" process alternatives within occupational education programs for specific student types. It also

*Another process to determine end program capabilities involves the use of judges, and is beyond MISOE scope.

allows the presentation of "maximizing" efficiency information from specific student characteristics, through specific process elements, to a specific range of occupational capabilities, and finally to specific impacts on explicit societal goals. In general, within occupational education program decisions are based on process product information (given product-impact relationships). These decisions are largely a function of the detailed analytical information within the MISOE sample, particularly those data describing process-product relationships. These decisions are also somewhat dependent on summary descriptive data for each IPPI element within a specific occupational education program.

Decisions over occupational education programs generally determine the distribution of capital and human resources to specific occupational education programs and the levels at which these programs are to be offered. Therefore, information for this decision type is designed to estimate both the "least cost" occupational education program mix for societal goal attainment as well as the "maximum" impact of occupational education on explicit societal goals, at incremental funding levels. Analytical and descriptive data for these decision types is focused at the occupational education program level. Since this management level is solely responsible for the management of occupational education, i.e., distributing resources within occupational education and presenting occupational education's real and potential impact on societal goals to over all education and societal managers, they will require access to all MISOE data. A general statement would be that this management type requires less specific analytical data than within occupational education managers and more detailed analytical and descriptive information than decision makers over all education and all society.

The over all occupational education decision types represent those decisions which MISOE is primarily designed to support. Therefore, all MISOE descriptive and analytical information previously cited will be carefully arrayed and summarized for decision making at this level.*

Up to this point, Occasional Paper #6 has described the type of information MISOE will produce and specified the ways in which this information will be displayed for occupational education decision making. The general nature of the decision making-information relationships discussed to this point is "after the fact", i.e., information is fed back into the decision making process after a decision was made. Such information describes the results of decisions, and can also be used as a basis for current decisions which seek to cause changes in the future, as previously described. The following and final section will describe a MISOE forecasting process which allows decision makers to use a computerized, simulation facility to analyze and estimate the future consequences of current decisions, based on past analytical and descriptive data of MISOE. This process allows the combining of complex arrays of information describing past realities and relationships in a variety of new patterns such that the interaction of these new combinations can be both perceived and analyzed. Such a process allows man the manager an opportunity to use information which describes previous realities or relationships as a basis for estimating the future consequences of current decisions before committing human and capital resources.

*It should be pointed out that it was at this decision level that MISOE was initiated.

I. Introduction to Simulation as a Management Tool

Two essential ingredients of the rational decision-making process described in Occasional Paper #5 are:

(1) the availability of information to the manager.

(2) the way in which the manager interacts with the information which is made available to him.

Information provides a manager with a tool by which he can attain a better understanding of the system which he is managing and thereby make more rational (e.g., goal-related) decisions. The two types of information which managers have traditionally sought are:

(1) What are the important relationships within the system that is being managed? (This information is obtainable through empirical analyses of available information).

(2) How has the system responded to past decisions? Managers use information about the consequences of past decisions as a basis for current decision-making.

The cyclical interaction of the decision maker with historical information is the crux of the management information feedback system referred to in MISOE: A decision is made on the basis of available information, consequences of the decision are analyzed and this new information forms the basis of the next decision, etc. Although this mode of manager-information interaction is invaluable to the rational decision-making process, Jay W. Forrester in Principles of Systems*, points out some of the drawbacks of information feedback as the sole decision-making tool available to managers of complex systems such as those encompassed by MISOE:

*We are indebted to Jay W. Forrester for his brilliant development of the process of dynamic simulation; this section of the paper borrows heavily from his pioneering effort in this field.

(1) A manager has no objective means of judging the relative merits of alternative courses of action in light of the achievement of specified goals without actually implementing a course of action and waiting to observe the consequences. If the desired results are not obtained via that course of action the manager might decide to implement an alternative plan. However, the resources which were used to implement the unsuccessful decision would have been wasted and any alternative decisions would be constrained by the availability of fewer resources.

(2) In a complex system a decision which is meant to have goal-related effects on specific parts of the system can produce unpredicted changes in other parts of the system; these changes may be either unrelated to or actually contradictory to achievement of the desired goal.

Thus, although information feedback as a management tool allows the manager to have a better understanding of isolated relationships within a complex system, it does not provide an understanding of the operation of the system as a whole, nor does it allow the consequences of various decisions or solutions to a problem to be examined until after the decisions have actually been implemented and resources have actually been spent.

Simulation is a relatively new decision-making tool which attempts to compensate for the previously discussed drawbacks of information feedback as a decision-making tool. The major innovations offered by simulation as a management tool are:

(1) It allows a manager to interact with available information in a feed-forward manner: Given information which describes the

existing state of the system, a manager can examine the likely consequences of alternative decisions within a system without actually committing resources to any one course of action. Maximum resources can then be committed to that course of action which appears most desirable in terms of specific goals.

(2) It allows a manager to trace the highly interactive consequences of a decision made within a complex system thereby providing the manager with a better understanding of how the system as a whole operates. (The process by which this occurs will be discussed at a later point in this paper).

Thus, simulation provides the manager of complex systems such as those encompassed by MISOE with a unique and powerful decision-making tool which allows the decision maker to interact with information in a feed-forward manner. In essence, simulation enables a manager to deal with a system as a dynamic entity in which conscious changes within the system become more and more predictable as a function of an increasing awareness of how the system as a whole operates. Rather than basing goal-related decisions on any momentary state of a system, simulation enables the decision maker to take the changing state of a system into account so that the ways in which a decision alters a system are consistent with the manager's stated goals for the system and occur at a cost which the manager is willing to incur to achieve those goals.

In order to bring about desired changes within a dynamic system it is essential to have an understanding of the elements of which a system is composed and the relationships among these elements. A simulation model is developed in order to fulfill this need. This simulation model represents a decision-maker's abstract conception of the mathematical and interactive relationships within a closed (i.e., feedback type) dynamic system; it is the decision maker's formalized conception, stated in terms of specific diagrams and equations of how the system which he intends to influence operates. Simulation models should not be judged in terms of accuracy in predicting system behavior, but in comparison with the basis upon which decisions would be made in the absence of a simulation model. Understanding rather than prediction of dynamic systems behavior is what is really essential to rational decision making, and simulation provides an excellent tool for working toward that understanding. A formalized simulation model of systems behavior contributes to increased understanding of a system in that the model's underlying assumptions can be examined and communicated to others; simulation also permits examination of dynamic (i.e., time-related) aspects of systems behavior.

The next section of this paper is concerned with important definitions and explanations of the elements of which a simulation model is composed. (It should be noted that feedback information and information describing empirical relationships within a system are essential to the process of of simulation in ways which will be made clear later in this paper.

The Simulation Model

As previously discussed, a simulation model represents a decision maker's formalized (in terms of specific diagrams and equations) conception of the dynamic behavior of the system which he is managing. There are two categories of systems which differ primarily in their responsivity to past action:

a) Open systems - are systems in which future action is not controlled by past action, and action within the system is not goal-achievement oriented.

b) Closed systems - also known as feedback systems have a closed-loop structure that brings results from past action of the system back to control future action. The feedback loop is the basic structure of which a feedback system is composed.

The feedback loop in its most basic form consists of a closed path which connects in sequence

1) a rate which is defined as a decision and controls action within a feedback loop;

2) a level which consists of a quantitative description of a state or condition of the system at a particular time;

3) information about the level which returns to the decision-making point (i.e., the rate) and helps to determine the next rate of flow. [Available information about the level at the time of observation provides the basis for the current decision (i.e., rate) which then determines the action stream within the feedback loops causing the level to change, and thereby supplying the new information on which the next decision (or rate) is based. Levels and rates will be discussed in more detail later in the paper]. A simple feedback loop is depicted in Figure 1.

Two classes of feedback loops exist, i.e., negative and positive, and they are described as follows:

1) the negative feedback loop is a system loop in which the decision that controls the action stream (i.e., the rate)

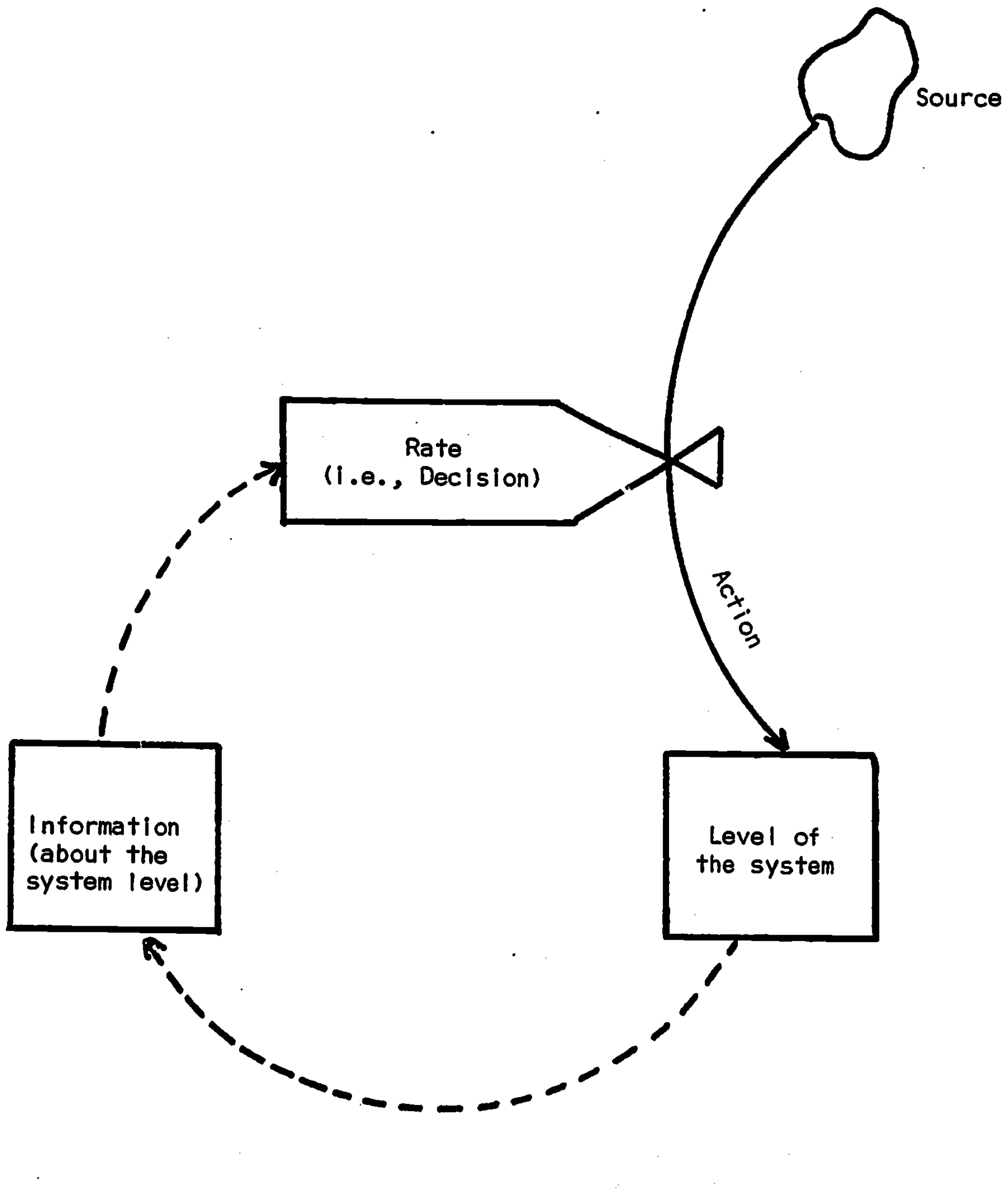


FIGURE 1: The Basic Elements of a Feedback Loop

is regulated by attainment of a specified goal, within a feedback loop.

A simple negative feedback loop is depicted in Figure 2. A hypothetical example is provided in order to demonstrate how the negative feedback loop works. Money from an income source is being deposited into a savings account at the rate of $5 per year. (There are no withdrawals in this hypothetical example). The current level of the savings account is $20. The rate at which future deposits will be made is regulated by the $40 goal which has been set for the savings account level and the length of time chosen for the achievement of that goal (Adjustment Time - 5 years). The computation of the savings account level as measured every two years for a period of twenty years is presented in Table I. (The derivation of the level and rate equations used to generate this Table will be discussed at a later time.) The solution time (DT) refers to the length of time between observations of the savings account level. The dynamic aspects of this negative feedback loop are depicted in Figure 4. Note that the savings account level overshoots the $40 goal, but the rate of savings compensates for this so that the level is adjusted toward the goal. This is an extremely simple example of a negative feedback loop. In more complex examples (e.g., those entailing time delays between information transfer or more complex loops) the level fluctuates around the goal.

2) the positive feedback loop is a system loop which generates growth processes wherein action (i.e., a rate) creates a system level which, when information concerning this level is

TABLE I: Dynamic Simulation In A Negative Feedback Loop

DT (Time)	Change in Savings Account (DT x Rate)	Savings Account Level (Dollars)	Rate of Savings* (Dollars Per Year)
0		20.00	4.00
2	8.00	28.00	2.40
4	4.80	32.80	6.56
6	13.12	45.92	-1.18
8	-2.37	43.55	- .71
10	-1.42	42.13	- .43
12	- .85	41.28	- .26
14	- .52	40.76	- .15
16	- .30	40.76	- .09
18	- .18	40.28	- .06
20	- .12	40.16	- .03

Solution Time (DT) = 2 years

Savings Account Level (SAL) = present SAL + change in SAL

Change in SAL = Savings Rate x DT

$$\text{Savings Rate (SR)} = \frac{\text{Desired SAL} - \text{SAL}}{\text{Savings Account Adjustment Time (SAAT)}}$$

SAAT = 5 years

Desired SAL = $40

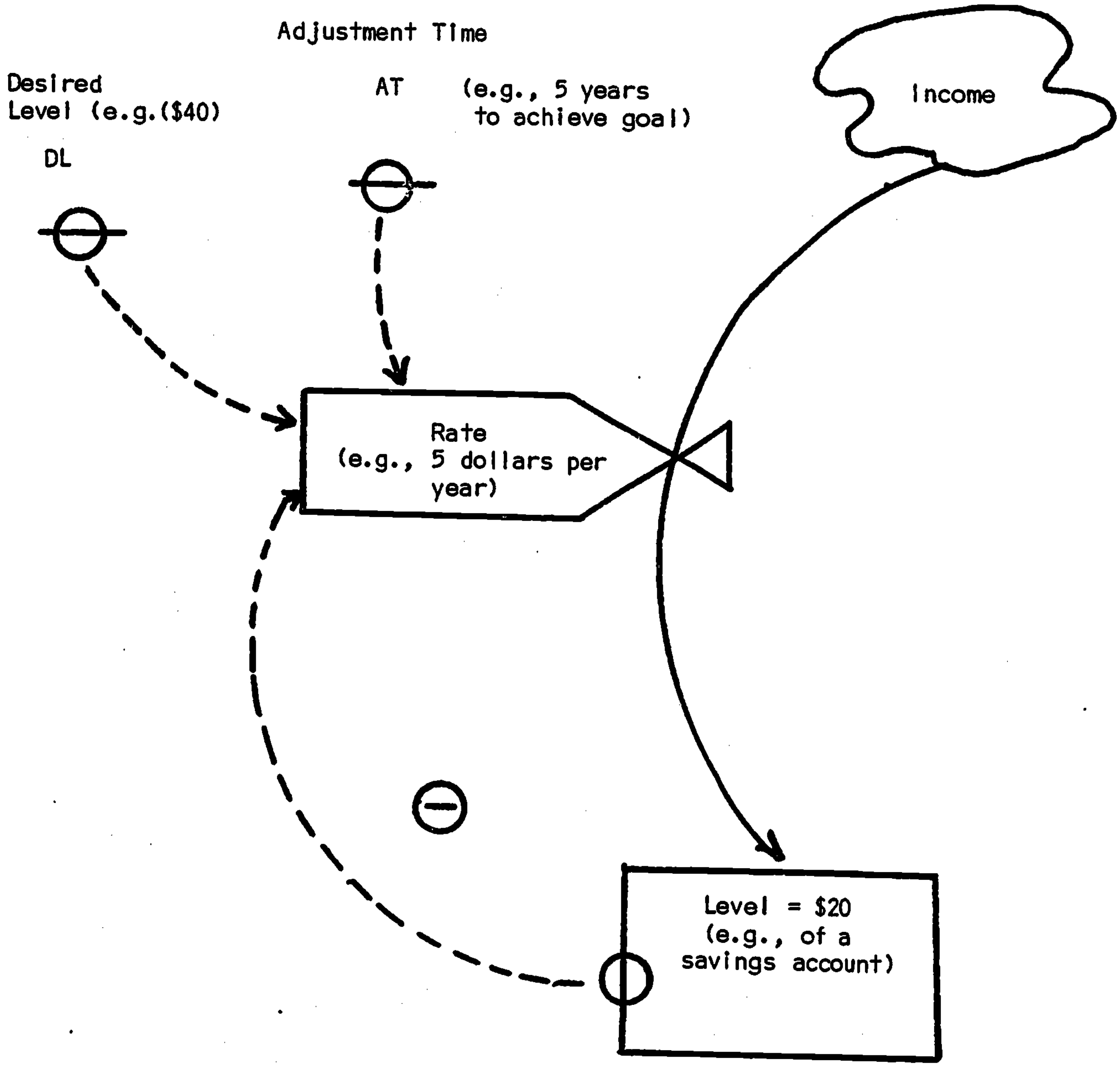


FIGURE 2: Negative Feedback Loop

returned to the decision point, generates still greater action. The result is that the level grows and grows.

