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ABSTRACT

This demonstration of the use of a computer simulation research method based on the System Dynamics modeling technique for studying distance education reviews research methods in distance education, including the broad categories of conceptual and case studies, and presents a rationale for the application of systems research in this area. The technique of model development using the System Dynamics approach and the DYNAMO simulation language is then described, and six steps for model development are outlined and applied to the development of a prototype model: (1) identifying a problem and conceptualizing a system model representing the problem; (2) developing a causal-loop diagram of system functions; (3) developing a flow diagram based on the causal-loop diagram; (4) developing a set of DYNAMO equations representing the model; (5) running and testing the model; and (6) evaluating policy options in relation to the problem and in light of the results of the simulation. Discussions of the limitations of the simulation exercise and the development of a more complex and realistic model conclude the paper. Diagrams are included throughout, and a list of 17 references and a sample DYNAMO program are attached. (MES)

RESEARCH IN DISTANCE EDUCATION; A SYSTEM MODELING APPROACH

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INTRODUCTION

This presentation will demonstrate a computer simulation research method based on System Dynamics modeling technique for studying distance education systems. The presentation will include:

- a brief review of research methods in distance education,
- rationale for systems research in distance education,
- technique of model development using System Dynamics approach and the DYNAMO simulation language.
- display of a computer simulation of a prototype model.
- audience participation in changing critical variables in the prototype model to observe related changes in the model's behavior.

RESEARCH METHODS IN STUDYING DISTANCE EDUCATION SYSTEMS[1]

Published research in the field of distance education covers two broad categories of conceptual studies and case studies:

Conceptual studies- Literature related to concepts of distance education have served at least three purposes. They have:

- offered definitions for the field,
- provided conceptual models for various systems and,
- presented current and future trends in the field.

For example, Keegan (1980), analyzed several definitions of distance education suggested by experts in the field, and discussed their conceptual, organizational and social ramifications. Furthermore, Keegan (1980) and Holmberg (1981) have delineated the purpose of distance education as follows:

- to eliminate time and distance constraints in the delivery and utilization of educational services,
- to provide educational services to those unable to participate in conventional learning, and
- to provide continuing education to adults who wish to acquire new skills and knowledge.

Pery (1977) provided a detailed account of the British Open University (BU). Besides its own merits Pery's work is significant in that BU has been emulated in several parts of the world as a viable model for developing new distance education organizations. Zigrell (1984) reviewed distance education systems in the United States and presented a

1 Distance education is a relatively new term for a field that has encompassed educational broadcasting, as well as non-electronic means of disseminating educational information. In this presentation, the term distance education includes electronic as well as non-electronic means of reaching learners in diverse geographic locations.

pragmatic approach to the field that is based on student needs, available delivery systems and economic realities.

Case studies- In studying distance education systems researchers have relied heavily on the case study method of inquiry. In such studies either the entire structure of a distance education system has been analyzed, or a particular function is selected for analysis. In most case studies at least one or all of the following functions within a structure are analyzed:

- Social context and the governance of the system,
- Administration and organization,
- Modes of communication,
- Instructional (curriculum) development,
- Production, distribution and utilization,
- Attitudes towards the system and
- Learners and learning outcomes.

For example, Mayo and Hornik (1976) provided a comprehensive study of the educational television system in El Salvador. Schramm, Nelson and Betham (1981) studied the educational television system in American Samoa. Concentrating on higher education's use of distance education, Harry and Rumble (1982) edited an anthology in which case studies on several countries were presented. These included the U.S.S.R., the United Kingdom, the United States, and the People's Republic of China.

In case studies that are concerned with a distance education system in its entirety, as well as those studies that are only concerned with a specific function within a system, different methods of inquiry have been employed to learn about each function. For example:

- descriptive analysis is used to show how distance education systems are organized and governed.
- cost-benefit analysis is used to study financing and budgeting of systems,
- course evaluation methods are used to study curriculum effectiveness,
- survey methods are used to study utilization patterns and user attitudes towards the system,
- experimental research methods are used to study learners and to measure learning outcomes.

RATIONALE FOR SYSTEM RESEARCH IN DISTANCE EDUCATION

The research methods outlined above, while provide information about each functions of a distance education system, do not shed any light on the relationships among these functions. For example, descriptive studies show different organization structures and governance practices, and experimental studies show how well learners learn through distant means. But neither of these methods, nor other methods mentioned above provide any information about the relationship between how a system is organized and governed and how well learners learn. System research provides four critical types of information that may not be readily attainable through the use of other research methods. They are:

- how one part of the system affects the other parts and is affected by the other parts.

- how each part as well as all parts, collectively, help or hinder the system to achieve its goals.
- how the system interacts with its social context (environment.)
- what alternative policies r ..ve the system toward its goals in the future.

For example, systems research can produce information on how the governance and financing of a system may affect instructional development, production, dissemination and learning outcomes within a system. Or how increased or decreased learning outcomes may affect financial and political support for the system (through its governance function) that in turn affects all the other parts of the system.

Furthermore, system research can provide information on how each system is affected by changes in its environment: How social change, political change or economic development as a whole may affect the behavior and the life of a distance education system. Using system analysis one can delve into questions such as how distance education systems could be affected by:

- demographics of a society (aging of a population, change in ethnic composition of a society, etc.) and/or;
- political mood of a society (rise in conservatism, isolationist attitudes etc.) and/or;
- economic developments (increase in high-tech manufacturing, fluctuating cost of transportation , etc.)

In addition, systems research and particularly System Dynamics assist evaluators, managers and personnel of an organization to:

- explicate their assumptions and perceptions about goals objectives, policies and.future plans
- articulate their assumptions, and perceptions in precise terms.
- share their assumptions, and perceptions with colleagues in public.
- modify their assumptions and perception to reach organizational goals more effectively, and efficiently.

