A system dynamics model of the relationship between the distribution of a universitys funds and its enrollment patterns
by Mark Andrew Hinrichs

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE i n Industrial and Management Engineering
Montana State University

Abstract:
The well-documented coming decline in the number of college age youth has profound implications for the future of higher education. Barring fundamental changes in the nature of higher educations university administrators face the prospect of having to deal with the unpleasant reality of an imbalance in the demand for education and the extant capacity to supply education. The complex nature of the inter-related processes, however, makes intuitive human assessments of the effects of policy decisions of questionable accuracy.

This situation implies the need for a facility whereby higher education managers can project and contrast the effects of a range of alternate policies. Of particular interest is the relationship between the distribution of today's funds upon tomorrow's enrollments.

The techniques of System Dynamics were applied to this problem. The system of budgeting which molds the university’s degree program offerings, which Iin turn influences the overall enrollment profile of the university was studied in depth. A computer simulation model using the DYNAMO simulation language was built to represent this system. Imbedded in the model were demographic data descriptive of the conditions in the state of Montana and other data specific to conditions and procedures found at Montana State University.

In the limited sense, this thesis project demonstrates the effectivity of the application, of the principles, of System Dynamics to the relationship between the distribution of funds in a university and the resulting enrollment profile the university eventually experiences. More importantly, it. illustrates the use of an approach to the solution of large-scale problems which has' tremendous potential for improving the manner in which we deal with the wealth of such problems this society currently faces.

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Date 22 MAY 1981

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Approved:

D. A. Dyreson
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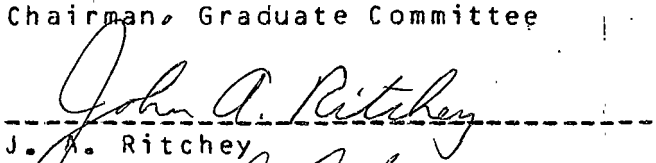

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ABSTRACT

The well-documented coming decline in the number of college age youth has profound implications for the future of higher education. Barring fundamental changes in the nature of higher education, university administrators face the prospect of having to deal with the unpleasant reality of an imbalance in the demand for education and the extant capacity to supply education. The complex nature of the inter-related processes, however, makes intuitive human assessments of the effects of policy decisions of questionable accuracy.

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Chapter 1

INTRODUCTION

Perhaps the most serious problem facing higher education in the remainder of the twentieth century is neither what to teach nor how to teach it but, more importantly, to whom it shall be taught. The phenomenon of dramatically declining enrollments has already beset our nation's primary and secondary school systems, with predictably unpalatable effects: numerous closings of facilities; curtailments of programs in traditional as well as special areas; decline in employment prospects for educators at all levels; a pervasive drop in student and faculty morale; the diminishment of educational achievement. Clearly, we in higher education are about to enter a period of austerity. Some would say it is already upon us. It is the intent of this thesis to present higher education management with a policy-shaping tool, a tool which may help to ameliorate some of the effects of the impending austerity by indicating which curriculum emphasis/de-emphasis policies will most likely lead to the types of enrollment patterns desired.

The roots of the problem of declining enrollments are not as simple as might initially be thought. Indeed, before the topic of declining enrollments may be properly examined, an

answer to the question "Declining from what?" must be sought. Many would argue that we have been living in a period of untenable per capita enrollments. For most institutions of higher learning, the mid-1950's to late 1960's was a period of explosive growth in demand for their services. The post-war "Baby Boom", was supplying them with unprecedented numbers of potential 'customers'. The reaction of the nation's leaders to the temporary Soviet dominance in the Aero-space arena was to make universal high educational achievement a national goal. Funding for instructional and research needs was, by comparison with today's situation, virtually limitless. The state of the nation's economy was also such that expansion of facilities and programs to meet the increased demand was well within the reach of administrations nation-wide. Consequently, record proportions of record populations availed themselves of the opportunity to pursue a more complete education.