A simple positive feedback loop is depicted in Figure 3. The example which was used to demonstrate dynamic action within a negative feedback loop has been altered in order to demonstrate dynamic action in a positive feedback loop. The initial level and rate of savings are the same as in the previous example, but note that there are only two factors which influence the rate - 1) an arbitrarily chosen time is the amount of time that it would take for the level of savings to double at the current rate of savings [Savings Account Doubling Time (SADT)].

$$\text{SADT} = \frac{2 \times \text{current level}}{\text{current rate}} \times \frac{2 \times (\$20)}{\frac{\$5}{\text{year}}} = 8 \text{ years}$$

and, 2) information about the system level at each solution time (e.g., every two years). Note that the growth of the level in the positive feedback loop is not regulated by a goal which influences the rate of growth as had been the case in the negative feedback loop. The dynamic computation of the savings account level in a positive feedback loop is presented in Table 2 and depicted in Figure 4. It can be seen that action within a positive loop acts to increase the discrepancy between the system level and a reference point (e.g., the initial value of the level). This reference point is also referred to as a "goal". Complex systems are composed of combinations of positive and negative feedback loops. Each feedback loop contains at least one rate and one level. The next part of this paper is concerned with a more detailed description of the basic components of all feedback loops, levels and rates - and the means by which they are computed in a dynamic simulation model.

TABLE 2: Dynamic Simulation In A Positive Feedback Loop

DT (Time)	Change in Savings Account (DT x Rate)	Savings Account Level (Dollars)	Rate of Savings (Dollars Per Year)
0		20.00	5.00
2	10.00	30.00	7.50
4	15.00	45.00	11.25
6	22.50	67.50	16.88
8	33.75	101.25	25.31
10	50.62	151.87	37.98
12	75.93	227.80	56.95
14	113.90	341.70	85.43
16	170.85	512.55	128.14
18	256.27	768.82	192.21
20	384.41	1153.23	288.31

SAL = Present SAL + change in SAL

Change in SAL = SR x DT

$$SR = \frac{SAL}{\text{Savings Account Doubling Time (SADT)}}$$

SADT = 4 years

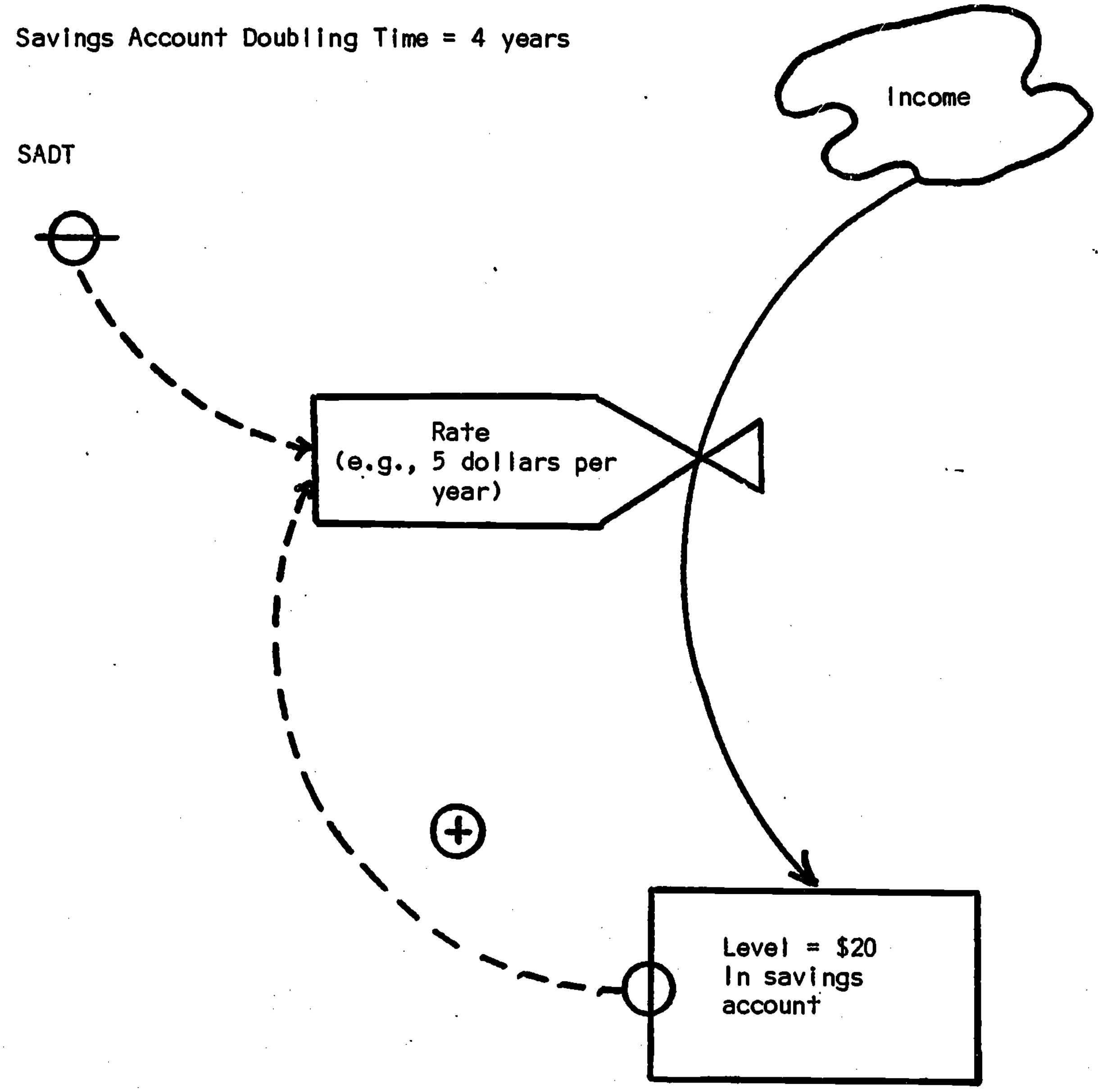


FIGURE 3: Positive Feedback Loop

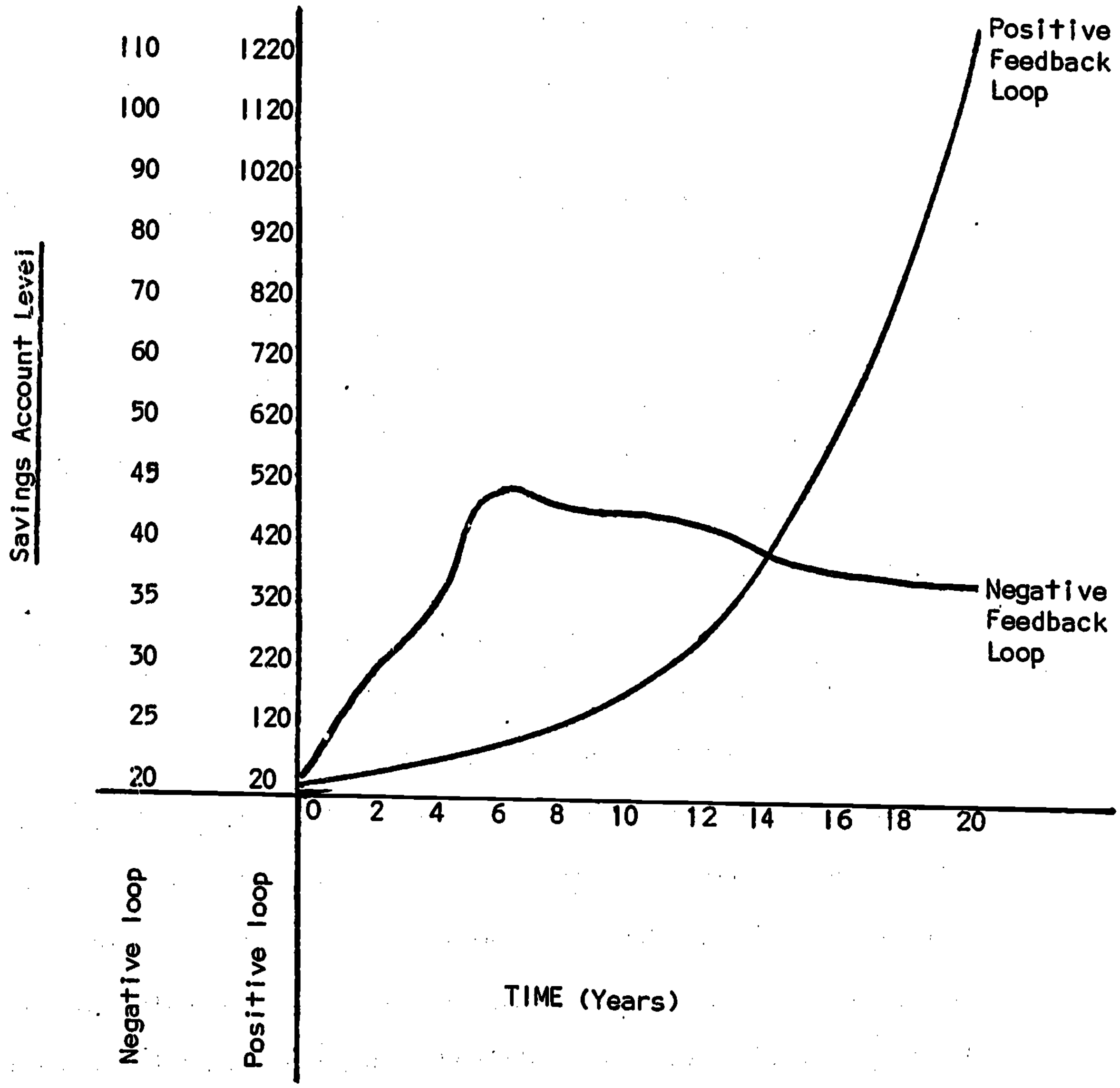


FIGURE 4: Dynamic action within the simplest form of the positive and negative feedback loop.

Levels and Rates - The Basic Elements in a Simulation Model

I. Levels

As previously noted, levels (also referred to as level variables) describe a condition of a system at a particular time. The current value of a level variable depends upon the accumulation or integration of all past action (i.e., past rates of flow) within the feedback loop (i.e., system) containing that level. Thus, the present rate does not determine the present level. The value of a level cannot be directly dependent on another level; only rates can directly influence levels. In our earlier example a rate of flow into a level variable was shown. It should be noted that there are also rates of flow out of level variables (e.g., in the earlier examples, a rate of flow out of the savings account level would be the withdrawal rate). Levels accumulate the net difference between inflow and outflow rates over time. The symbol which is used to depict a level variable is a rectangle.

Since level variables are time-dependent they create continuity within a system between points in time. All of the presently available history of a system is contained in the level variables. If the values of the levels within a system are known, the rates can be determined. (This will be explained at a later point in this paper). A system model must contain one level for each quantity needed to describe the system.

The computation of level variables follows from the previously given definitions. A level variable is computed by the change, due to a rate of flow which alters the previous value of a level. Thus, the new value of a level variable consists of the previous value of that variable plus the net change in the previous value of the level due to inflows and outflows over the solution interval (DT). The changes in the level variable are found by multiplying the rates of flow during the solution interval by the solution time interval as illustrated in Tables 1 and 2. (As previously mentioned, the solution interval is the arbitrarily chosen length of time that must pass between each observation of the system.) Flow rates are accumulated by levels over the successive solution intervals. In our earlier examples the system was observed every two years. The appropriate range of lengths for the solution intervals is determined by a simple computational procedure based upon the length of time delays in the rate of flow of information within the system. The actual equation for the computation of a level variable is presented in Table 3.

2. Rates

As previously mentioned, the rate is the decision point in a feedback loop that controls the flow of action within the loop. A decision process is always part of a feedback loop. Unlike levels which are time-dependent, flow rates (i.e., action decisions) occur instantaneously and are therefore theoretically independent of time. In reality no rate of flow can be measured except as an average over a period of time. However, the time required to observe rates is usually insignificant compared to the delays inherent in other parts of a system, regardless of the nature of the system. Rates are the action variables in a simulation model; they represent instantaneous policy statements. If all action within a system ceases, the levels would still be observable, but the rates would no longer exist. Since the results of flow rates must accumulate somewhere (i.e., in levels), a rate cannot be directly influenced by another rate; there must be an intervening level variable.

The value of a rate variable depends only on constants and on the observed values of related level variables (i.e., on information which describes those values). As previously mentioned, in a negative feedback loop the control decision (i.e., the rate) attempts to adjust an observed system condition (i.e., a level) to an externally specified constant (i.e., the desired level or goal of the level variable). In a positive feedback loop the goal is the reference point from which action within the system departs, thereby causing the discrepancy between the level and the goal to continually increase. In all feedback loops the value of the rate variable also depends upon an arbitrarily specified time constant which indicates how action within a system is to be based upon the discrepancy between the observed level of a variable and the goal. Therefore, the basic elements in each rate equation are as follows:

a) the externally specified constant - <u>the goal</u>

b) <u>information</u> describing the <u>observed value of a level</u>

c) an <u>expression of the discrepancy</u> between the observed <u>level</u> and the <u>goal</u>

d) a statement, in the form of a <u>time-constant</u>, which indicates how action within the system is to be based upon the discrepancy between level and goal.

TABLE 3: Basic Formula for the Computation of Level Equations

Computation of a Level Equation

$$\boxed{L.K = L.J + (DT)(RA.JK - RS.JK)}$$

L = Level

L.K = New value of a level being computed at K (i.e., present) time.

L.J = Previous (J Time) value of a level (i.e., value of level at one solution interval previous to the present time).

DT = The length of the solution interval (i.e., Time K - Time J).

RA.JK = The value of the rate added to the level during the JK time interval

RS.JK = The value of the rate subtracted during the JK time interval.

[For example, in Table I, the savings account level at the time of the third observation (DT = 4) was determined as follows:

$$SAL.K = SAL.J + (DT)(RA.JK - RS.JK)$$
$$= \$28 + 2(\$2.4 - 0)$$
$$= \$32.8]$$

The basic formulae for rate equations in negative and positive feedback loops are given in Table 4.