Distance education as a system- In recent years, social scientists have used the concept of general systems theory and related modeling methods for understanding complex social phenomena and for designing new organizations (Ackoff and Emery 1972, Forrester, 1972, Churchman 1979, Roberts, et. al., 1983, Wilson 1984). In the field of distance education systems research has been minimal. Saba and Root (1976) used System Dynamics methods to design and simulate a distance education system in the Middle East. Vazques-Abad and Mitchell (1983) used system modeling concepts to develop an economic evaluation model for distance education projects.

Realizing the paucity of system research in educational technology in general Heinich (1984) called for an increased use of systems analysis techniques for learning about education and for designing new organizations for educational purposes. If applied to distance education, system analysis could assist educators to:

- understand the comprehensive structure of distance education;
- identify critical functions of distance education;
- predict and control the intertwined relationships among the functions of a distance education system;

- determine the optimal performance of a distance education system for serving its clients (learners, parents, etc.);
- determine the impact of environmental changes on a distance education system and the impact of the system's performance on its environment.
- design more effective and efficient distance education systems.

SYSTEM DYNAMICS

Description and applications- System Dynamics is a technique for translating intuitive models into causal-loop diagrams in which the effect of one system function on other affected functions are clearly depicted through positive or negative feedback loops. Based on such feedback loops or causal-loops, flow diagrams are developed in which each system function is shown in terms of a level or a rate of performance. The technique provides for translating the flow diagram into a set of more formal mathematical equations in DYNAMO: a simulation language.

System Dynamics allow objective observation of each system function in terms of its present level of performance and the rate in which this level is decreased or increased through time. DYNAMO is capable of plotting the performance of each system function and the performance of the system as a whole in specific time intervals in the future. Objective observation of system functions is not limited to collection of statistical data on rates or, levels of system variables. The strength of this technique is that it allows for inclusion of underlying assumptions about how system functions behave, or how they should behave. These assumptions that are made by the personnel in charge of system functions, are not overlooked, and are included as key elements in developing system diagrams and writing equations to represent these diagrams.

This method has been used to study a variety of social phenomena, organizations and systems ranging from the future of the world (Forrester 1961) to industrial relations, ecological systems and the growth and decay of cities. (Meadows & Robinson 1985.) If applied to research in education, it is a versatile research method that can provide much needed information on how educational systems are affected by the nature of their own structure and organization as well as their contextual environments.

Technique of model development- Roberts et al (1983) suggests six steps for model development using System Dynamics:

1- Identifying a problem and conceptualizing a system model representing the problem.

2- Developing a casual-loop diagram of system functions.

3- Developing a flow diagram based on the casual-loop diagram.

4- Developing a set of DYNAMO equations representing the model.

5- Running and testing the model.

6- Evaluating policy options in relation to the problem and in light of the results of the simulation.(pp. 8)

The same steps were followed in developing this simulation exercise.

1- The Problem

Hawkridge and Robinson (1982) studied twelve educational broadcasting systems in Africa, Asia, Europe, South America and the United States and observed that distance education systems receive their funding from a variety of sources. They found that some systems are funded by federal, regional or local governments, while others receive their funds from student fees or private donations. All observations, however, showed that financing of the system was a very influencial factor in how the system is managed. These observations led Hawkridge and Robinson to recommend that:

> a) Managers should carry out detailed analyses of sources of financing for educational broadcasting, to avoid neglecting potenti. sources, and
>
> b) In the same way, they should carry out cost analyses based on functions (for example general administration, conception, production, distribution, utilization, evaluation) to enable them to determine the balance of resources allocated to each function and whether this is the correct balance. (pp. 149-150).

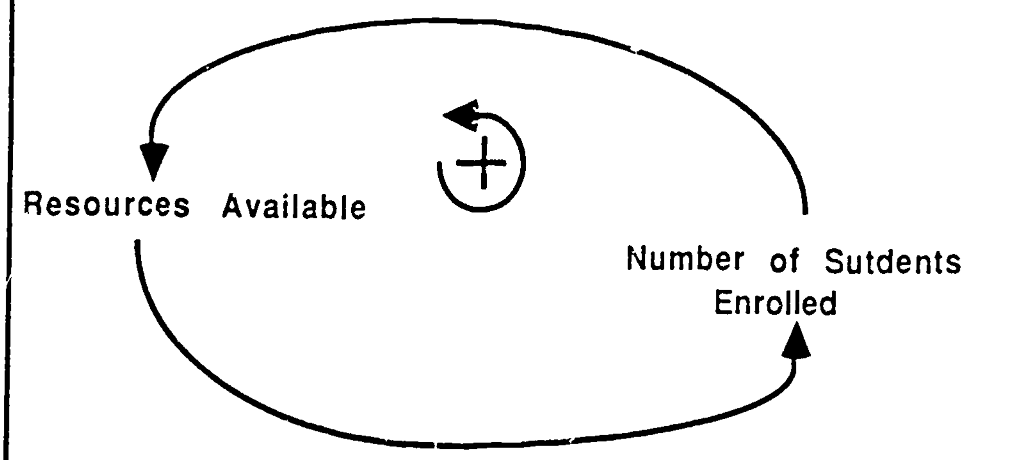
These recommendations provided the framework for formulating two basic questions for the simulation exercise:

a) Does the initial number of students enrolled in a distance education system affect the resources allocated to the system?

b) How do resources available to the system affect the performance of each system function?

2- The Causal Loop Diagram.