This trend, however, started to decline in the late-1960's. The effect of the baby boom had peaked and started, slowly, to decline. From 1960 to 1970, the number of 5-year-olds, the prime traditional market for higher education in the late-seventies and eighties, declined by fifteen percent. Indications are that that declination may reach forty percent.(25) The economy was not in quite the vigorous

expansion-driven state it had earlier enjoyed. The national schism over foreign policy, especially that with regard to Southeast Asia, had not yet reached sufficient balance in forces to legitimize the objections of the minority. Thus, many universities found funds harder to obtain as the governing conservative majority 'punished' them for their students' dissension. Further, the disenchantment with traditional societal values began to erode the perception of the need for and value of educational attainment. As the sixties gave way to the seventies, this particular trend became pronounced. The national labor force was rife with examples of the ills of education-for-its-own- sake: people with advanced degrees for which there was simply no demand. While it is difficult to conceive of education as being without value, it is an economic fact of life that, unless an investment of time and money, such as education requires, can be shown to possess at least the potential of showing a desirable return, it must be regarded as a luxury. In times of economic austerity, luxuries tend to lose their appeal.

One approach to the problem of declining markets is to uniformly diminish capacity to provide services. Unfortunately, this approach would tend to ignore any inherent differential in demand for one variety of service over another. The diminishment of a capacity for which demand has

not diminished will injure the institution in both the short-term, in terms of lost enrollees turned away due to inability to serve them, and the long term, as the public perception of that service's decline influences future potential enrollees to seek education elsewhere. Clearly, this approach is undesirable.

Another means of solving the problem of reduced funding which will accompany a reduction in enrollments is to focus the energies of the institution, emphasizing one program at the inevitable expense of another. Inherent in this approach, however, are a number of problems. If the overall goal of the university is to maximize enrollments in the short term, fluctuating patterns of enrollment might result with concomitant fluctuations in staffing levels. Most administrators would view this situation as undesirable. Clearly, what is needed is a means of projecting the short and long term effects upon the institution of a variety of fund-distribution scenarios.

The problem of making projections about a system of this nature is that, as it is a feed-back system, its behavior is counter-intuitive. That is, the system will react to perturbations in its parameters in ways which are difficult for human intuition to predict. Jay W. Forrester, in developing the now-famous Club of Rome sponsored World Models,

solved this very problem of dealing with the dynamics of complex systems. His solution, which includes an analysis tool, the system dynamics approach, and a synthesis tool, the universal language for systems modeling, is applicable to any sufficiently large and complex system of inter-related processes. It is the contention of this thesis that the system of funding which influences future enrollments which determine future funding is such a system. It is the intent of the author to build a model of this system which will then be useful in evaluating the long and short term effects of alternative policies for conformance with management's goals.

Chapter 2

REVIEW OF FORMATIVE LITERATURE

THE PROBLEM OF DECLINING ENROLLMENTS

The premise that higher education in America is in for some lean years has apparently been ceded by those informed in the matter. Earl Chiet, Dean of the School of Business, University of California, noted as early as 1971 that many institutions were experiencing a declining rate of growth in income.(3) Some had even seen a decline in real income by that time. The academic community's perception of the potential for serious higher education management problems in the 1980's began to grow in the mid 1970's. In 1980 Robert Zemsky noted the "dismal" demographic outlook for many colleges and universities.(25:10) The question of how to cope with the impending crunch was answered primarily in two ways. The first solution was to reduce capacity to serve in direct proportion to reduction in demand. Predictably, this solution was not generally well received. Another approach was formulated by the American Council on Education(5:11), which published a twelve-point plan aimed at stanching the erosion of enrollments in the coming decades. In general, the Council's recommendations take the form "Increase(decrease)

the rate at which this group enters (leaves) the higher education marketplace by that small fraction." In essence, the approach stresses setting ambitious but attainable goals. Implicit in these suggestions is a much more sophisticated recruitment/marketing effort. Conspicuous in its absence from the Council's plan, however, is any mention of determining what educational services/curricula are needed. Marketing without market research is generally ill-advised.