3. Auxiliary Equations and Information Conversion Links: The Subelements of Rate Equations

Unlike level equations which are straightforward and simple in form, rate equations can become quite complicated. The value of any single rate may be a function of any number of constants and information linkages from system levels. When rate equations become complicated they can be subdivided and their parts can be expressed in the form of auxiliary equations. Auxiliary equations, then, are algebraic subdivisions of rate equations. They are represented by circular symbols in simulation models.

In the examples cited earlier in this paper the only information about a level variable, which served as an input to a rate variable, described a level variable which was itself part of the conservative subsystem containing that rate (i.e., the current savings account level was an input which influenced the savings rate which in turn altered the savings account level, etc.). The systems represented in the savings account exampies constitute what is known as conservative subsystems in simulation models. A conservative subsystem is a system in which all levels have the same units of measure (number of dollars in the earlier examples), and all rates are measured in those same units divided by time (dollars per year in the earlier examples). The systems in the previous examples were conservative in that a depletable quantity measured in one unit (i.e., money) actually flowed from one place to another (the level) within

TABLE 4: Basic Formulae for the Computation of Rate Equations

Computation of the Basic Rate Equation

R.KL = f (levels and constants)

a) In a negative feedback loop

$$\boxed{R.KL = \frac{1}{T}(DL - L.K)}$$

b) In a positive feedback loop

$$\boxed{R.KL = \frac{1}{T}(L.K)}$$

L.K = Level at the present time.

R.KL = Rate of flow into or out of a level variable during the time interval between the present time (K Time) and some future time (L Time) one solution interval later than the present time.

DL = The externally specified constant which represents the goal or desired level of a variable in a negative feedback loop.

DL-L.K = The discrepancy between the present value of the level and the goal.

$\frac{1}{T}$ = An arbitrary statement of how action within the system is to be based on the discrepancy between the present value of the level and the desired level (i.e., the goal).

[For example, in Table I, the initial savings rate in a negative feedback loop was determined as follows:

$$RS \cdot KL = \frac{1}{SAAT}(DSAL - SAL \cdot K)$$

$$= \frac{1}{5 \text{ years}}(\$40 - \$20) = \$4 \text{ per year}$$

The initial savings rate in the positive feedback loop in Table 2 was determined in the following manner:

$$RS \cdot KL = \frac{1}{SAAT}(SAL \cdot K)$$

$$= \frac{1}{4 \text{ years}}(\$20) = \$5 \text{ per year}$$

55

within the system. The flow of information, however, even within a conservative subsystem, is not a conservative flow because information is not depleted by usage; information can be transmitted between levels within a system without altering its existence at the source. (Information flow is symbolized by dashed lines in simulation models while the flow of an actual quantigy is symbolized by solid lines. See Figures 2 and 3).

Information links are the means by which different conservative subsystems can be made interdependent in complex system models. Information about a level in one conservative subsystem can serve as an input to a rate in a different conservative subsystem. For example, the savings rate in the earlier examples (units of measure were in dollars per year) might be made dependent upon a level variable in a different conservative subsystem - e.g., the number of a particular item that is sold in that year (units of measure are number of items per year). The laws of equation writing dictate that both sides of an equation must be measured in the same unit. Thus, rate of savings, measured in dollars per year must be expressed by a term which is also measured in units of dollars per year. The translation of the units of one conservative subsystem into the units of another conservative subsystem is accomplished by means of converstion coefficients. For example, the rate of savings per year can be made to be a function of the number of items sold in the following manner:

Let Savings Rate = f (# items sold)

$$\frac{\text{Dollars}}{\text{Year}} = f\ (\text{items})$$

In order to achieve dimensional equality convert equation to:

Savings Rate = f [# of items sold per year x cost per item]

$$\frac{\text{Dollars}}{\text{Year}} = \frac{\text{\# of items}}{\text{Year}} \times \frac{\text{Dollars}}{\text{Item}}$$

In this manner the savings rate can be made dependent on the number of items sold; both sides of the equation are measured in units of dollars per year.

Conversion coefficients enable system behavior (e.g., behavior which is generated within the bounds of a system) to be influenced by information which is external to the actual system. Thus, research findings (i.e., discovery of important relationships between elements within a system) can be incorporated into simulation models. The conversion coefficients usually accompany the information links in the rate equations and are expressed in auxiliary equations.

Sequence of Computation in Dynamic Simulation

As previously mentioned, once the initial values of the system levels have been ascertained the rates can be determined. The time at which the initial levels are determined is referred to as J time (i.e., time past.) The rate of flow between J time and K time (i.e., between time past and time present) is then computed based on those levels and any initially specified constants. (Recall that rates are a function of levels and constants.) The present levels (i.e., at K time) can then be computed. (Note that K time is one solution interval later than J time.) Given levels at K time, the flow rates over a future time one solution interval in length (i.e., KL time) can be determined. Based on net changes due to flow rates in KL time the future level of a variable (i.e., the level at L time) can be determined. Levels at time L can then be treated in the same manner as those in time J and rates and levels can be similarly determined for each future point in time. The sequence of computation can be summarized as follows: first levels, then auxiliary equations, then rates.

The preceding pages represent an attempt to explain the basic principles of the process of simulation. It is hoped that this simplified explanation of simulation can serve as an elementary introduction to the MISOE information forecasting process. The next section of the paper will be concerned with some hypothetical examples of how the simulation process can be useful as a management tool at each of the management levels encompassed by MISOE.

A Forecasting Example*

The hypothetical example which has been constructed in order to demonstrate how a decision maker at each of the four management levels encompassed by MISOE might use simulation as a management tool concerns the problem of crime. (The problem is similar to the example presented in Occasional Paper #5). The over all agencies level of management (i.e., the societal policy makers in the state legislature) become aware of a conflict between the societal value "law and order" and the number of robberies committed last year. Since robberies are committed by robbers-on-the-loose (ROL's), the legislators establish as their societal goal a reduction in the ratio of robbers-on-the-loose per good citizen from the current ratio of 100 ROL's per good citizen to zero ROL's per good citizen (i.e., to eliminate robbers-on-the-loose). Twenty years is chosen as the length of time in which

*Figure 5 is a "tuck in" so it can be taken out at this time and referred to during the reading of this section. It is practically impossible to put this all together in a reasonable time frame otherwise. Please, take out tucked in Figure 5 now.

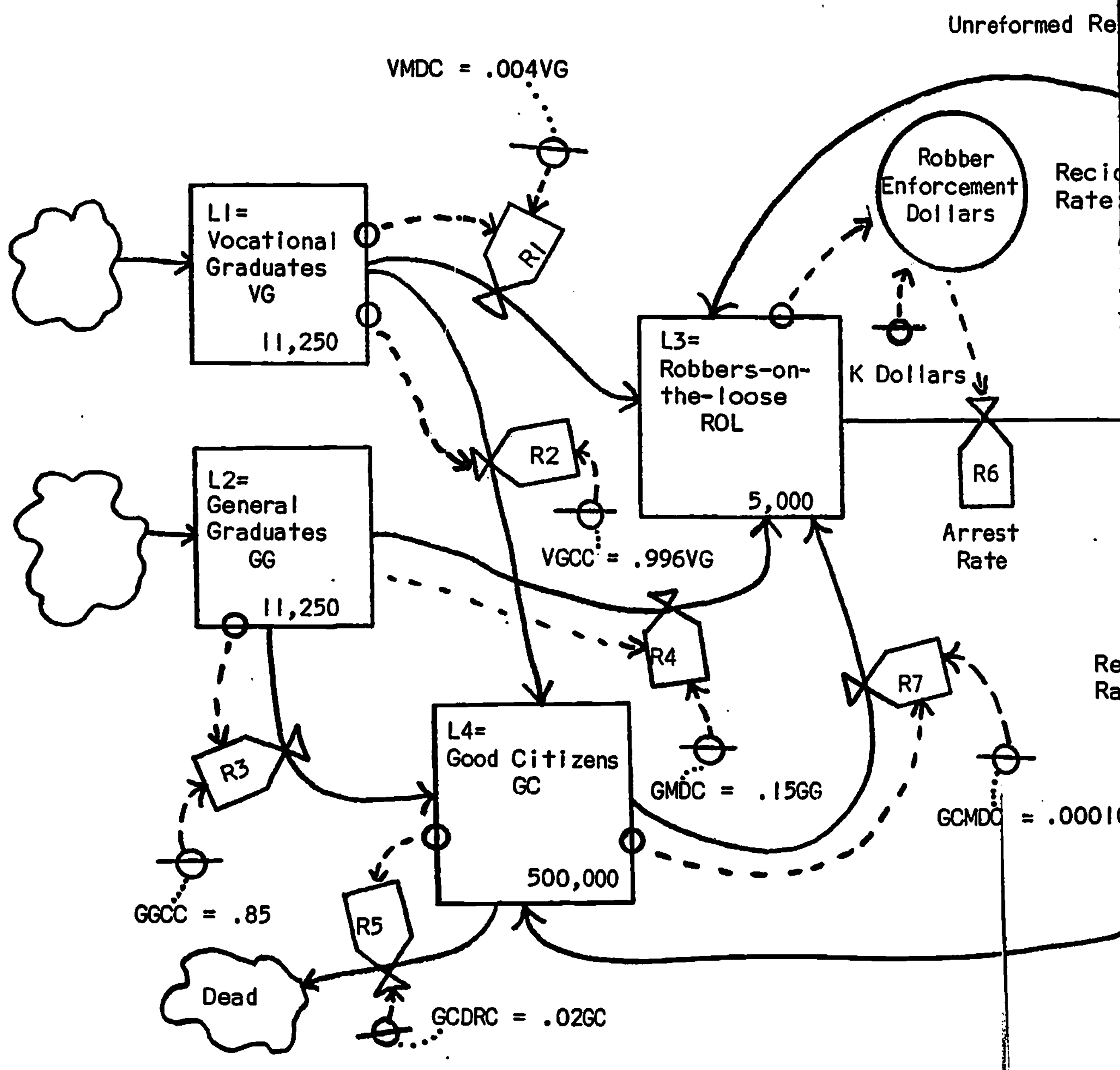
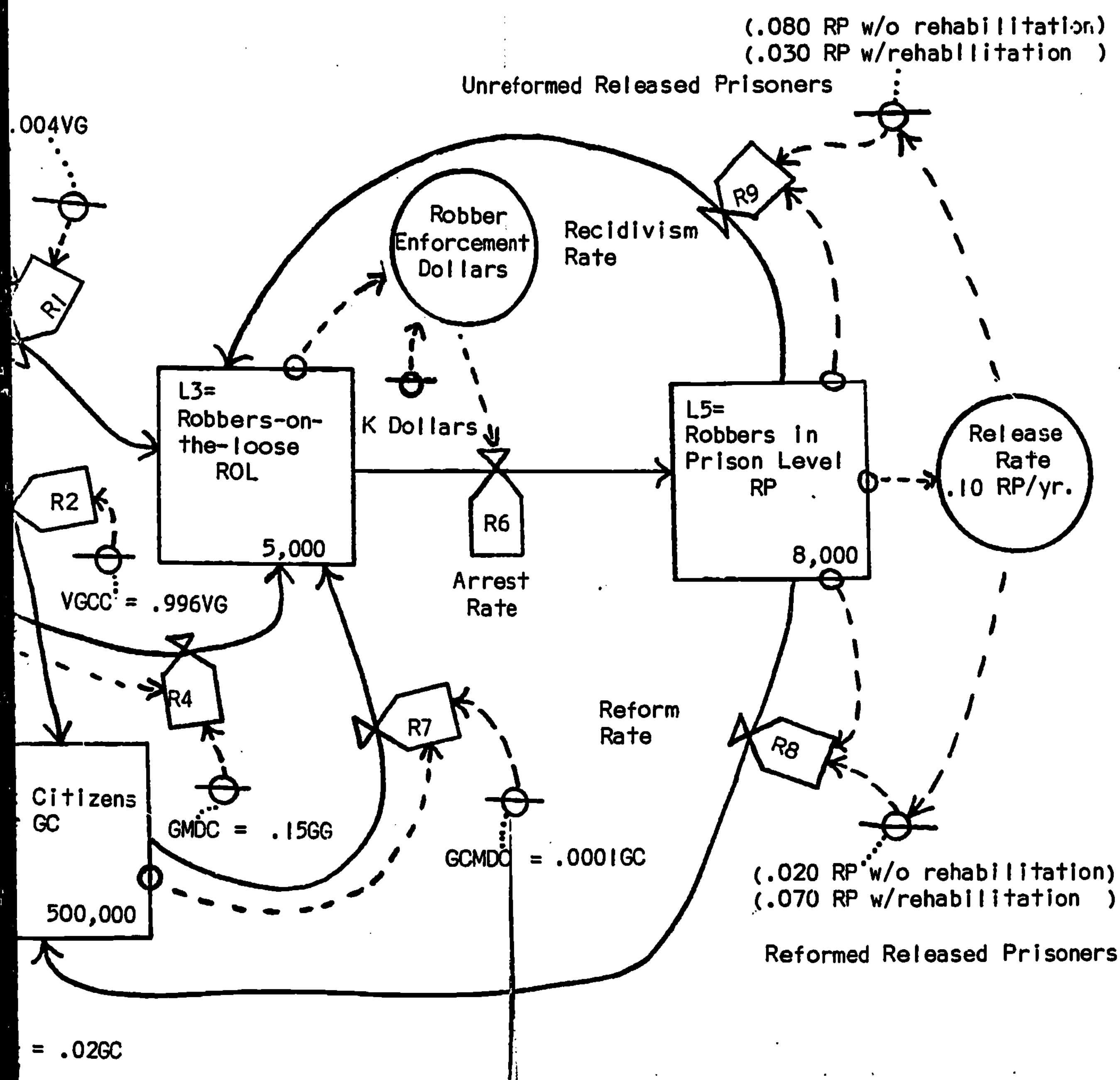


FIGURE 5: Robbers-on-the-loose simulation diagr
with initial levels specified.



GURE 5: Robbers-on-the-loose simulation diagram with initial levels specified.

this goal is to be achieved. Furthermore, the goal is to be achieved through implementation of a "least cost" solution.* (The concept of the least cost solution was fully described in an earlier section of the paper). The number of robbers-on-the-loose is estimated from knowledge of: the number of crimes committed last year; the number of robbers arrested last year; and the average number of crimes committed by each arrested robber. For example, if each robber in prison is known to have committed an average of two crimes in a one year period, then the number of robbers-on-the-loose for any year would equal half the number of reported crimes for that year. The ROL level can also be computed as a function of the net change in ROL's as a result of the number of new persons who become ROL's per year and the number of ROL's who are arrested each year (i.e., the previously discussed level formula).

The legislature requests each of several social service agencies to submit a detailed plan that describes how that agency can contribute to the reduction of robbers-on-the-loose (i.e., impact upon the legislature's stipulated societal goal) and the costs associated with each plan. The state policy makers use the information made available to them to construct a simulation model (i.e., a flow diagram) which depicts their conception of the relationship between those social service agencies and the robbers-on-the-loose in that state. The hypothetical simulation model, with initial levels specified, is depicted in Figure 5. In the interest of simplicity there are no information delays in this model and systems behavior is observed yearly (DT = 1 year). The model contains six levels and nine rates and an information conversion link.