To answer these questions, by developing a casual-loop, we assumed a positive feedback loop between the number of students enrolled in a system and the amount of resources made available to the system; that is the more individual **students pay** to take telecourses, the more money available for that system. And the the more resources made available to the system, the greater the number of students that can be served by the system. This assumption defines the purpose of a distance education system: To use its resources to **reach as many members of its intended audience as possible** to enhance their learning. Diagram No. 1 demonstrates this basic relationship.

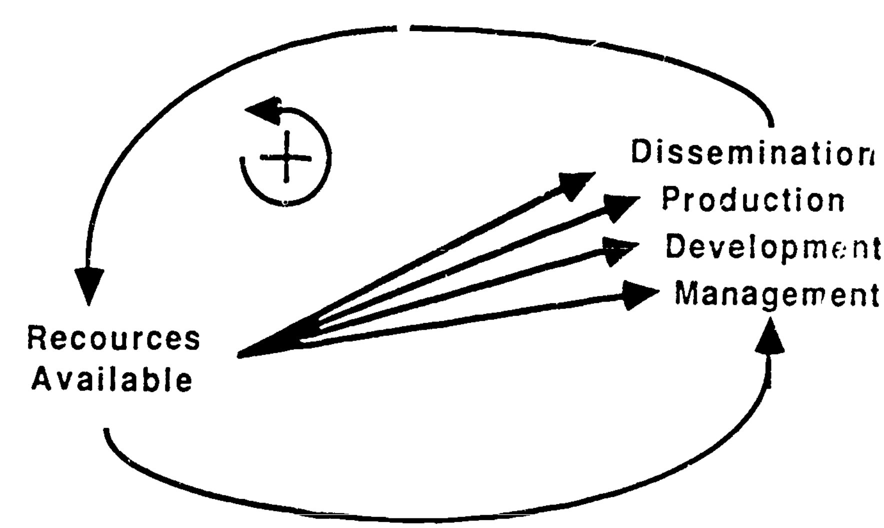


Causal Loop Diagram No.1

The next step in further development of the causal loop diagram was to determine the basic functions of a distance education system, since our second question is how resources available to a system affect the performance of its different functions. The literature survey showed that while, the structure of educational broadcasting systems differ greatly, most systems possess the minimum functions required for fulfilling their purpose. Most organization charts depicted by Hawkridge and Robinson (1982) included the following essential functions:

- management and administration,
- instructional development,
- media production and
- dissemination of instructional information.

The causal loop diagram, therefore, was augmented to show that resources available to a distance education system support its basic functions of organization development, instructional development and production. Instructional programs developed through these functions are made available to the learner by another function which is dissemination. An intuitive assumption was that programs disseminated affect the number of students enrolled, which in turn affect the level of resources available to the system.



Causal Loop Diagram No. 2

Simplicity was a basic criteria in developing the system model at this stage, therefore, several intervening functions were left out of the diagram. For example, resources made available to a system may be affected by other elements in addition to the number of students enrolled. The wish of a community to support a distance education system, regardless of the number of students enrolled, may be instrumental in increasing or decreasing the rate of resources allocated to a distance education system. It is also reasonable to assume that the number of students enrolled may be affected by instructional support services. That is, the more instructional support services offered to students, the higher the number of students who would be willing to receive educational services from a distance education system. These examples contain crucial environmental variables in distance education projects. These functions are extremely important and should be included in more complex models.

3- The Flow Diagram.

A flow diagram was developed based on the causal-loop diagrams to further explicate and formalize the assumptions for model development. A prose description of the flow diagram follows:

The *level* of available resources to a distance education system at the present time (RESAV .K) is assumed to be affected by a steady *rate* of monetary allocations (RESAL) from *funds* that is dependent upon the number of students enrolled. The *rate* of expenditure (RESSPT) is increased or decreased by four functions or *auxiliaries* : organization development (ORGD), instructional development (DEV) and production (PROD). It is assumed that these auxiliaries control the rate of a fourth auxiliary which is dissemination (DISS). Dissemination in turn controls the rate of enrollments (ENROLL) and the rate of enrollments affect the level of student population at the present time (STPOP .K). In addition, this level is affected by another rate which reflect the students who graduate or drop out of the system. Student population at the present time influence an auxiliary or *funds* which in turn controls the rate of resources allocated to the system.

4- Equations for the Model.

The following equations were developed to represent a mathematical formulation of the flow diagram:

Insert the equations about here.

The following is a prose description of the model to make the model assumptions more clear:

Dynamo Distance Education Simulation Description of Terms

RESAV	This represents the level of money available for use in meeting working expences. (Resources available)
RESAL	This represents the rate of funding to the whole distance education process. (Resources allocated)
RESSPT	This is the rate of expenditures. (Resources spent)

T=48	Three years or 48 months is the time allocated to the simulation. This is an arbitrary figure, yet a resonable time to determine wheather or not a projection is reflecting reality.
PROD	The production costs: printing, footage, talent and other working, production expences.
PRODIN=0.1	This is the percentage of resources available used for production during each time frame (1 month).
DEV	The development costs: research and instructional development.
DEVIN=0.05	This is the percentage of resources available used for development during each time frame (1 month).
ORGD	This represents the organizations management budget: salarys, office expences, administration expences ect.
ORGDIN=0.05	This is the percentage of resources available used for management and administration during each time frame (1 month).
ACBUDJ	This is the total accumulated budgets: Production,Development and Organization Management.
DISS	This is the cost of disseminating instruction: equipment, power, maintenance, etc.. (The total dissemination is dependent upon the accumulated budgets.)
DISSIN=0.2	The percentage of resources available used for the dissemination of an instructional product.
STUPOP	This represents the level of student population or the number of students currently receiving services (instruction) from the system.
ENROLL	This is the rate of enrollment. The rate at which students begin to use instructional services.
ENROFR	This is the enrollment fraction table showing theprojected effect of enrollment Table figures are based on estimated expenditures.
TENROL	This is the enrollment fraction based upon tabular data.
FROTOP	This represents the fraction of the total population that are students receiving instruction.
TOTPOP= 500	A total population amount.
GRDROP	This is the rate at which students exit the student population and are not receiving instruction.
STUPOP=25.00	This is the inital number of students in the studentpopulation This is a seed number and will be manipulated by the calculations in the porgram.
FUNDS	The level of funds going into the resources available. Funding is dependent upon the student population.
DOLPER=10	The cost of instruction per/student. (dollar/per/student) .