MODELING IN EDUCATION MANAGEMENT

According to a 1977 report by the Educational Resources Information Center(16), the use of qantitative methods in education management became widespread during the late 1960's to mid 1970's. This change in methodology evidently was hastened by the inability of universities to deal with competition for critical resources in the face of declining public perception of the value of and return from investments in higher education.

Initial applications of modeling theory to decision-making in the higher education arena were fairly limited in scope. The majority of models developed focused on either of two separate topics of concern to management, namely the projection of enrollments or the budgeting of funds. In either case, early attempts at modeling were predictably primitive.

Enrollment models were typified by the trend projection and population participation methods. The former seeks to estimate future enrollment by projecting historical enrollment trends into the future without regard to demographic changes or shifts in societal influences. While this approach is probably not grossly inaccurate in the short (2 to 5 year) term, it is prone to error in the mid to long term. An enhancement of this approach was the population participation method which introduced consideration of shifts in the trend line due strictly to regional demographic considerations. While this presents a notable improvement in accuracy, it still ignores the impact of any changes in societal perception of educational needs.

A later improvement expanded the population participation method by projecting trends in individual departments and sub-units of the university. In a study conducted at Kansas State University, Orwig, Jones and Lenning(19) applied known departmental proportions to the results of an existing institution-wide model. This provided sub-unit administrators with data they needed to prepare informed plans for managing their departments in the short term. In all cases yet seen, the models ignored any impact of shifts in the focus of societal needs.

Budget models were no less restricted in their range

during this period. Most models consider only data and/or procedures related directly to the budgeting process. A model was constructed by the President's National Commission on the Financing of Post Secondary Education(17:6) which examined the impact on the financial health of universities caused by enrollment changes resulting from changes in tuition rates and the availability of financial aid. In this model, at least, feedback of inter-related factors was considered.

THE SYSTEM DYNAMICS APPROACH

Until recently, the use of modeling in higher education management has been restricted to small scale models which try to ignore the complexities of the real-world inter-related processes involved. In part, this may have been due to the need for a tool capable of enabling the modeler first to understand the behaviors of dynamic systems, and second to represent them in a form suitable for evaluation by computer. In recent years, however, the use of advanced techniques of system analysis and improvements in modeling theory have provided these necessary facilities.

In "Principles of Systems"(11), Jay W. Forrester has produced perhaps the definitive work on analysis and simulation of large-scale feedback systems. It is his contention that virtually all social systems fall into the category of high-order feedback system on which his work has

focused. He characterizes these systems as having a number of common traits, among which are

1. Counter-intuitivity of system behavior;
2. Insensitivity to perturbation in many parameters;
3. Stubborn resistance to policy changes;
4. Existence of pressure points in unexpected areas;
5. Opposing polarities of long- and short-term responses to a given set of policy changes; and
6. Tendency toward low levels of performance.

(11),(8)

Forrester's work has lead him to conclude that "The human mind is not adapted to interpreting how social systems behave." This human inability, coupled with the tendency which complex systems exhibit toward oscillatory behavior, often leads to long term effects of policy adjustments which are diametrically opposed to those intended. Short term results are often politically desirable and seductive, but bear disastrous fruit in the long term.

> "If we were malicious and wanted to create urban slums, trap low-income people in ghetto areas, and increase the number of people on welfare, we could do little better than follow the present policies."
> (8:13)

Forrester's major criticism of current practice in the social sciences is that the emphasis seems to be being placed upon statistical analyses of dynamic phenomena. This would be

akin to describing domestic alternating current electrical power as having an average voltage of zero volts: the description is valid, but meaningless. In Forrester's words

> "...the social sciences have fallen into some mistaken "scientific" practices that compound man's natural shortcomings. Computers are often used for what the computer does poorly and the human mind does well. At the same time the human mind is used for what the human mind does poorly and the computer does well."(8:5)