*Goal attainment must also be consistent with societal values

There are four sources of robbers-on-the-loose in this model:

(1, 2) Students who graduate from high school - both vocational program graduates and general program graduates. The total number of graduates each year is a constant 23,000 (the sum of levels 1 and 2). There were an equal number of vocational and general graduates at the time that the system was initially observed (level 1 - level 2). The rates at which vocational and general graduates flow into robbers-on-the-loose (level 3) are constants. General graduates flow into robbers-on-the-loose (rate 4) at a faster rate than vocational graduates (rate 1). These rates are referred to as the General Moral Degradation Constant (GMDC), and the Vocational Moral Degradation Constant (VMDC). Conversely, vocational graduates flow (rate 2) into good citizens (level 4) at a faster rate than do general graduates (rate 3). These rates are referred to as the Vocational Good Citizen Constant (VGCC) and the General Good Citizen Constant (GGCC). Thus, each year there is a constant supply of new robbers-on-the-loose from the ranks of the high school graduates. This supply is largely composed of general program graduates. (Dropouts who become ROL's are not a part of this model. It can be assumed that general program dropouts are more likely to become ROL's than vocational program dropouts because of their lack of marketable skills. For the sake of simplicity in the model we will assume that the general and vocational dropouts become ROL's in the same ratio as the completors and therefore need not be included in the model.)

(3) Robbers released from prison who return to society unreformed (rate 9 = recidivism rate). The recidivism rate depends upon the number of prisoners released each year (the yearly release rate is indicated in the form of an auxiliary variable and is equal to one-tenth of the number of robbers-in-prison. Thus, if there were 8,000 robbers in prison, 800 would be released.) The recidivism rate is higher for those released prisoners who did not participate in a rehabilitation program while in prison (recidivism rate of unrehabilitated robbers = .80 robbers released = .080 robbers in prison*) than for those prisoners who did participate in a rehabilitation program (recidivism rate of rehabilitated robbers = .30 robbers released = .030 robbers in prison). Conversely, the reform rate, rate 8, measures the flow of robbers released from prison into good citizens. It is higher for released robbers who have participated in a rehabilitation program (reform rate of unrehabilitated robbers = .20 robbers released = .020 robbers in prison) than for those who have not (reform rate of rehabilitated robbers = .70 robbers released = .070 robbers in prison). In this example rehabilitation is conducted on an all-or-none basis (i.e., either all robbers-in-prison or none are rehabilitated for a given simulation). Robbers-in-prison who underwent a rehabilitation program and those who did not undergo a rehabilitation program are indicated by one rectangle (level 5) for the sake of simplicity.

*This is true because 10 per cent of the robbers-in-prison are released. For example, if 800 unrehabilitated robbers are released, 640 will return to being ROL's. These 640 robbers = 80 per cent of the robbers released which = 8 per cent of the prison population.

(4) Good Citizens who become robbers-on-the-loose (rate 7). Each year a very small percentage of good citizens become robbers-on-the-loose. This rate is referred to as the Good Citizen Moral Degradation Constant (GCMDC). A small percentage of good citizens also die each year as measured by rate 5. This is the Good Citizen Death Rate, (GCDR). For the sake of simplicity, in this model the death rates of students, ROL's and prisoners are not taken into account since it is assumed that they would be relatively small.

Thus, the new number of robbers-on-the-loose each year is equal to the sum of the number of high school graduates, unreformed prisoners and good citizens who flow in the robbers-on-the-loose pool each year.

In Figure 5 it can be seen that there is only one flow (rate 6) out of the robbers-on-the-loose level; that flow is the arrest rate (i.e., the number of robbers-on-the-loose who become robbers-in-prison each year). In this model the arrest rate depends upon the number of dollars which are spent by the police in order to arrest robbers. Robber Enforcement Dollars (RED) is an auxiliary variable which depends upon the discrepancy between the number of robbers currently on the loose and the previously established goal of eliminating ROL's in twenty years time and a dollar constant. The dollar constant (K) is an arbitrary figure which is used in the formula that determines the amount of money allocated to the police to catch robbers each year. The larger the constant the more money available to the police (i.e., the more Robber Enforcement Dollars) and the more arrests that can be made. In our example K = $4000 for the lower level of police spending, and K = $10,000 for the higher level of police spending. As previously mentioned, the desired number of ROL's (DROL) equals zero.

$$RED = f\ \frac{(DROL - ROL)}{(\text{20 Years})} \times (\text{-K Dollars})$$

In order to achieve dimensional equality (e.g., both sides measured in dollars per year) this equation was converted to the following form:

$$RED = \frac{(DROL - ROL)}{\text{20 years}} \times \frac{(\text{-K Dollars})}{\frac{\text{robber}}{\text{year}}}$$

The cost of arresting one robber is known to be $1,000; thus, .001 robbers can be arrested for each Robber Enforcement Dollar allocated to the police. As previously noted, the arrest rate in this model is a function of Robber Enforcement Dollars:

$$\frac{\text{Robbers Into Prison}}{\text{Year}} = f\ (RED)$$

Once again, in order to achieve dimensional equality in the equation, the arrest rate is expressed as follows:

$$\frac{\text{Robbers Into Prison}}{\text{Year}} = \frac{\text{Robber Enforcement Dollars}}{\text{Year}} \times \frac{\text{\# of Robbers Arrested}}{\text{Robber Enforcement Dollar}}$$

Thus, information conversion links allow the arrest rate to be dependent upon the amount of money that is spent by the police on the apprehension of robbers. (Robber Enforcement Dollars are in turn dependent on the number of robbers-on-the-loose, also via an information conversion link.

The level of robbers-on-the-loose for any one year is equal to the previous level of robbers-on-the-loose, plus the sum of the new robbers-on-the-loose for that year, minus the number of robbers arrested that year. It is this level that the legislature wishes to reduce. As previously mentioned, there is a constant influx of new robbers-on-the-loose from the ranks of the high school graduates. Since general graduates are more likely to become robbers than vocational graduates, the educational agency has indicated that it can help to reduce the number of robbers-on-the-loose by changing the educational mix, thereby producing more vocational graduates than general graduages. This solution would require an additional expenditure on education since it costs twice as much, on the average, to train a vocational graduate ($5,000) as it does to train a general graduate ($2,500) over a three-year long program. [These figures are based on the average cost per year of training a student in the vocational program (i.e., one third of the total average cost of a vocational graduate - $1,667) and the average cost per year of training a student in the general program (i.e., one third of the total average cost of a general graduate = $833)].

The Prison Agency indicates that it can reduce the number of robbers-on-the-loose by putting all robbers now in prison through a rehabilitation program. For evidance they point to the difference in the recidivism rates of those released prisoners who were in a rehabilitation program as opposed to those who were not. This solution to the robbers-on-the-loose problem would require an additional expenditure on prisons since having each robber in prison undergo a rehabilitation program raises the cost of keeping a robber in jail for one year by $3,000. (Prisoners who do not undergo a rehabilitation program cost $10,000 per year to maintain. Those who do undergo a rehabilitation program cost $13,000 per year to maintain).

The Police Agency indicates that it can reduce the number of robbers-on-the-loose if more money is made available to the police for the apprehension of robbers since the arrest rate in this model is a function of Robber Enforcement Dollars.* As previously mentioned, one robber-on-the-loose can be imprisoned for each $1,000 spent by the police to apprehend robbers.

*These agency expenditures are really marginal extra costs and they are related to marginal or extra benefits, i.e., additional expenditures, fewer robbers-on-the-loose.

Thus, there are several options available to the legislature in terms of achieving their societal goal. They can choose any one of the three social service agencies to impact upon their societal goal of reducing robbers-on-the-loose, or they can assign impact goals to any combination of the three social service agencies. It is at this point that simulation becomes a useful management tool. Tables I - VIII in the appendix contain the system levels, cost levels (per agency and total) and system rates for eight different simulated solutions to the robbers-on-the-loose problem. Each simulation was conducted over twenty solution intervals of one year's duration. (The equations for these simulations are contained in Table IX in the appendix). The eight simulated solutions to the robbers-on-the-loose problem are:

Table I - Do Nothing Solution: What would happen to the number of ROL's and what are the costs involved if nothing is done?*

Table II - Police Solution: What would happen to the number of ROL's and what are the costs involved if Robber Enforcement Dollars (i.e., Police Expenditures) are substantially increased? (The dollar constant in the do nothing solution for determining Robber Enforcement Dollars is $4,000. In this solution the dollar constant is raised to $10,000 thereby increasing the number of Robber Enforcement Dollars allocated to police. As previously mentioned, the more money allocated to police, the more ROL's that can be arrested, in accordance with the earlier formulae).

Table III - Rehabilitation Solution: What would happen to the number of ROL's and what are the costs involved if all robbers

*This solution represents a status-quo bench mark, very useful for comparisons against alternative decisions.

in prison are put through a rehabilitation program prior to being released from prison?

Table iv - Education Solution: What would happen to the number of ROL's and what are the costs involved if the education mix is changed so that there are 15,000 vocational graduates and 7,500 general graduates per year instead of an equal number of each type of graduate?

Table v - Education and Rehabilitation Solution: What would happen to number of ROL's and what are the costs involved if all prisoners are put through a rehabilitation program and the education mix is changed?

Table vi - Police and Rehabilitation Solution: What would happen to the number of ROL's and what costs are involved if all prisoners are put through a rehabilitation program and the police receive more money for arresting robbers?

Table vii - Education and Police Solution: What would happen to the number of ROL's and what costs are involved if the education mix is changed and the police receive more money to arrest robbers?

Table viii - Rehabilitation, Education and Police Solution: What would happen to the number of ROL's and what are the costs involved if all prisoners are put through a rehabilitation program, the education mix is changed and the police receive more money for arresting robbers?

Figures i - viii in the appendix are graphic representations of the eight different simulation solutions presented in Tables i - viii.* The total cost curves and the robbers-on-the-loose curves are ratios which represent the number of ROL's per good citizen and the total costs per good citizen for each solution interval. (Therefore, in some solutions although total costs or number of ROL's may increase in absolute value, they may actually be decreasing relative to the level of good citizens at a particular observation time.) Clearly, the Do Nothing or Status Quo Solution (Figure i) is highly undesirable as both costs and ROL's per good citizen continue to increase. The police solution (Figure ii) keeps ROL's per good citizen at a stable level, but costs per good citizen continue to increase. In the rehabilitation solution (Figure iii) costs per good citizen stay at a high level and ROL's per good citizen increase and then level off. Costs per good citizens remain fairly stable while ROL's per good citizen increase slowly in the education solution (Figure iv). Costs per good citizen remain stable at a fairly low level while ROL's per good citizen remain stable in the rehabilitation and education solution (Figure v). ROL's per good citizen decrease for the first time and then level off in the rehabilitation and police solution (Figure vi) but costs per good citizen increase and then level off at a high level; similar results are obtained in the education and police solution (Figure vii). It is only in the education, police and rehabilitation solution (Figure viii) that both costs per good citizen and ROL's per good citizen decrease. This solution comes closest to achieving the societal goal of eliminating ROL's in twenty years time. Note that in no case does the ratio of robbers-on-the-loose to good citizens equal zero (e.g., the societal goal). The inability of any of the simulated solutions to achieve the goal is a function of the particular simulation model which was

*Tables and Figures i - viii are juxtaposed in the appendix to facilitate understanding.

developed. The education, police and rehabilitation solution, however, comes closest to achieving this goal. This solution requires an initial increase in total costs, but over time this solution is no more costly than any of the others and is more effective in terms of achieving the desired societal goal.

A time plot of the ratio of ROL's and costs to good citizens under the eight different solutions is presented in Figure ix in the appendix. Those solutions which are closest to the origin of the graph after twenty years' time are the most desirable (i.e., solutions in which both costs and ROL's are lowest relative to good citizens). The two most desirable solutions can be seen to be the rehabilitation and education solution, in which both costs and ROL's remain relatively stable, and the rehabilitation education and police solution, which is somewhat more costly than the rehabilitation and education solution but has the advantage of decreasing the number of ROL's relative to good citizens.

The particular solution which the over all agencies manager (i.e., the legislator) decides to implement is a function of many factors, including the resources available to him and his priorities in terms of achieving that societal goal. The process of simulation has enabled the manager to "try out" several different solutions without actually allocating resources to any one solution. The manager can therefore choose to implement that solution which seems most suited to his needs (i.e., he can assign impact goals and monetary resources to those social service agencies involved in the preferred solution).

It is important to point out at this time that although MISOE does serve over-all-agencies decision types, it is primarily concerned with decisions within occupational education. The simulation example described above was offered for instructional purposes. It would be a gross misrepresentation of

MISOE's primary focus to assume that simulation as a management tool would be used extensively at the over-all-agencies level in the MISOE system as the example just offered would seem to indicate. However, MISOE will construct models for simulation at this level for role playing at the within occupational education level and will stand ready to expand this component upon demand.

It should also be pointed out that the previously offered example of the usefulness of simulation as a management tool dealt with the achievement of only one goal (i.e., reduction of robbers-on-the-loose). In reality, most managers are concerned with the achievement of more than one goal. Frequently the decision making process is a "Rob Peter to pay Paul" proposition. For example, the achievement of one goal must sometimes be sacrificed in order to achieve another. Cost factors often play a significant role in determining exactly which goals and how many goals a given manager can hope to achieve.

In order to demonstrate how the simulation process described in the previous example might be extended to include the various levels of educational management encompassed by MISOE, let us assume that the over all agencies manager chooses to implement the education solution (i.e., to increase the number of vocational high school graduates and decrease the number of general high school graduates). The simulation example can then be extended to include all of the management levels encompassed by MISOE. (It should ne noted that the simulation example at the over all agencies level does not correspond on a one-to-one basis with the examples at the various educational levels; furthermore, the examples offered at the educational levels are not in themselves examples of the process of simulation in that they lend themselves to analytical solutions).

The over all education manager, as previously mentioned, would be asked to indicate how the educational agency might impact upon the legislature's societal goal of reducing the number of robbers-on-the-loose. Since a good number of new robbers-on-the-loose come from the yearly pool of high school graduates, the over all education manager would be interested in knowing which high school students are most likely to become robbers. Furthermore, let us assume that there is evidence that those non-college preparatory (i.e., occupational and general) high school students who are unemployed and/or dropouts are most likely to become robbers-on-the-loose. The over all education manager might base his decision to increase the number of occupational education students relative to the number of general students on data which indicates that general students are more likely than occupational education students to be either unemployed and/or droupouts. Therefore, in order to contribute to the societal goal of decreasing the number of robbers-on-the-loose, the over all education manager would request that more money be allocated to education so that more students can be placed into the more costly occupational education programs, since these students are less likely than general students to become robbers-on-the-loose.

The hypothetical data upon which the over all education manager in our example bases his decision to increase training of occupational education high school students and decrease training of general high school students is presented in Table 5. Note that more than four times as many general students as occupational education students fall into the category of unemployed dropouts. Recall that previous evidence indicated that these are high risk students in terms of their likelihood of becoming robbers-on-the-loose. Note also that there is a considerably higher incidence of both unemployment and dropoutism for general students than among occupational education students. (In fact, almost all general dropouts (90%) are unemployed whereas occupational education dropouts are about as likely to be employed as unemployed - probably because of the skills that they have learned previous to dropping out. On the

TABLE 5: Hypothetical Data which shows the incidence and interaction of completion-dropoutism and employment-unemployment among general and occupational education high school students.

I. Occupational Education Students (N = 15,000)

	Employed	Unemployed	Sum
Completors	12,150 (81%)	1,350 (9%)	13,500 (90%)
Dropouts	725 (4.8%)	775 (5.2%)	1,500 (10%)
	12,875 (85.8%)	2,125 (14.2%)	15,000

II. General Students (N = 15,000)

	Employed	Unemployed	Sum
Completors	6,750 (45%)	4,500 (30%)	11,250 (75%)
Dropouts	375 (2.5%)	3.375 (22.5%)	3,750 (25%)
	7,875 (52.5%)	7,125 (47.5%)	15,000

benefit side, the occupational education students clearly fared better than their general student counterparts. Note that almost twice as many occupational education students are employed. Thus, the over all education manager decides that if more students are placed into the occupational education program rather than into the general program, education can have an increased impact on reducing the number of robbers-on-the-loose.