5- Running the Model.

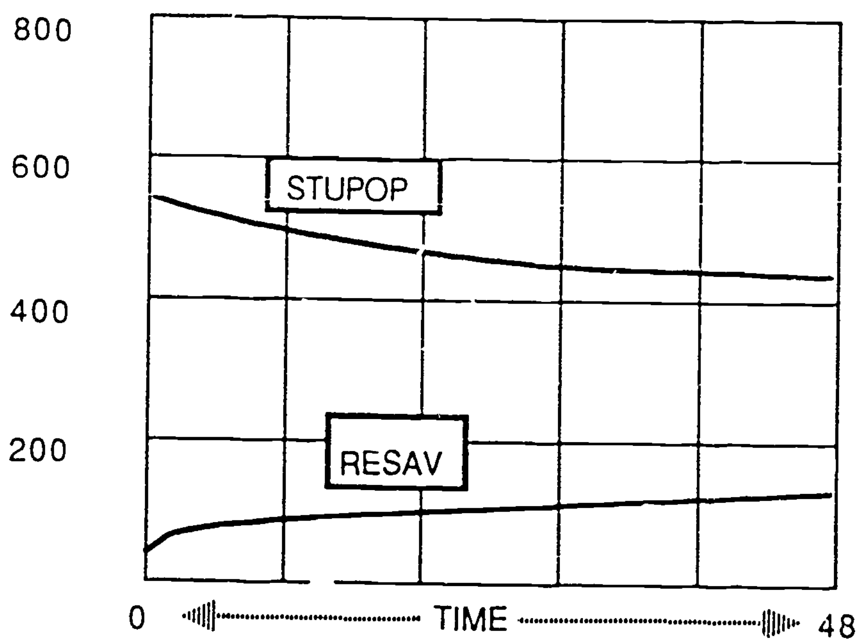
Several runs were made to test the equations and debug the formulas. Then the model was run under two different initial enrollment levels. The first run of the model represents a student population of 75 out of a total potential student population of 500 (or 15%). Under this condition in a 48 month period the following changes in the behavior of the model were observed:

• the level of resources available to the system declined and continued to decrease. while the level of student population increased moderately (slightly surpassing 100) and then started to level off. (See Plot No. 1.1.)

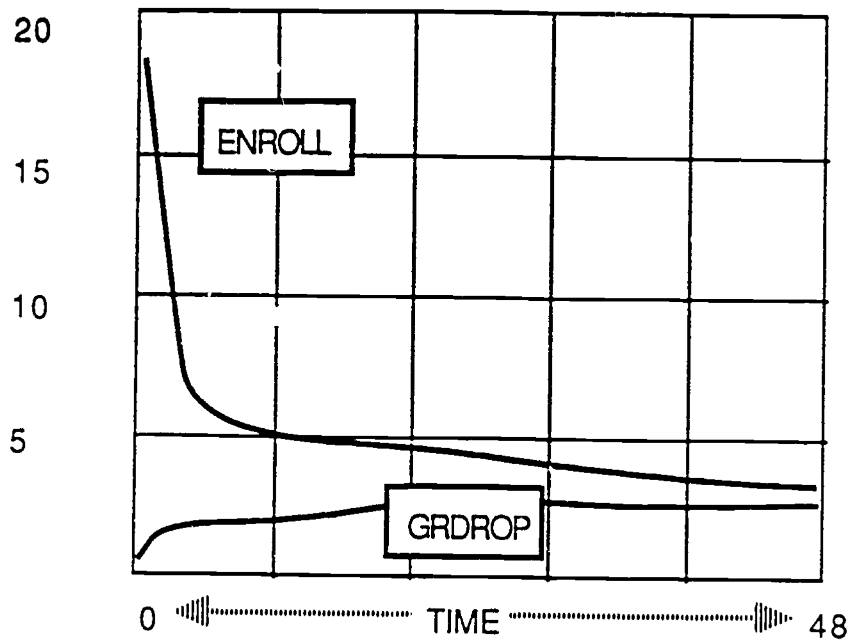
• there was a dramatic decline in the rate of enrollments in the first six months of the operation. The decline was not as dramatic after this period. but it did continue to do so. The rate of graduation slowly increased in the first year and then it slowed down to approach the same value as the rate of enrollments. (See Plot No. 1.2.)

• the functions also declined throughout the time of the simulation. The most dramatic was the rate of production which showed a steady decline throughout the 48 months. All other functions. instructional development. organization development and dissemination also declined toward zero.(See Plot No. 1.4.)