> "The key to success is not in having a computer; the important thing is how the computer is used. With respect to models, the key is not to computerize a model but to have a model structure and relationships that properly represent the system that is being considered."(8:8)

C. West Churchman(7) proposes that the critical phase of system analysis is most accurately performed when a scientific approach is followed. His major point is that every view of the world is "terribly restricted". Only when an inter-disciplinary and objective approach to a system is adopted can the resulting analysis be considered valid. He advocates a process wherein the definition of the motivating problem is a critical first step. Given the precise and accurate definition of the problem, his approach mandates the consideration of five elements of the system:

1. The system's goal or objective, and its means of measurement of progress toward/proximity to it;

2. The resources the system may manipulate in seeking the goal;
3. The constraints placed upon the system by its environment;
4. The components or sub-systems which comprise the system; and
5. The management process of the system; the means by which goal-seeking policy decisions are implemented.(7)

The model developed in this study is based on the work of these two men and the implementation thereof by others. Forrester's research into the nature of systems resulted in the creation of the Universal Language for describing systems. This, in turn, was developed into a computer simulation language called DYNAMO(20). Because of its direct applicability to the subject at hand DYNAMO was chosen as the means by which the model was implemented.

THE UNIVERSAL LANGUAGE AND DYNAMO

The Universal Language is comprised of a relatively small set of symbols which are graphically combined to form the representation of a system. The chief elements of the language are the Level, the Rate, the Constant, and the Auxiliary. The concept of time flow is critical to the implementation of the Universal Language in DYNAMO, but is not

present in the graphical representation of a system which the language provides. Please refer to the example provided in Figure 2.1, page 15.

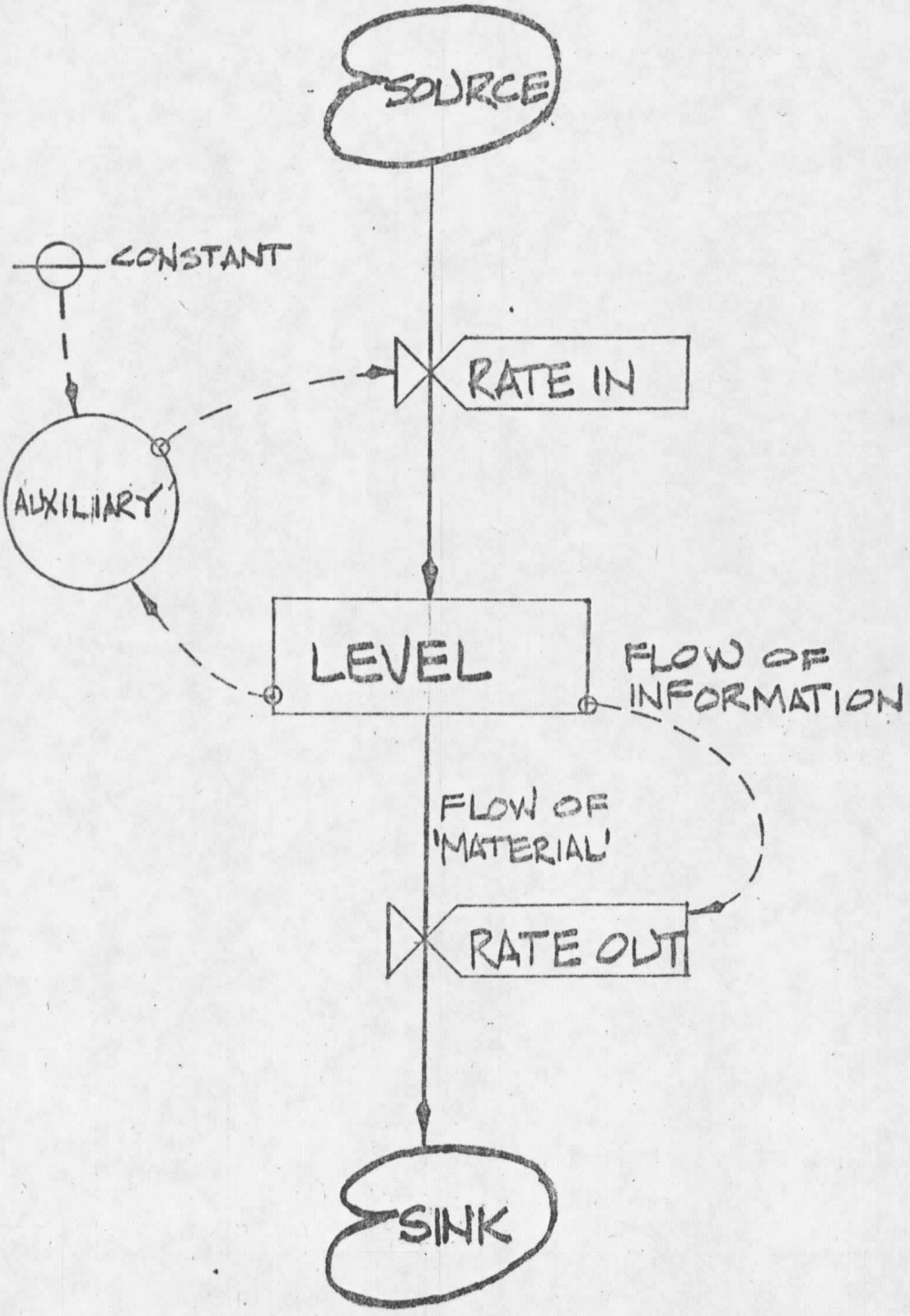
The Level is a construct which represents a quantity of some physically measurable substance of importance in the system. The state of the system at any given point in time is contained within its levels. Levels are the accumulations of the actions of the system, which actions are represented by the Rates. Rates are the only means by which the status of the system is changed. Rates are not instantaneously measurable. That is, their impact can only be discerned as an average over a period of time. The concept of time in the language (and DYNAMO) is that it is continuous, and that discrete measures are meaningless. The value of a level at any point in time is given by the value it had at the previous time it was checked modified by the affect of the rates acting upon it in the intervening time. Levels create continuity between points of time in the system.