Once the decision has been made to train more occupational education students and funds have been allocated to the over all education manager for this purpose, the over all occupational education program manager would want to know which occupational education programs turn out students who are least likely to fall into the high risk category in terms of becoming robbers-on-the-loose, and what are the cost factors involved in those programs.* Some hypothetical data is presented in Table 6; three programs were compared in terms of their costs, and the incidence and interaction of completion-dropoutism and/or employment-unemployment of the students in those programs. It can be seen that the automechanics and machine shop programs are identical in terms of the incidence of both student completion and/or employment. The only difference between these two programs is that the automechanics program costs $1,000 more per completor than the machine shop program.

The upholstery program is clearly inferior to either of the other programs; it is more costly and more than twice as many of the students in this program as compared to the other two programs fall into the high risk unemployed dropout category. Also whereas a high percentage of automechanic students and machine shop students find jobs, more upholstery students are unemployed than are employed. The dropout rate in the upholstery program is also higher than in the other programs. Thus, the over all occupational education

*Such data is to be a regular part of MISOE

TABLE 6: Hypothetical Data on the incidence and interaction of employment-unemployment and completion-dropoutism among occupational education students in three different occupational education programs. (N = 5,000 in each program).

Program 1 - Upholstering
(costs = $6,000 per completor)

	Employed	Unemployed	Sum
Completor	2100 (42%)	1400 (28%)	3500 (70%)
Dropout	150 (3%)	1350 (27%)	1500 (30%)
Sum	2250 (45%)	2750 (55%)	5000

Program 2 - Automechanics
(costs = $5500 per completor)

	Employed	Unemployed	Sum
Completor	3600 (72%)	400 (8%)	4000 (80%)
Dropout	480 (9.6%)	520 (10.4%)	1000 (20%)
Sum	4080 (81.6%)	920 (18.4%)	5000

Program 3 - Machine Shop
(costs = $4500 per completor)

	Employed	Unemployed	Sum
Completor	3600 (72%)	400 (8%)	4000 (80%)
Dropout	480 (9.6%)	520 (10.4%)	1000 (20%)
Sum	4080 (81.6%)	920 (18.4%)	5000

programs manager might decide that in order to maximize results at a given cost in terms of turning out highly employable students who graduate from high school, the upholstery program should be phased out and students should be trained as either automechanics or machinists. Although it is less expensive to train machinists than automechanics, the over all occupational education programs manager might decide that it is best to train automechanics as well in order to prevent flooding the market with machinists. Once again it must be remembered that the examples offered in this paper are very simplified; in reality most managers must deal with more than one goal at a time.

The within occupational education program manager (e.g., the head of the automotive mechanics program) would be interested in maximizing results in terms of turning out highly employable automechanics who graduate from high school at a given cost. He would therefore be interested in knowing which process mixes turn out employed completor automechanics and at what cost. Hypothetical data comparing three different process mixes within the automotive program in terms of a) the product data associated with each of those process mixes (i.e., completion or non-completion and the number of behavioral objectives passed by each automechanic) and, b) the impact data associated with each of the products (e.g., employment-unemployment) is presented in Table 7. Students who underwent process mix three obtained more objectives over all than students in either of the other process mixes. However, process mix three is longer than process mixes one and two, and more costly. In addition, process mix three students were much more likely than students in either process mix one or two to fall into the high risk category of unemployed dropouts. The dropout rate of process mix three students is many times higher than that of students in the other two process mixes; the unemployment rate for process mix

TABLE 7: Hypothetical product - impact mix data associated with three process mixes within an automotive mechanics program.

Process Mix (Significant Factors)	*Average Cost Per Completor	Average Number of Objectives Passed Per Completor	Impact Data (N = 500)			
				Employed	Unemployed	Sum
1. length = 2 years no cooperative work program live model repair pupil/teacher ratio = 15:1	$4500	250	Completor	320 (64%)	80 (16%)	400 (80%)
			Dropout	50 (10%)	50 (10%)	100 (20%)
			Sum	370 (74%)	130 (26%)	500
				Employed	Unemployed	Sum
2. length = 2 years cooperative work program mockup and live model repair pupil/teacher ratio = 15:1 student/tutor program	$5000	325	Completor	428 (85.6%)	22 (4.4%)	450 (90%)
			Dropout	25 (5%)	25 (5%)	50 (10%)
			Sum	453 (90.6%)	47 (9.4%)	500
				Employed	Unemployed	Sum
3. length = 3 years cooperative work program live model repair pupil/teacher ratio = 15:1	$7200	400	Completor	225 (45%)	25 (5%)	250 (50%)
			Dropout	125 (25%)	125 (25%)	250 (50%)
			Sum	350 (70%)	150 (30%)	500

*The cost of dropouts is included in these averages since these average costs are a function of dividing the number of completors into total program costs over the duration of the program.

three students is slightly higher than that of process mix one students, but it is more than three times as high as for process mix two students. Process mix three compares favorably with process mix two in terms of the small number of students who become unemployed completors. More than three times as many of the process mix one students fall into the category of unemployed completors than students in either of the other two process mixes. However, in terms of the number of students who become completors, process mix three is clearly inferior to either of the other process mixes. Of those process mix three students who do complete, almost all (90%) find jobs. This compares favorably to the employment rate of process mix two completors (95%) and is higher than the employment rate of process mix one completors (64%). Thus, process mix three might be characterized as being "tough but good", in that although many students drop out, those students who do complete enter the job market with a large number of attained behavioral objectives and are highly employable.

Process mix two is somewhat more costly than process mix one; they are both the same length, but students in process mix two participate in a cooperative work program and work on mockups as well as live models. The teacher-pupil ratios are identical in all three process mixes, but in process mix two the better students tutor the poorer students. The student-tutor program has the advantages of reducing the teacher-pupil ratio (in effect) and aiding both the poorer and the better students through their mutual interaction in a learning experience. It can be seen that process mix two students attain more behavioral objectives in two years time than process mix one students; in addition, the number of process mix two students who fall into the unemployed dropout category is half of the number of process mix one students who fall into this category. Process mix two is also superior to process mix one in terms of the number of students who complete and the number of students who complete and the number of students who find jobs. The lower rate of employment of process mix one students relative to process mix two students may be attributable to the lack of a cooperative work program in this process mix; students with work experience are more immediately employable than those without work experience.

Although students who underwent the longer process three mix obtained more objectives than students who underwent process mix two, the average cost of each objective obtained per completor is higher in process mix three ($18 per objective per completor) than in process mix two ($15.39 per objective per completor).

$$\text{average cost per objective per completor} = \frac{\text{average cost of process mix per completor}}{\text{avg. \# of objectives attained per completor}}$$

Furthermore, the employment rate of process mix two students is slightly higher than that of process mix three students even though the latter obtained more objectives, i.e., the additional objectives do not appear to be related to employment (This could be a case of educational overkill.)

In light of the single goal which has been used to demonstrate the interconnective nature of MISOE as a system, the within-occupational education programs manager would probably conclude the process mix two is superior to process mixes one and three in that process mix two automechanics are least likely to be dropouts and/or unemployed and are therefore less likely to become robbers-on-the-loose.

It is hoped that this simplified example of the simulation process at the over-all-agencies level of MISOE and the demonstration of the interconnectiveness of MISOE as a system will provide a more complete understanding of the dynamic aspects of MISOE. MISOE will construct models for simulation at all management levels for use by management personnel within the Division of Occupational Education and for managers at over-all education and over-all social agency levels. MISOE's static data will be arrayed such that it will be useful in simulation. The models for simulation will be developed by MISOE in consultation with practicing managers at all levels.

APPENDIX

EXPLANATORY NOTE

The Figures in the appendix are based on the correspondingly numbered Tables. Costs and numbers of robbers-on-the-loose were observed at intervals of five years. Each cost figure and each ROL figure for each five year interval was then divided by the number of good citizens observed at that time interval. It is these ratios that are plotted in the Figures that correspond to each Table. For example, Table I in the appendix contains the yearly figures for a status quo or do-nothing simulated solution to the robbers-on-the-loose problem. At the first five year interval (e.g., year 5) there are 9,767 robbers-on-the-loose and 552,746 good citizens. The ratio of ROL's per good citizen is therefore equal to $\frac{\text{\# ROL's}}{\text{\# G.C.'s}} = \frac{9767}{552,746} = .018$ robbers-on-the-loose per good citizen. It is this ratio of ROL's per G. C. that is plotted at Time 5 in Figure I. Similarly, the total costs to society of robbers-on-the-loose at year 5 in Table I are $194,598,000; there are 552,746 good citizens. Therefore, the total cost per good citizen of robbers-on-the-loose is equal to $\frac{\$194,598,000}{552,746} = \$352$. This is the cost figure that is plotted at time 5 in Figure I. The cost curves and ROL curves were all determined in this manner.

LIST OF TABLES

LIST OF FIGURES

Table 1

ROBBERY SIMULATION: DO NOTHING (STATUS QUO) SOLUTION

YEAR	ROL	RP	GC	TOTAL COSTS	PRISON COSTS	EDUC COSTS	POLICE COSTS	ARRESTS	RECID	REFORM	NEW ROL
	LEVELS			COST LEVELS				RATES			
0	5000	8000	500000	165375000	80000000	84375000	1000000	1000	560	240	1782
1	6342	8200	510957	167643000	82000000	84375000	1268000	1268	574	246	1783
2	7431	8648	521699	172341000	86480000	84375000	1486000	1486	605	259	1784
3	8334	9269	532238	178731000	92690000	84375000	1666000	1666	648	278	1785
4	9101	10008	542585	186275000	100080000	84375000	1820000	1820	700	300	1786
5	9767	10827	552746	194598000	108270000	84375000	1953000	1953	757	324	1787
6	10358	11697	562726	203416000	116970000	84375000	2071000	2071	818	350	1788
7	10893	12598	572532	212533000	125980000	84375000	2178000	2178	881	377	1789
8	11385	13516	582168	221812000	135160000	84375000	2277000	2277	946	405	1790
9	11844	14441	591638	231153000	144410000	84375000	2368000	2368	1010	433	1791
10	12277	15364	600946	240470000	153640000	84375000	2455000	2455	1075	460	1792
11	12689	16282	610093	249732000	162820000	84375000	2537000	2537	1139	488	1793
12	13084	17190	619085	258891000	171900000	84375000	2616000	2616	1203	515	1793
13	13464	18087	627923	267937000	180870000	84375000	2692000	2692	1266	542	1794
14	13832	18970	636610	276841000	189700000	84375000	2766000	2766	1327	569	1795
15	14188	19839	645150	285602000	198390000	84375000	2837000	2837	1388	595	1796
16	14535	20692	653544	294202000	206920000	84375000	2907000	2907	1448	620	1797
17	14873	21529	661794	302639000	215290000	84375000	2974000	2974	1507	645	1798
18	15204	22350	669903	310915000	223500000	84375000	3040000	3040	1564	670	1798
19	15526	23155	677874	319030000	231550000	84375000	3105000	3105	1620	694	1799
20	15840	23944	685709	326983000	239440000	84375000	3168000	3168	1676	718	1800

i

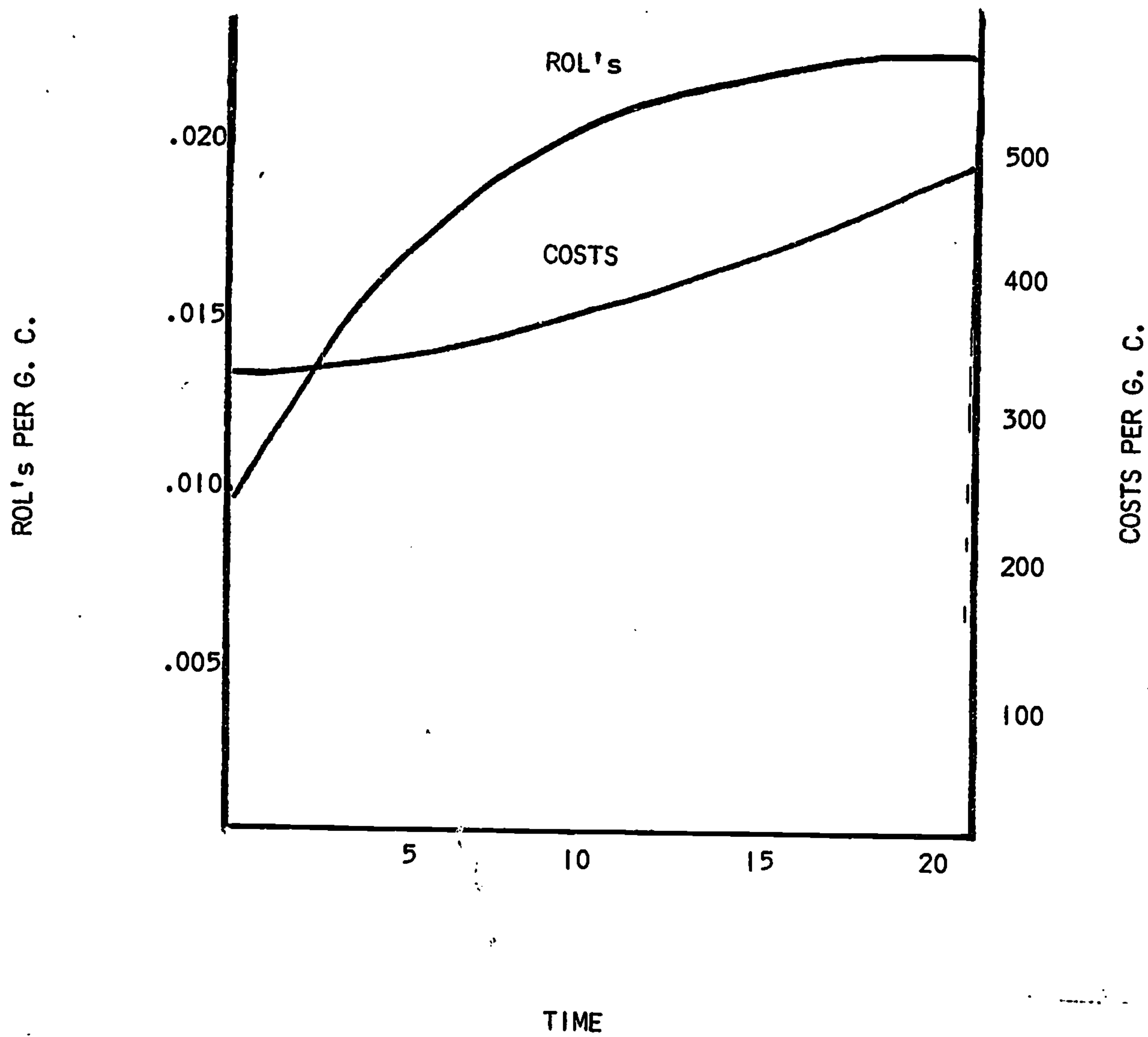


FIGURE 1: Simulation of ROL's per G. C. and costs per G. C. under a no change solution.