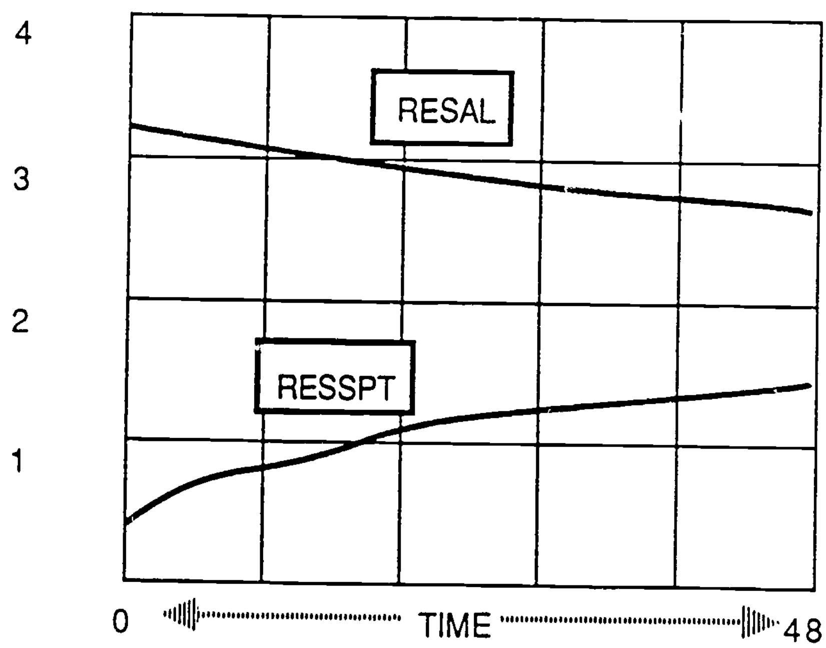
PLOT NO 1.1

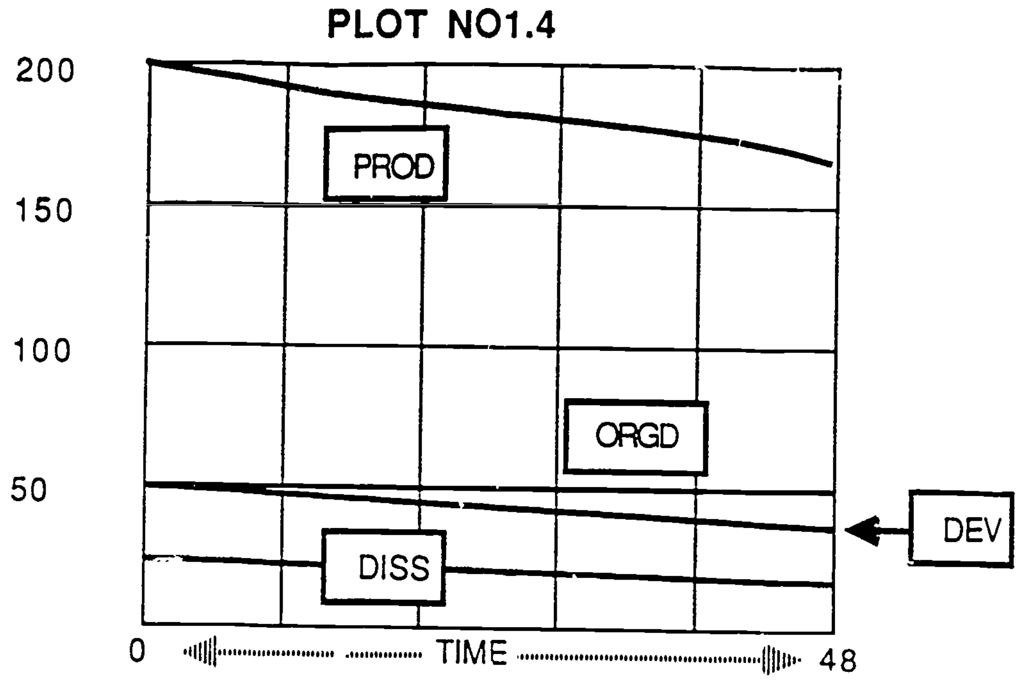


PLOT NO 1.2



PLOT NO 1.3





For the second run of the model the initial student population was changed to 100 to represent 20% of the total population. Under this condition it was observed that:

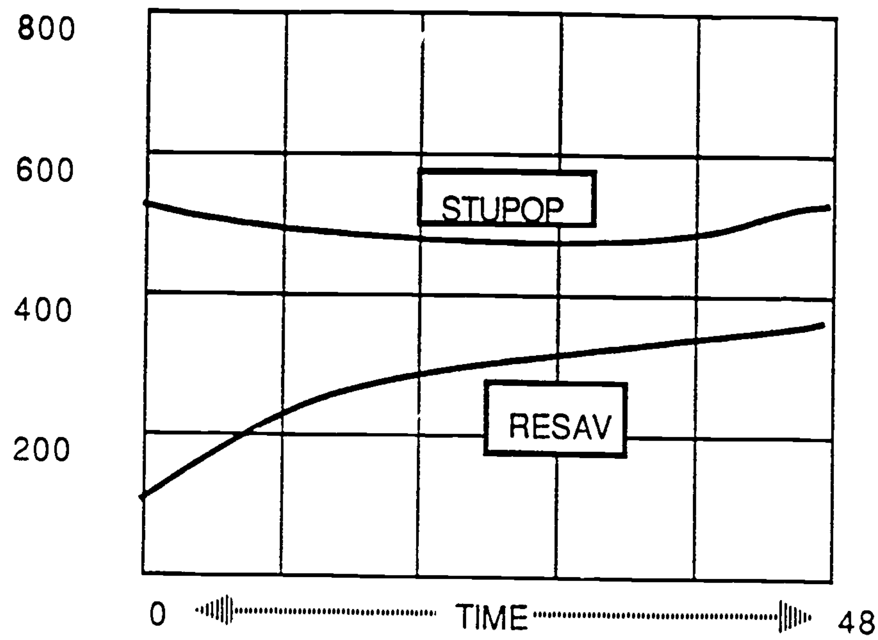
• the level of available resources declined slightly in the first few months, but then it went back to its initial value and stayed there for the rest of the time. The level of student population, however, showed a dramatic increase to almost include the total population near the 48th month. (See Plot No. 2.1.)