Rates represent the actions of the system, and may either add to the value of a level (influx) or subtract from it (efflux). Rates are represented as algebraic statements, without regard to time or any previous values they might have held. Auxiliaries are organizational constructs which represent sub-divisions of the rates. They represent

intangible quantities from the standpoint of the system, and are primarily useful in clarifying the actions and processes of the system.

Two important concepts relating to the interactions of rates and levels are the existence of 'natural' rates and the balance of influx and efflux at equilibrium. A natural rate is conceived as being the rate at which a process would act upon a level in the absence of whatever influences the modeler is attempting to study. That is, it forms the basis for comparison, and any policy-induced modifications to it may then be isolated. The natural rates are generally determined by long term statistical analysis, which filters out transient influences. Further, if a system is to reach or maintain equilibrium, the natural rates of influx and efflux for any given level must be in balance.

FIGURE 2.1 : SAMPLE UNIVERSAL LANGUAGE DIAGRAM



Chapter 3

MODEL DEVELOPMENT

The impingent problem of declining enrollments which gave impetus to this project is systemic. That is, its effect will eventually be felt on all fronts. In Montana, the University of Montana has already been hard-hit by declining enrollments, while Montana State University, for the present, continues to extend its enrollment level records. The initial intent of the author was to build a generic model; ie, one which would be as useful to administrators of Liberal Arts oriented institutions, such as UM, as it would to Agriculture-Engineering ones, such as MSU. Unfortunately, the availability of complete and coherent data, as well as access to individuals with insight into the actual inter-relationships of the processes involved often played an influential part in the shaping of the resulting model. In its present form, the model is neither a completely generic one nor is it solely representative of conditions and practices here at MSU. Rather, it lies somewhere between these two. It is the hope of the author that any ambiguity in the ensuing discussion of the model's development may be resolved by the reader's bearing in mind the necessary