Table II

ROBBERY SIMULATION: POLICE SOLUTION

	LEVELS			COST LEVELS				RATES			
YEAR	ROL	RP	GC	TOTAL COSTS	PRISON COSTS	EDUC COSTS	POLICE COSTS	ARRESTS	RECID	REFORM	NEW ROL
0	5000	8000	500000	166875000	80000000	84375000	2500000	2500	560	240	1782
1	4842	9700	510957	183796000	97000000	84375000	2421000	2421	679	291	1783
2	4883	11151	521744	198326000	111510000	84375000	2441000	2441	780	334	1784
3	5006	12476	532357	211638000	124760000	84375000	2503000	2503	873	374	1785
4	5161	13731	542797	224265000	137310000	84375000	2580000	2580	961	411	1786
5	5328	14937	553064	236409000	149370000	84375000	2664000	2664	1045	448	1787
6	5496	16107	563162	248193000	161070000	84375000	2748000	2748	1127	483	1788
7	5663	17244	573092	259646000	172440000	84375000	2831000	2831	1207	517	1789
8	5828	18350	582856	270789000	183500000	84375000	2914000	2914	1284	550	1790
9	5988	19429	592457	281659000	194290000	84375000	2994000	2994	1360	582	1791
10	6145	20480	601897	292247000	204800000	84375000	3072000	3072	1433	614	1792
11	6298	21504	611179	302564000	215040000	84375000	3149000	3149	1505	645	1793
12	6447	22502	620306	312618000	225020000	84375000	3223000	3223	1575	675	1794
13	6593	23474	629279	322411000	234740000	84375000	3296000	3296	1643	704	1794
14	6734	24422	638101	331962000	244220000	84375000	3367000	3367	1709	732	1795
15	6871	25346	646774	341270000	253460000	84375000	3435000	3435	1774	760	1796
16	7006	26246	655300	350338000	262460000	84375000	3503000	3503	1837	787	1797
17	7137	27124	663682	359183000	271240000	84375000	3568000	3568	1898	813	1798
18	7265	27979	671921	367797000	279790000	84375000	3632000	3632	1958	839	1799
19	7390	28813	680021	376200000	288130000	84375000	3695000	3695	2016	864	1800
20	7511	29626	687983	384390000	296260000	84375000	3755000	3755	2073	888	1800

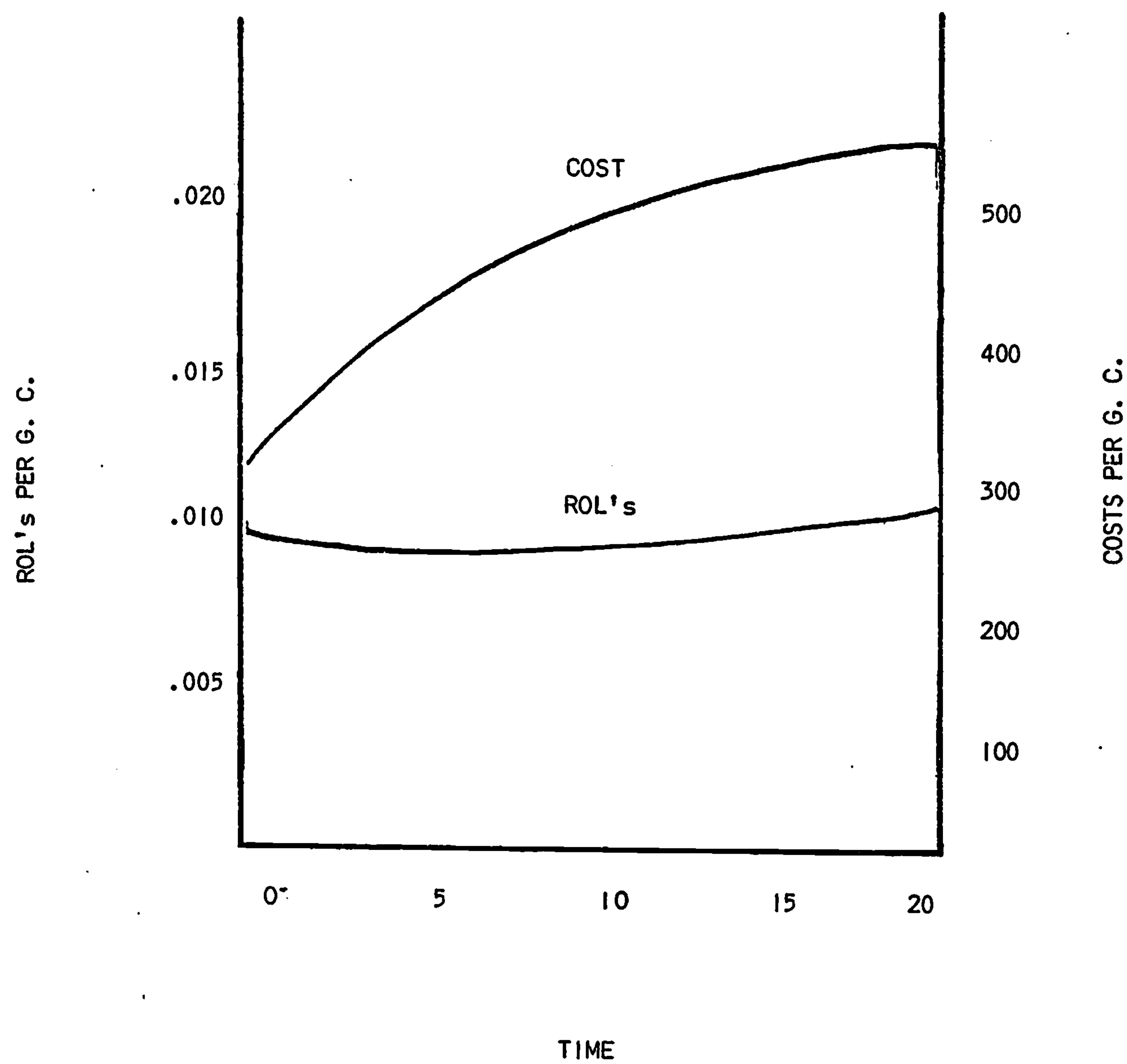


Figure ii: Simulation of ROL's per G. C. and costs per G. C. under a police solution.

Table iii

ROBBERY SIMULATION: REHABILITATION SOLUTION

	LEVELS			COST LEVELS				RATES			
YEAR	ROL	RP	GC	TOTAL COSTS	PRISON COSTS	EDUC COSTS	POLICE COSTS	ARRESTS	RECID	REFORM	NEW ROL
0	5000	8000	500000	189375000	104000000	84375000	1000000	1000	160	640	1782
1	5942	8200	511357	192163000	106600000	84375000	1188000	1188	164	656	1783
2	6701	8568	522501	197099000	111384000	84375000	1340000	1340	171	685	1784
3	7316	9051	533450	203501000	117663000	84375000	1463000	1463	181	724	1785
4	7819	9608	544218	210842000	124904000	84375000	1563000	1563	192	768	1786
5	8234	10210	554814	218751000	132730000	84375000	1646000	1646	204	816	1787
6	8579	10835	565245	226945000	140855000	84375000	1715000	1715	216	866	1788
7	8868	11466	575516	235206000	149058000	84375000	1773000	1773	229	917	1789
8	9113	12092	585632	243393000	157196000	84375000	1822000	1822	241	967	1790
9	9322	12704	595594	251391000	165152000	84375000	1864000	1864	254	1016	1791
10	9503	13297	605405	259136000	172861000	84375000	1900000	1900	265	1063	1792
11	9660	13867	615066	266578000	180271000	84375000	1932000	1932	277	1109	1793
12	9798	14412	624579	273690000	187356000	84375000	1959000	1959	288	1152	1794
13	9921	14929	633943	280436000	194077000	84375000	1984000	1984	298	1194	1795
14	10030	15420	643161	286841000	200460000	84375000	2006000	2006	308	1233	1796
15	10128	15884	652233	292892000	206492000	84375000	2025000	2025	317	1270	1797
16	10217	16320	661160	298578000	212160000	84375000	2043000	2043	326	1305	1798
17	10298	16731	669942	303937000	217503000	84375000	2059000	2059	334	1338	1798
18	10371	17116	678581	308957000	222508000	84375000	2074000	2074	342	1369	1799
19	10438	17478	687077	313676000	227214000	84375000	2087000	2087	349	1398	1800
20	10500	17817	695431	318096000	231621000	84375000	2100000	2100	356	1425	1801

v

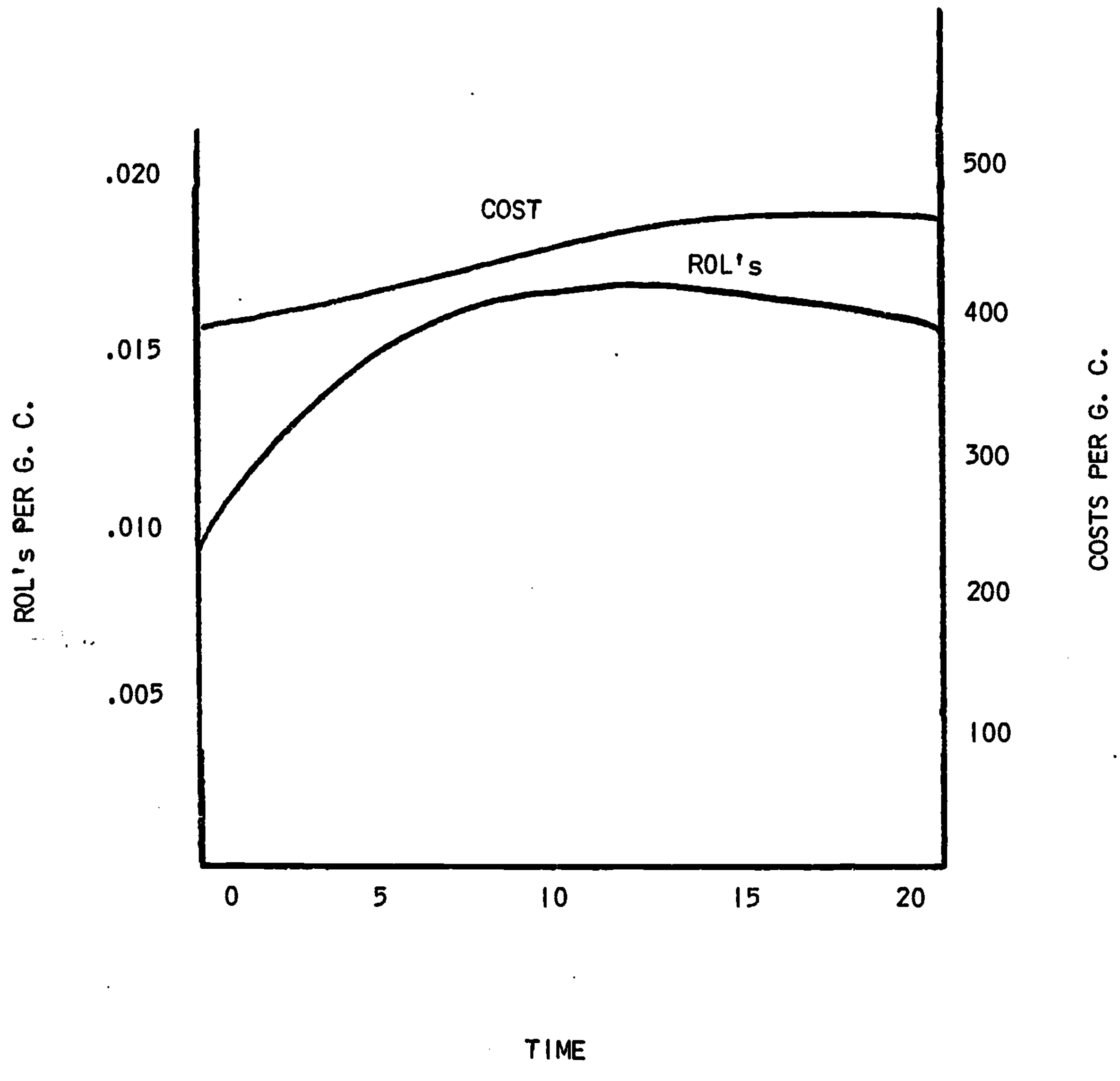


FIGURE III : Simulation of ROL's per G. C. and costs per G. C. under a rehabilitation solution.

Table iv

ROBBERY SIMULATION: EDUCATION SOLUTION

	LEVELS			COST LEVELS				RATES			
YEAR	ROL	RP	GC	TOTAL COSTS	PRISON COSTS	EDUC COSTS	POLICE COSTS	ARRESTS	RECID	REFORM	NEW ROL
0	5000	8000	500000	174750000	80000000	93750000	1000000	1000	560	240	1235
1	5795	8200	511505	176909000	82000000	93750000	1159000	1159	574	246	1236
2	6446	8539	522784	180429000	85390000	93750000	1289000	1289	597	256	1237
3	6991	8974	533847	184888000	89740000	93750000	1398000	1398	628	269	1238
4	7459	9474	544700	189981000	94740000	93750000	1491000	1491	663	284	1239
5	7870	10017	555350	195494000	100170000	93750000	1574000	1574	701	300	1240
6	8237	10589	565802	201287000	105890000	93750000	1647000	1647	741	317	1241
7	8572	11177	576061	207234000	111770000	93750000	1714000	1714	782	335	1242
8	8882	11773	586132	213256000	117730000	93750000	1776000	1776	824	353	1243
9	9173	12371	596018	219294000	123710000	93750000	1834000	1834	865	371	1244
10	9448	12967	605724	225309000	129670000	93750000	1889000	1889	907	389	1245
11	9711	13559	615252	231282000	135590000	93750000	1942000	1942	949	406	1246
12	9964	14145	624606	237192000	141450000	93750000	1992000	1992	990	424	1247
13	10209	14722	633790	243011000	147220000	93750000	2041000	2041	1030	441	1248
14	10446	15290	642806	248739000	152900000	93750000	2089000	2089	1070	458	1249
15	10676	15850	651658	254385000	158500000	93750000	2135000	2135	1109	475	1250
16	10900	16400	660349	259930000	164000000	93750000	2180000	2180	1148	492	1251
17	11119	16940	668882	265373000	169400000	93750000	2223000	2223	1185	508	1251
18	11332	17469	677260	270706000	174690000	93750000	2266000	2266	1222	524	1252
19	11540	17988	685486	275938000	179880000	93750000	2308000	2308	1259	539	1253
20	11744	18497	693561	281068000	184970000	93750000	2348000	2348	1294	554	1254

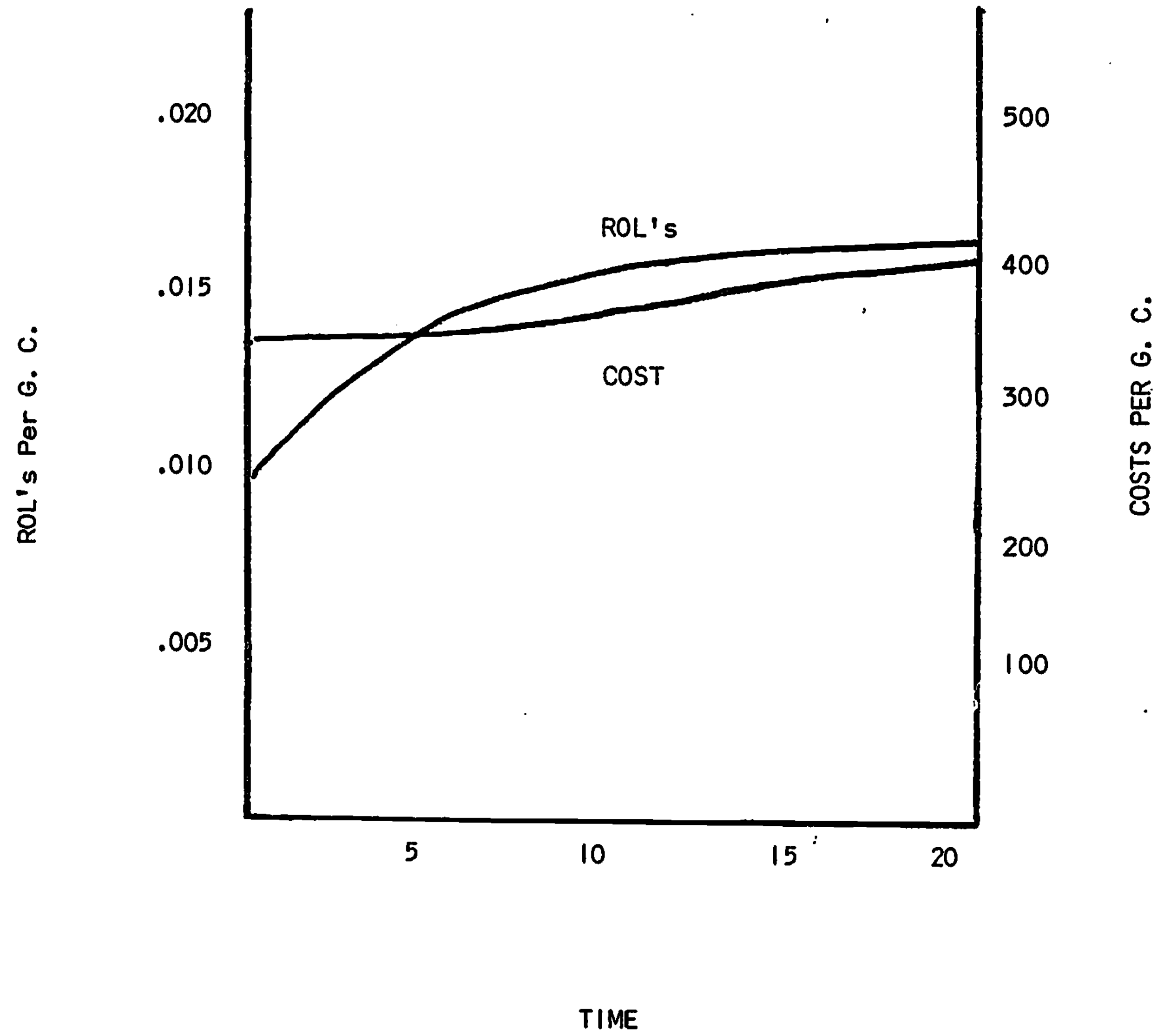


FIGURE iv: Simulation of ROL's per G. C. and costs per G. C. under an education solution.