• the rate of enrollments showed a decline during the first two years of the operation, while the rate of graduation increased during this time. As it could be expected, both rates showed a tendency to approach the same value in the future. (See Plot No. 2.2.)

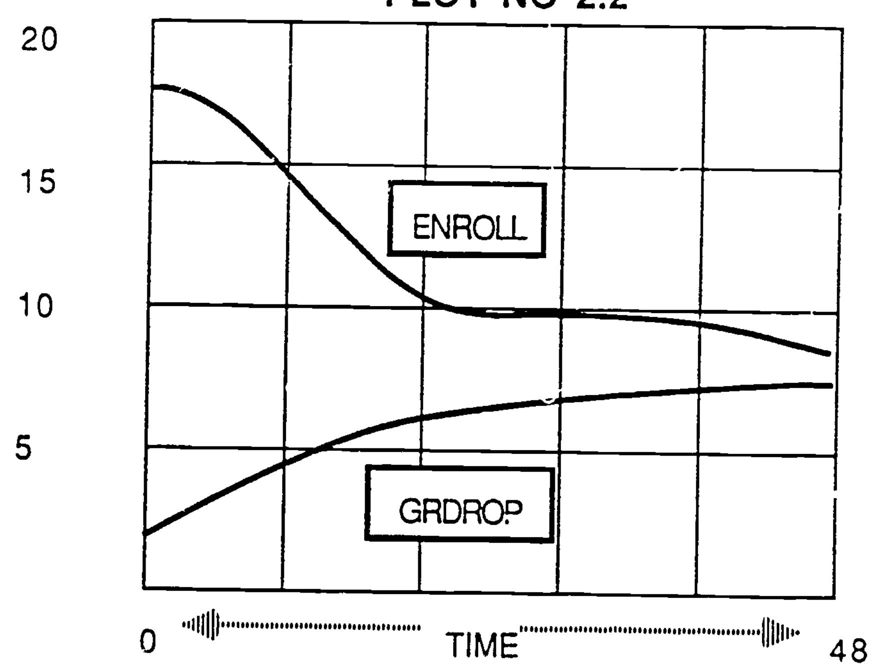
• the rate of resources allocated decreased slightly in the first half of the simulation, but then the rate went back to its initial value, and remained there. Whereas, the rate of expenditure showed a dramatic increase during the first 18 months, and although it began to slow down, it still remained at an impressive value. (See Plot No. 2.3.)

• the rate of functions experienced healthy values in this run. Production declined slightly during the first half of the simulation time, then it increased to regain its initial value. Instructional development, organizational development, and dissemination, however, kept the same rate of performance during the entire time. (See Plot No. 2.4.)