Table v

ROBBERY SIMULATION: EDUCATION & REHABILITATION SOLUTION

	LEVELS			COST LEVELS				RATES			
YEAR	ROL	RP	GC	TOTAL COSTS	PRISON COSTS	EDUC COSTS	POLICE COSTS	ARRESTS	RECID	REFORM	NEW ROL
0	5000	8000	500000	198750000	104000000	93750000	1000000	1000	160	640	1235
1	5395	8200	511905	201429000	106600000	93750000	1079000	1079	164	656	1236
2	5716	8459	523586	204860000	109967000	93750000	1143000	1143	169	676	1237
3	5979	8756	535052	208773000	113828000	93750000	1195000	1195	175	700	1238
4	6197	9075	546312	212964000	117975000	93750000	1239000	1239	181	726	1239
5	6378	9406	557372	217303000	122278000	93750000	1275000	1275	188	752	1240
6	6531	9740	568235	221676000	126620000	93750000	1306000	1306	194	779	1241
7	6660	10072	578907	226018000	130936000	93750000	1332000	1332	201	805	1242
8	6771	10396	589390	230252000	135148000	93750000	1354000	1354	207	831	1243
9	6867	10710	599689	234353000	139230000	93750000	1373000	1373	214	856	1244
10	6952	11012	609806	238296000	143156000	93750000	1390000	1390	220	880	1245
11	7027	11300	619743	242055000	146900000	93750000	1405000	1405	226	904	1246
12	7094	11575	629505	245643000	150475000	93750000	1418000	1418	231	926	1247
13	7154	11835	639092	249035000	153855000	93750000	1430000	1430	236	946	1248
14	7208	12081	648507	252244000	157053000	93750000	1441000	1441	241	966	1249
15	7257	12313	657753	255270000	160069000	93750000	1451000	1451	246	985	1250
16	7302	12532	666832	258126000	162916000	93750000	1460000	1460	250	1002	1251
17	7343	12738	675745	260812000	165594000	93750000	1468000	1468	254	1019	1252
18	7381	12932	684496	263342000	168116000	93750000	1476000	1476	258	1034	1253
19	7416	13114	693086	265715000	170482000	93750000	1483000	1483	262	1049	1254
20	7449	13285	701518	267944000	172705000	93750000	1489000	1489	265	1062	1255

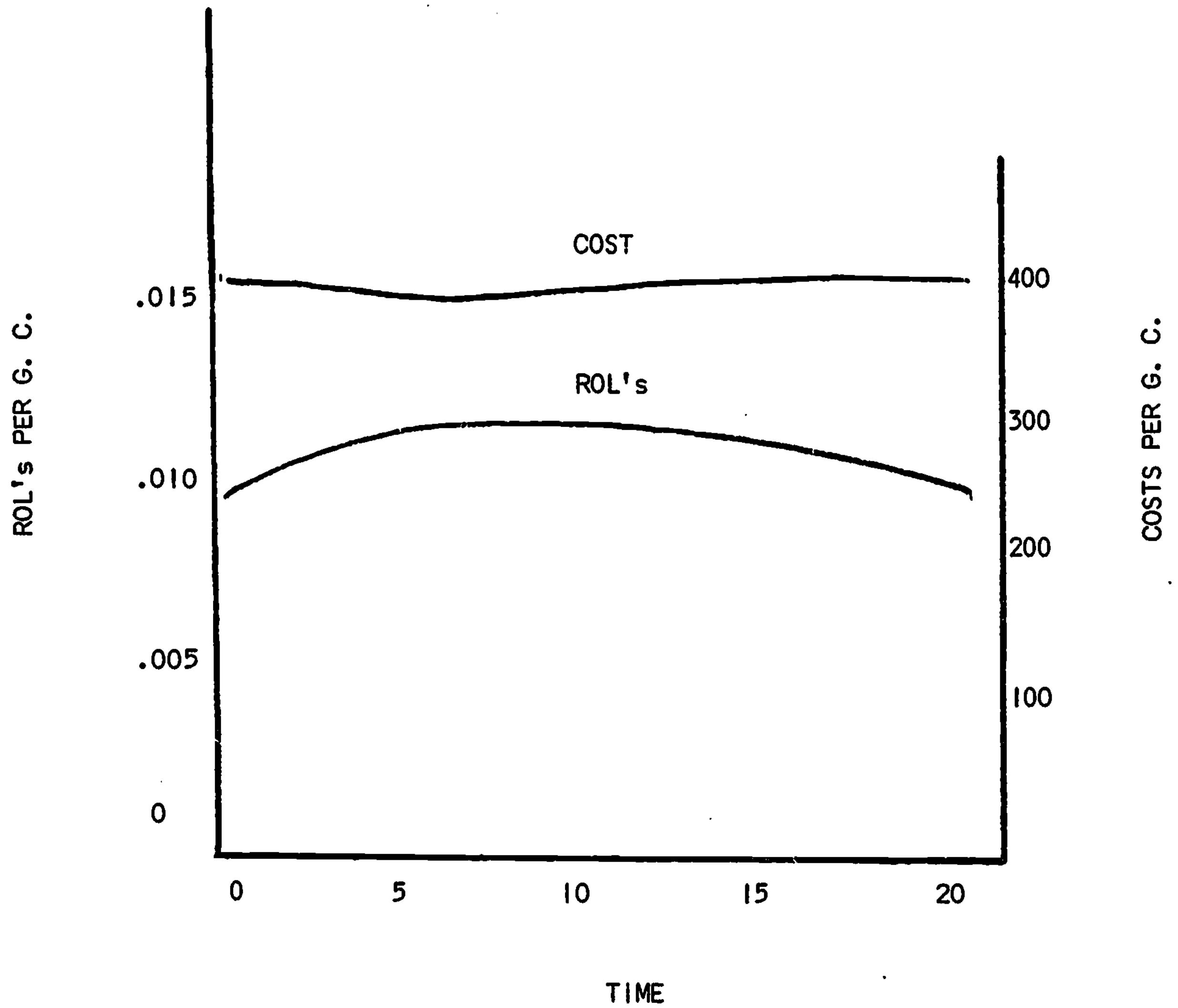


FIGURE v: Simulation of ROL's per G. C. and costs per G. C. under a rehabilitation and education solution.

x

Table vi

ROBBERY SIMULATION: POLICE & REHABILITATION SOLUTION

	LEVELS			COST LEVELS				RATES			
YEAR	ROL	RP	GC	TOTAL COSTS	PRISON COSTS	EDUC COSTS	POLICE COSTS	ARRESTS	RECID	REFORM	NEW ROL
0	5000	8000	500000	190875000	104000000	84375000	2500000	2500	160	640	1782
1	4442	9700	511357	212696000	126100000	84375000	2221000	2221	194	776	1783
2	4198	10951	522621	228837000	142363000	84375000	2099000	2099	219	876	1784
3	4102	11954	533759	241828000	155402000	84375000	2051000	2051	239	956	1785
4	4075	12809	544753	252929000	166517000	84375000	2037000	2037	256	1024	1786
5	4080	13565	555594	262760000	176345000	84375000	2040000	2040	271	1085	1787
6	4098	14248	566278	271648000	185224000	84375000	2049000	2049	284	1139	1788
7	4121	14872	576801	279771000	193336000	84375000	2060000	2060	297	1189	1789
8	4147	15444	587163	287220000	200772000	84375000	2073000	2073	308	1235	1790
9	4172	15972	597363	294097000	207636000	84375000	2066000	2086	319	1277	1791
10	4196	16460	607400	300453000	213980000	84375000	2098000	2098	329	1316	1792
11	4219	16912	617274	306340000	219856000	84375000	2109000	2109	338	1352	1793
12	4241	17329	626985	311772000	225277000	84375000	2120000	2120	346	1386	1794
13	4261	17716	636535	316813000	230308000	84375000	2130000	2130	354	1417	1795
14	4280	18074	645924	321477000	234962000	84375000	2140000	2140	361	1445	1796
15	4297	18406	655152	325801000	239278000	84375000	2148000	2148	368	1472	1797
16	4314	18713	664222	329801000	243269000	84375000	2157000	2157	374	1497	1798
17	4329	18998	673135	333513000	246974000	84375000	2164000	2164	379	1519	1799
18	4343	19262	681890	336952000	250406000	84375000	2171000	2171	385	1540	1800
19	4357	19506	690491	340131000	253578000	84375000	2178000	2178	390	1560	1801
20	4370	19733	698939	343089000	256529000	84375000	2185000	2185	394	1578	1801

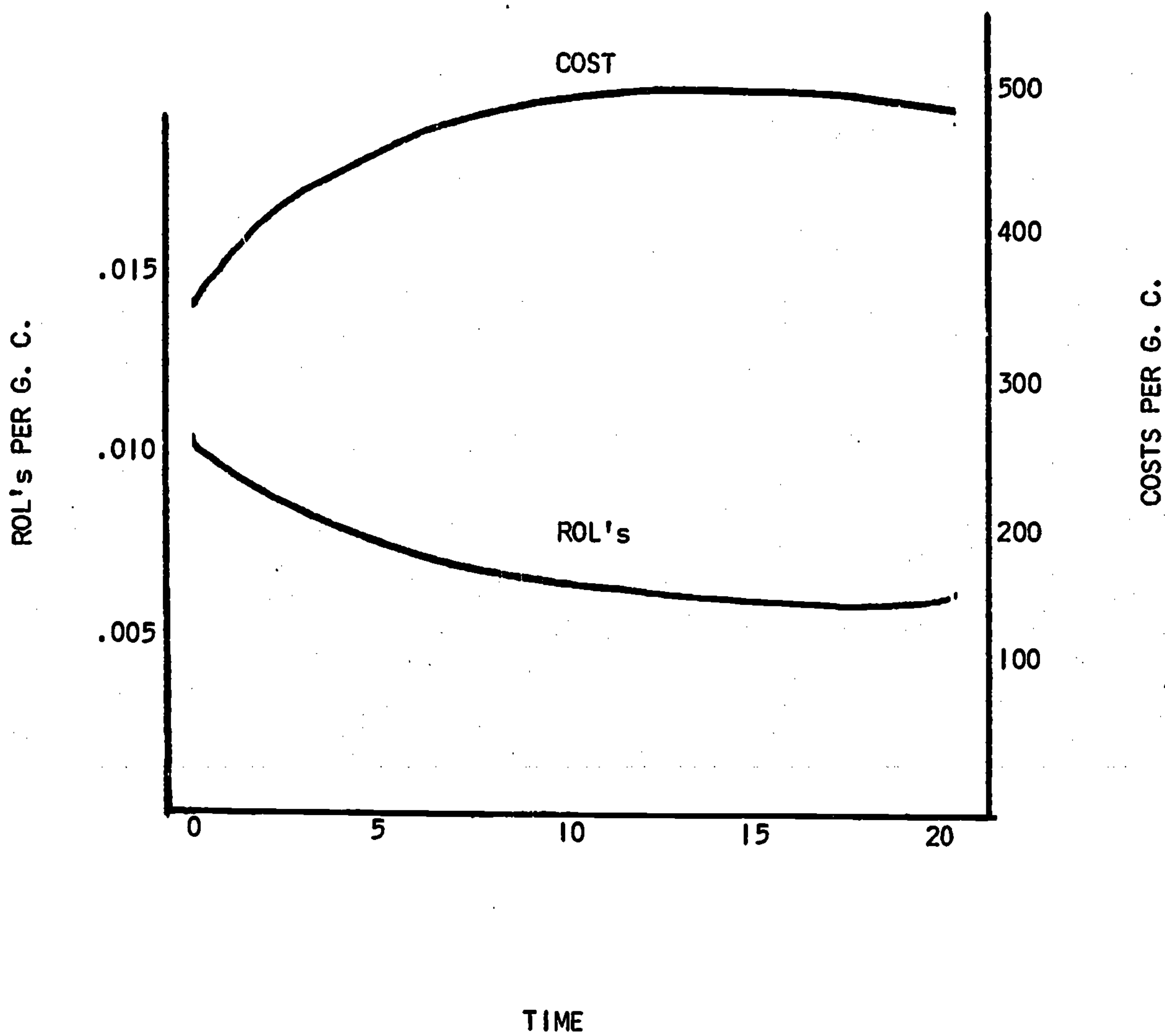


FIGURE vi: Simulation of ROL's per G. C. and costs per G. C. under a police and rehabilitation solution.

Table vii

ROBBERY SIMULATION: EDUCATION & POLICE SOLUTION

	LEVELS			COST LEVELS				RATES			
YEAR	ROL	RP	GC	TOTAL COSTS	PRISON COSTS	EDUC COSTS	POLICE COSTS	ARRESTS	RECID	REFORM	NEW ROL
0	5000	8000	500000	176250000	80000000	93750000	2500000	2500	560	240	1235
1	4295	9700	511505	192897000	97000000	93750000	2147000	2147	679	291	1236
2	4063	10877	522829	204551000	108770000	93750000	2031000	2031	761	326	1237
3	4030	11820	533961	213965000	118200000	93750000	2015000	2015	827	354	1238
4	4080	12653	544897	222320000	126530000	93750000	2040000	2040	885	379	1239
5	4164	13427	555638	230102000	134270000	93750000	2082000	2082	939	402	1240
6	4261	14166	566186	237540000	141660000	93750000	2130000	2130	991	424	1241
7	4363	14879	576544	244721000	148790000	93750000	2181000	2181	1041	446	1242
8	4465	15572	586716	251702000	155720000	93750000	2232000	2232	1090	467	1243
9	4566	16246	596705	258493000	162460000	93750000	2283000	2283	1137	487	1244
10	4664	16904	606513	265122000	169040000	93750000	2332000	2332	1183	507	1245
11	4760	17545	616144	271580000	175450000	93750000	2380000	2380	1228	526	1246
12	4854	18170	625600	277877000	161700000	93750000	2427000	2427	1271	545	1247
13	4945	18780	634885	284022000	187800000	93750000	2472000	2472	1314	563	1248
14	5035	19374	644001	290037000	193740000	93750000	2517000	2517	1356	581	1249
15	5123	19953	652952	295841000	199530000	93750000	2561000	2561	1396	598	1250
16	5208	20518	661740	301534000	205180000	93750000	2604000	2604	1436	615	1251
17	5291	21070	670369	307095000	210700000	93750000	2645000	2645	1474	632	1252
18	5372	21608	678841	312516000	216080000	93750000	2686000	2686	1512	648	1252
19	5450	22133	687159	317805000	221330000	93750000	2725000	2725	1549	663	1253
20	5527	22644	695325	322953000	226440000	93750000	2763000	2763	1585	679	1254

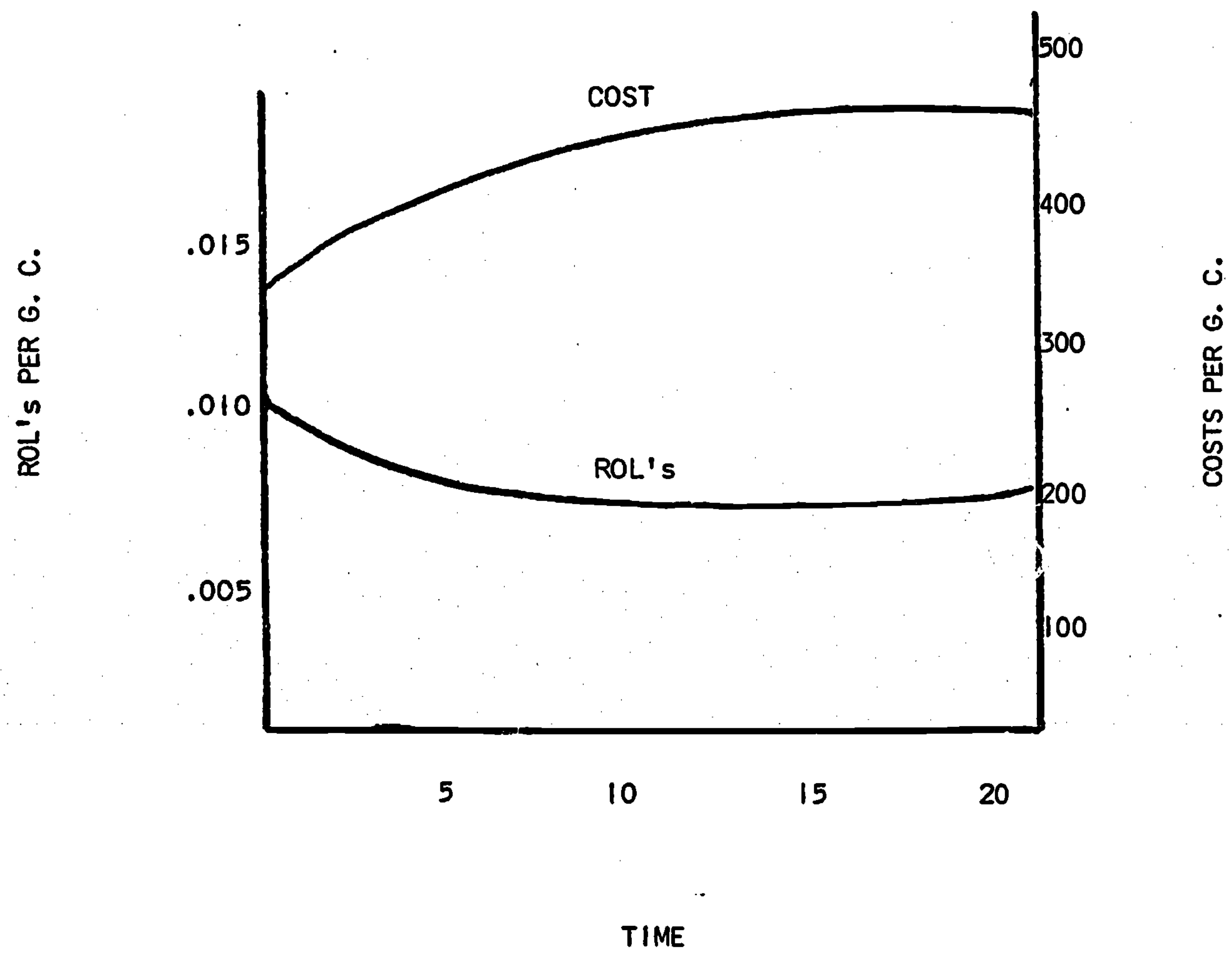


FIGURE vii: Simulation of ROL's per G. C. and costs per G. C. under an education and police solution.

Table viii

ROBBERY SIMULATION: REHABILITATION, EDUCATION & POLICE SOLUTION

	LEVELS			COST LEVELS				RATES				
YEAR	ROL	RP	GC	TOTAL COSTS	PRISON COSTS	EDUC COSTS	POLICE COSTS	ARRESTS	RECID	REFORM	NEW ROL
0	5000	8000	500000	200250000	104000000	93750000	2500000	2500	160	640	1235
1	3895	9700	511905	221797000	126100000	93750000	1947000	1947	194	776	1236
2	3378	10677	523706	234240000	138801000	93750000	1689000	1689	213	854	1237
3	3139	11298	535348	242193000	146874000	93750000	1569000	1569	225	903	1238
4	3033	11737	546805	247847000	152581000	93750000	1516000	1516	234	938	1239
5	2990	12079	558067	252272000	157027000	93750000	1495000	1495	241	966	1240
6	2976	12366	569130	255996000	160758000	93750000	1488000	1488	247	989	1241
7	2976	12617	579994	259259000	164021000	93750000	1488000	1488	252	1009	1242
8	2982	12843	590660	262200000	166959000	93750000	1491000	1491	256	1027	1244
9	2991	13049	601129	264882000	169637000	93750000	1495000	1495	260	1043	1245
10	3001	13239	611404	267357000	172107000	93750000	1500000	1500	264	1059	1246
11	3011	13415	621488	269650000	174395000	93750000	1505000	1505	268	1073	1247
12	3021	13578	631384	271774000	176514000	93750000	1510000	1510	271	1086	1248
13	3030	13730	641094	273755000	178490000	93750000	1515000	1515	274	1098	1249
14	3038	13872	650621	275605000	180336000	93750000	1519000	1519	277	1109	1250
15	3046	14003	659967	277312000	182039000	93750000	1523000	1523	280	1120	1250
16	3053	14125	669136	278901000	183625000	93750000	1526000	1526	282	1130	1251
17	3060	14238	678131	280374000	185094000	93750000	1530000	1530	284	1139	1252
18	3066	14344	686954	281755000	186472000	93750000	1533000	1533	286	1147	1253
19	3072	14442	695608	283032000	187746000	93750000	1536000	1536	288	1155	1254
20	3078	14533	704096	284218000	188929000	93750000	1539000	1539	290	1162	1255

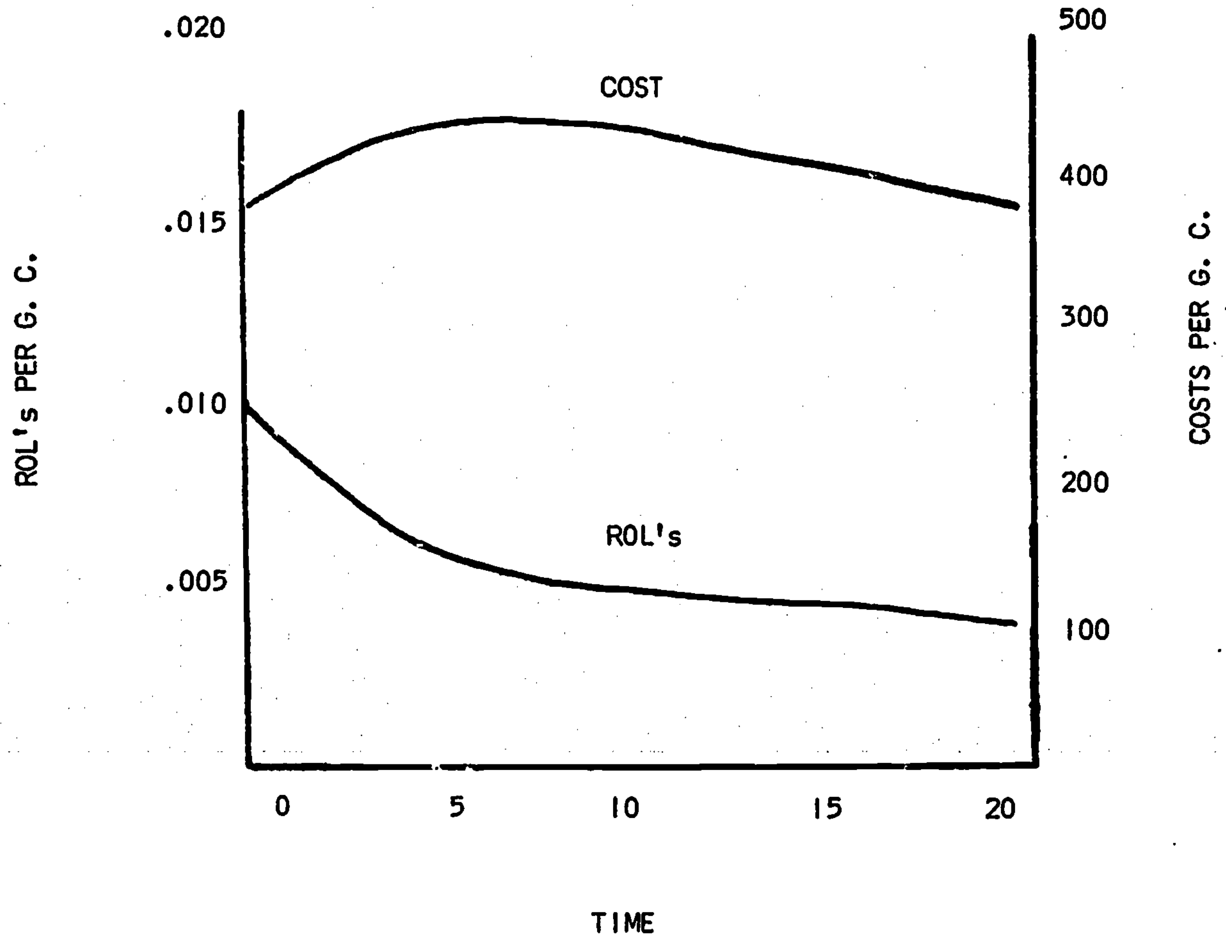


FIGURE viii: Simulation of ROL's per G. C. and costs per G. C. under a rehabilitation, education and police solution.

TABLE Ix

Equations used for the robbers-on-the-loose simulation example

I. Initially Specified Level Values

VG = GG = 11,250 w/o education simulation

VG = 15,000; GG = 7500 with education simulation

RP = 8,000

GC = 500,000

ROL = 5,000

Prison Costs w/o Rehabilitation Program = $10,000RP

" " with " " = $13,000RP

Education Costs = $5,000VG + $2,500GG

Total Costs = Prison Costs + Education Costs + Police Costs (RED)

II. Constants

VMDC = .004VG

GMDC = .15GG

VGCC = .996VG

GGCC = .85GG

GCMDC = .0001GC

GCDRC = .02GC

Release Rate = .10RP

Reform Rate w/o Rehabilitation = .020RP

" " with " = .070RP

Recidivism Rate w/o Rehabilitation = .080RP

" " with " = .030RP

Robbers arrested per RED = .001

III. Auxiliary Equations

$$\text{(Police Costs) RED} = \frac{\text{DROL} - \text{ROL}\cdot\text{J}}{\text{AT}} \times \text{ (-K Dollars)}$$

Where K is a constant equal to $4,000 where the police solution does not apply and $10,000 where the police solution does apply.

IV. Level Equations

ROL·K = ROL·J + DT (RI·JK + R4·JK + R7·JK - R6·JK)

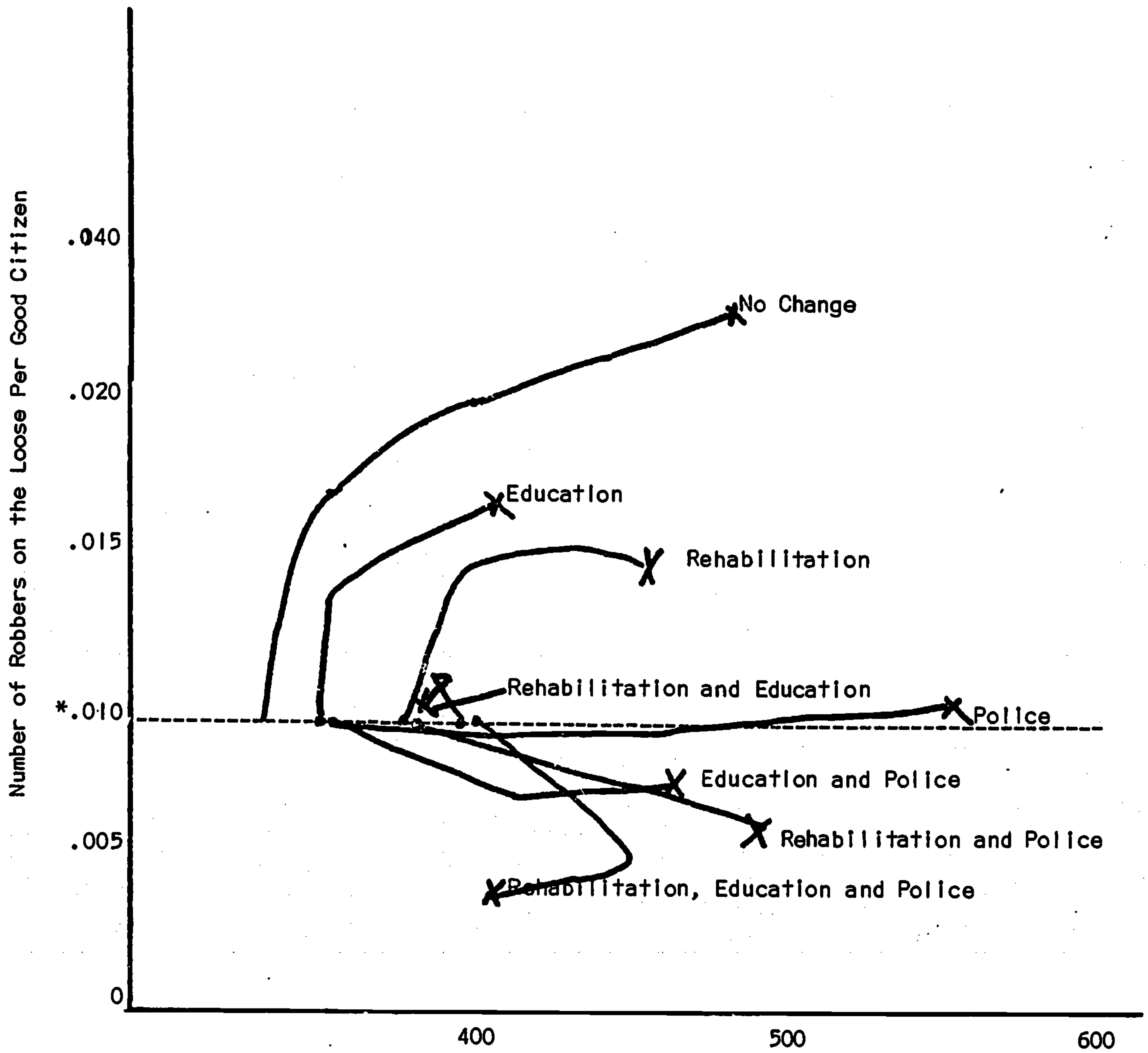
GC·K = GC·J + DT (R2·JK + R3·JK + R8·JK - R5·JK - R7·JK)

RP·K = RP·J + DT (R6·JK - R8·JK - R9·JK)

V. Rate Equations

$$\text{Arrest Rate (AR}\cdot\text{KL)} = \frac{\text{\# RED's}}{\text{year}} = \frac{\text{\# robbers arrested}}{\text{RED}}$$

where # robbers arrested per RED is a constant equal to .001



Number of Dollars Spent on Robbers on the Loose Per Good Citizen

*.010 is the initial level of humber of robbers on the loose per good citizen; goal is no robbers on the loose.

FIGURE ix: Time plot of the ratio of ROL's per good citizen to the cost of ROL's per good citizen at five points in future time under 8 different simulation conditions.