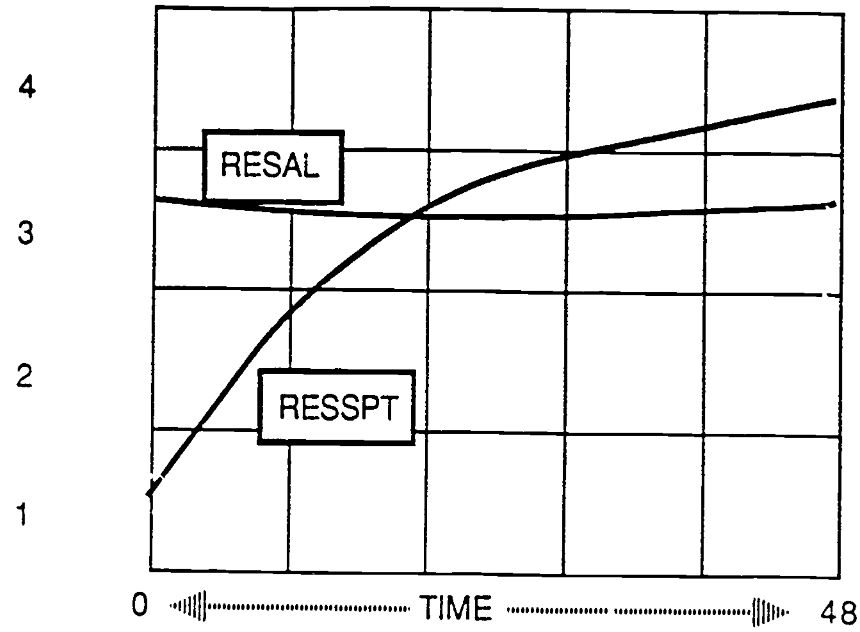
PLOT NO 2.1



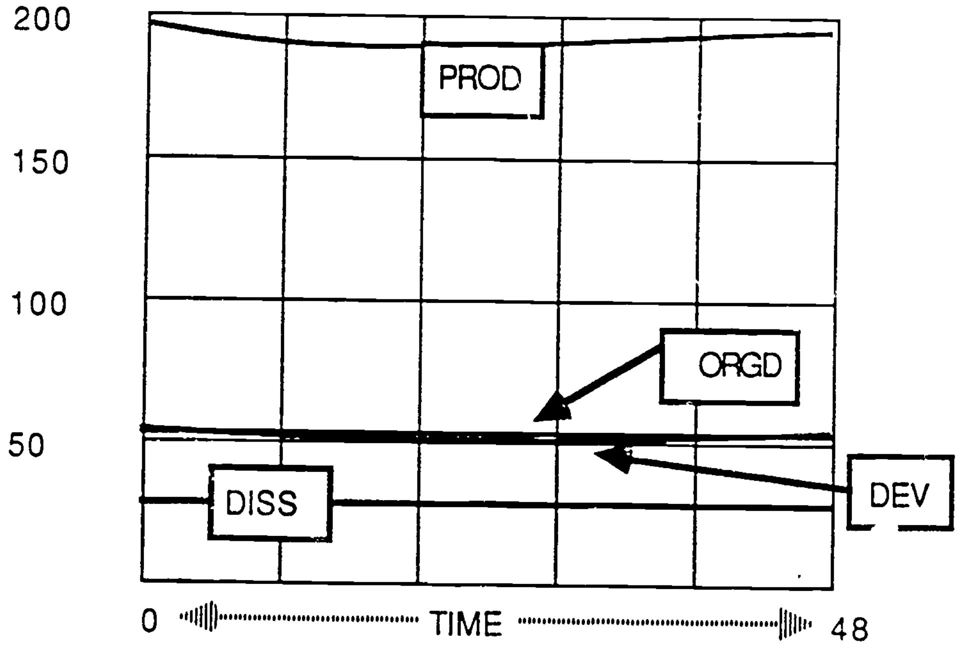
PLOT NO 2.2



PLOT NO 2.3



PLOT NO 2.4



DISCUSSION

The two initial values in student enrollment had different impacts on the resources made available to the system as well as on the behavior of its four functions. Starting with a student population of 75, or 15% of the total population and an initial available resource of $500 (where cost per student is $10), resources available to the system declined to almost $400 in 48 months. Whereas, with an initial student population of 100, resources available declined slightly to $475, but went back to its original value at the 48th month.

In the first scenario all four functions declined during the 48 months. As the system grew older the rate of resources allocated to organization development, instructional development, production, and dissemination sloped downward. Student population increased during the first few months of the simulation but , did not go beyond 100 students or 20% of the total population. In contrast, with the initial student population of 100 all four functions showed a steady rate of performance. Their rate neither increased nor decreased, except for a slight decrease in production; only for it to regain its initial value later on. Enrollments, however, did increase to include 400 students or 80% of the total population.

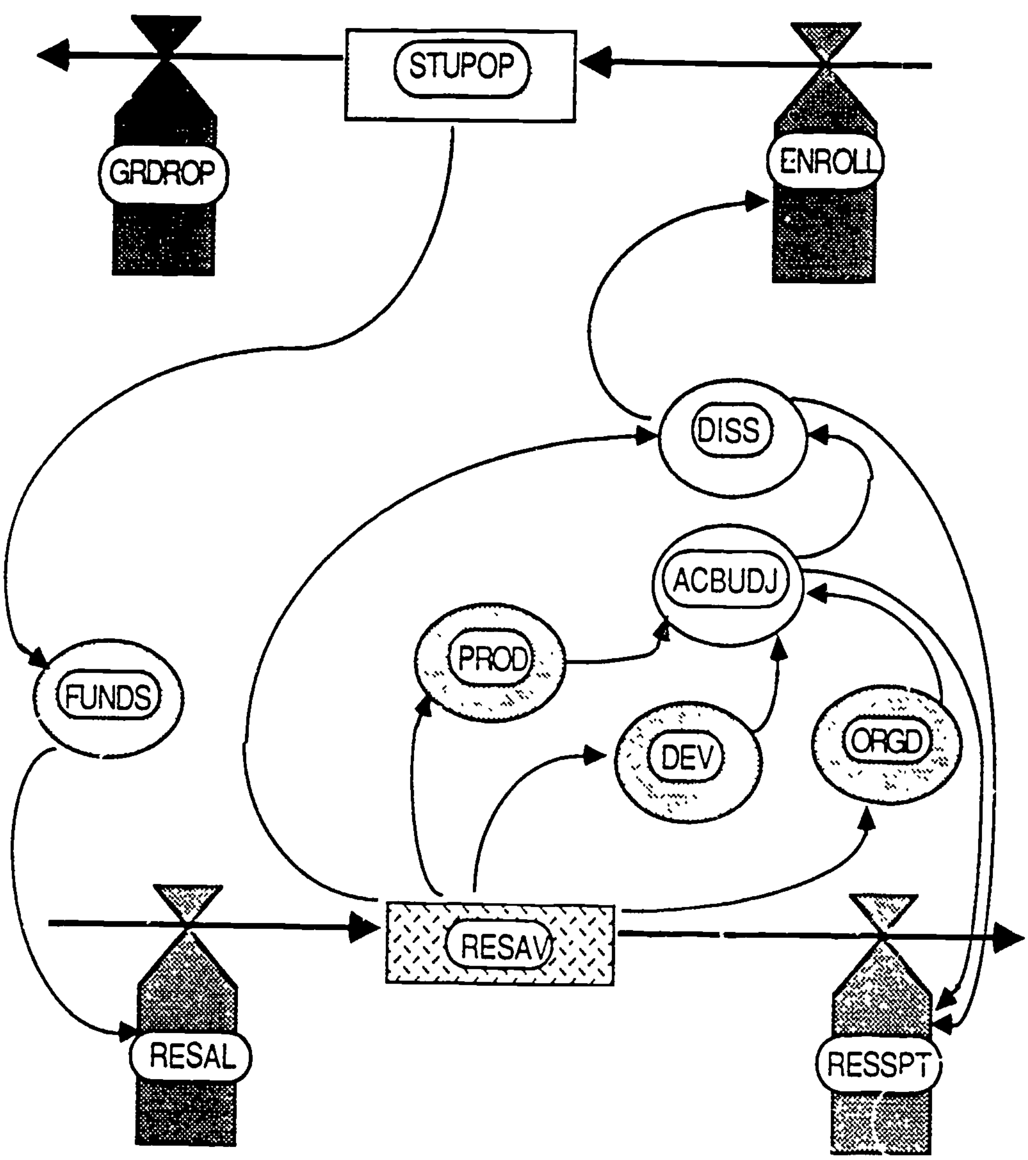
In this exercise, the second scenario showed a viable distance education system, which would be expected to function at least for four years, with healthy enrollment levels (80%) and rates of performance in its organization development, instructional development, production and dissemination functions. Whereas, the first scenario showed a system that would experience low levels of student enrollments (20%) and declining rates in all of its four functions. It is more likely for a system operating under the second scenario to grow and prosper, but less likely for a system to continue a healthy life under the assumptions of the first scenario. The behavior of the system under the first set of assumptions provide reasons for its managers to intervene and attempt to change one, or a few of the key factors to make it a more viable operation. The scenario under the second set of assumptions provide information about the kind and the degree of changes that would be necessary to make a system more viable.

CONCLUSION

The objective of this simulation exercise was limited to the demonstration of System Dynamics as a tool for research and organization development. It was specifically limited in scope in two respects: 1) It did not represent a real referent in so far as its assumptions were not based on observation of an operating distance education system. 2) The model neither included the influence of environmental elements on the "internal" functions of the system, nor was it concerned with the impact of the system on its environment. Many elements such as the will of the community, the effects of a support sub-system on enrollments etc., were left out at this stage.

To develop and simulate a more realistic model, assumptions reflected in the model should represent factual information from an operating distance education system. Such factual information should not be limited to statistics on expenditures, enrollments etc., but should reflect the assumptions of the key personnel in charge of functions, budgeting and planning. A main purpose for using System Dynamics is to make assumptions and perceptions of the people concerned about a system precise and public, so that they may be criticized and improved in the future.

In addition, a more complex model should be developed to reflect environmental factors, such as public expenditure on education, community policies, needs of employers, geographical factors, etc. A more complex model will help to enhance our understanding of the role of distance education in its societal context.



System Dynamics Flow Diagram for Simulating a Distance Education System

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*       DISTANCE _DUCATION SYSTEM ' 'DEL
NOTE        REVISION 11/26/86
NOTE
NOTE
NOTE          RESOURCE SECTOR
NOTE
L       RESAV.K=RESAV.J+(DT)(RESAL.JK-RESSPT.JK)
N       RESAV=500.00
NOTE          INITIAL RESOURCES
NOTE
R       RESAL.KL=FUNDS.K/T
NOTE          ALLOCATIONS DEPEND UPON FUNDINGS
NOTE             WHICH DEPENDS UPON STUDENT POPULATION
NOTE
R       RESSPT.KL=(ACBUDJ.K+DISS.K)*0.5/T
NOTE          EXPENDITURES DEPEND UPON ACCUMULATED BUDJETS
NOTE
NOTE
NOTE            REMEMBER T= TOTAL TIME OR 36 MONTHS
C       T=48
NOTE
NOTE            PRODUCTION BUDGET
NOTE
A       PROD.K=RESAV.K*PRODIN
C       PRODIN=0.1
NOTE
NOTE            DEVELOPMENT BUDGET
NOTE
A       DEV.K=RESAV.K*DEVIN
C       DEVIN=0.05
NOTE
NOTE            ORGANIZATION MANAGEMENT BUDGET
NOTE
A       ORGD.K=RESAV.K*ORGDIN
C       ORGDIN=0.05
NOTE
NOTE
NOTE            TOTAL ACCUMULATED BUDJETS
NOTE
A       ACBUDJ.K=PROD.K+DEV.K+ORGD.K
NOTE
NOTE
NOTE            INSTRUCTIONAL DEVELOPME   SYSTEM MODEL
NOTE
NOTE            DISSEMINATION SECTOR
NOTE
A       DISS.K=ACBUDJ.K+RESAV.K*DISSIN
C       DISSIN=0.2
NOTE
NOTE            TOTAL DISSEMINATION DEPENDS UPON ACCUMULATED BUDJETS
NOTE
NOTE            STUDENT POPULATION LEVEL
NOTE
L       STUPOP.K=STUPOP.J+(DT)(ENROLL.JK-GRDROP.JK)
NOTE
R       ENROLL.KL=DISS.K*ENROFR.K
```

```
NOTE         RATE OF ENROLLMENT DEPENDS UPON EXPENDITURES
NOTE
NOTE
A       ENROFR.K=TABLE(TENROL,FROTOP.K,0,1,0.1)
NOTE
NOTE         ENROLLMENT FRACTION BASED UPON TABULAR DATA
NOTE
T       TENROL=0.10/0.10/0.09/0.09/0.08/0.07/0.05/0.05/0.04/0.03/0.02
NOTE
NOTE         ENROLLMENT TABLE
NOTE
A       FROTOP.K=STUPOP.K/TOTPOP
NOTE
NOTE         FRACTION OF TOTAL POPULATION WHO ARE STUDENTS
NOTE
C       TOTPOP=500
NOTE         TOTAL INITIAL POPULATION
NOTE
NOTE
R       GRDROP.KL=STUPOP.K/T
NOTE         RATE OF MATRICULATION
NOTE
N       STUPOP=25.00
NOTE         INITIAL STUDENT POPULATION

NOTE         FUNDING
NOTE
NOTE          FUNDING IS DEPENDENT ON STUDENT POPULATION     +STUPOP=+FUND

A       FUNDS.K=STUPOP.K*.05*DOLPER
C       DOLPER=10
NOTE          DOLLARS PER STUDENT
NOTE          FUNDS THEN FEED BACK INTO RESOURCE ALLOCATION RATE
NOTE
NOTE
NOTE

PLOT    RESAV=R,STUPOP=S
SPEC    DT=1/PLTPER=1/LENGTH=48
PLOT    ENROLL=E,GRDROP=M
PLOT    RESAL=L,RESSPT=R
PLOT    PROD=X,DEV=D,ORGD=O,DISS=S
RUN
```