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SYSTEMS ANALYSIS AND UNIVERSITY PLANNING.

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DESCRIPTORS- *UNIVERSITIES, *COLLEGE PLANNING, *SYSTEMS ANALYSIS, MODELS, *INPUT OUTPUT ANALYSIS, HEALTH OCCUPATIONS EDUCATION,

SYSTEMS ANALYSIS IS DEFINED AS AN APPROACH TO PROBLEMS OF DECISION-MAKING WHICH PROCEEDS BY ASCERTAINING OBJECTIVES, DETERMINING CONSTRAINTS, ELABORATING ALTERNATIVES, AND ESTIMATING THE COSTS, BENEFITS, AND RISKS OF FEASIBLE ALTERNATIVES. THE SYSTEMS ANALYSIS DESCRIBED HERE IS BEING CONDUCTED IN SUPPORT OF PLANNING FOR THE HEALTH SCIENCES FACULTIES OF THE UNIVERSITY OF TORONTO. MOST OF THE WORK HEREIN CONCERNS THE FACULTY OF MEDICINE. THE OBJECTIVE WAS TO EMPLOY SYSTEMS ANALYSIS TO IMPROVE THE PLANNING AND OPERATION OF THE HEALTH SCIENCES FACULTIES. THE HEALTH SCIENCES FACULTIES, AS A SYSTEM, IS DISCUSSED. MAJOR DECISION AREAS ARE REVIEWED. A MODEL WHICH QUANTITATIVELY ASSESSES THE RESOURCE IMPLICATIONS OF ALTERNATIVE PLANS FOR EXPANDING AND IMPROVING HEALTH SCIENCE PROGRAMS WAS DEVELOPED. CALLED THE JCL3W MODEL, IT ACCEPTS TECHNOLOGICAL DESCRIPTIONS OF THE SYSTEM AND OUTPUT LEVELS. IT PROCEEDS TO COMPUTE THE QUANTITIES OF INPUTS REQUIRED TO PRODUCE THE OUTPUTS. THE MODEL IS USEFUL FOR INPUT-OUTPUT ANALYSIS OF HEALTH SCIENCE EDUCATION BY STRUCTURED CURRICULA. THE DIFFICULTIES OF UNIVERSITY DECISION-MAKING CALL FOR FURTHER DEVELOPMENT AND USE OF SYSTEMS ANALYSIS IN THIS SETTING. THIS PAPER WAS PRESENTED AT THE AMERIACAN EDUCATIONAL RESEARCH ASSOCIATION CONVENTION, WASHINGTON, D.C., NOVEMBER, 1967. (IM)

SYSTEMS ANALYSIS and UNIVERSITY PLANNING.

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CONTENTS

CONTENTS (cont.)

1. INTRODUCTION

1.1. Objectives of This Paper

There are three main objectives of this paper: (1) To illustrate how systems analysis may be able to aid university planning, (2) To display some applications of systems analysis to a specific university planning situation, and (3) To indicate how some of the difficulties of decision-making in universities pose the need for further development of systems analysis.

1.2. A Brief Exposition of Systems Analysis

The term "systems analysis" gained currency in the early post-world War II period. The name was suggested because analysts were primarily concerned with weapon systems. Studies undertaken to assist military decision-makers to choose from among weapon systems were called "systems analyses".[1/]

Later, the idea of "systems analysis" came to connote the antithesis of partial and piecemeal analysis. Analysts were urged to take account of interactions and interdependencies among subsystems of larger systems.[2/]

More recently, the term "systems analysis" has been used almost interchangeably with operations research, management science, and applied economic analysis.

As we understand it, systems analysis means an approach to problems of decision-making which proceeds by ascertaining objectives, determining constraints, elaborating alternatives, and estimating the costs, benefits and risks of feasible alternatives.

First of all, we postulate the existence of a "system" whose behavior we wish to predict or control. What is and what is not considered to be in system is a determination that should be dictated by expediency. In general, the sharing of strong common purpose or strong technological interdependence are sufficient reasons for regarding a set of elements as belonging to a system.

Every system has variables (inputs and outputs), and a technology whereby inputs are transformed into outputs. We seek to capture the main interdependencies among important variables by building models of the system. The implicit form of a model may be shown as a set of relations:

$$g(x, b) = o \qquad (1.1.)$$

where:

x - a set of input variables
b - a set of output variables.

Frequently, it is assumed that a second transformation exists which maps the inputs and outputs into a scalar measure

of the system's performance. This second transformation is often called the "objective function" whose extremum is sought subject to the constraint of the technology. Expressed as a maximisation, the problem may be stated as:

$$\max_{a,b} \; y = y(a,b) \quad \text{Subject to} \quad g(x,b) = o \qquad (1.2.)$$

Systems analysis may proceed on various levels. For present purposes, it is convenient to make three groupings: (1) Input-Output analysis, (2) Efficiency analysis, and (3) Optimality analysis.

1.2.1. Input-Output analysis

The purpose of input-output analysis is to explore the relationships among a system's inputs, its technology, and its outputs. Such analysis avoids all consideration of optimisation and the objective function is totally suppressed. To illustrate this idea, suppose that the model mentioned in (1.1.) takes the form of a set of linear equations as shown in (1.2.)

$$g(x,b) = Ax - b = o \qquad (1.2.)$$

Here A is a square matrix of coefficients of the "technology" which transforms the inputs x into the outputs b.

Given the system's technology, we may alter the outputs and record the implications for the inputs required. This is

equivalent to solving (1.2.) for x in terms of A and B.

$$x = A^{-1}b \qquad (1.3.)$$

This may be done for a large number of possible b vectors; if it is, we will have explored the input consequences for the corresponding set of possible outputs.

Alternatively, we may again retain the technology unchanged but alter the system's inputs and observe the resultant change in the outputs. In our illustration, this involves simply the multiplication indicated in (1.2.)

Quite obviously, it is possible to experiment with alternative technologies by altering some or all of the values of A. With given values for the output vector, the input implications of those technological changes may be explored by post-multiplying the inverse of the altered A matrix by the vector b.

Input-output analysis is systems analysis of a relatively low order but it may be very useful. Decision-makers often lack the most elementary input-output information and the systems analyst may perform a useful function by providing it. The analyst labors to build a good set of transformation relations or models (characterised by the technology matrix A in our

preceding example). He then solicits alternative vectors of outputs and uses his model to compute their input implications. He may also vary coefficients of his model in ways corresponding to alternative policies and technological designs. Most of the systems analysis done by the Health Sciences Functional Planning Unit falls into the category of input-output analysis.

1.2.2. Efficiency analysis

In the efficiency analysis of systems, we suppose that we know the arguments of the objective function, but we do not know the form of the function. We assume to be known only the signs of the first derivatives of the objective function with respect to all of its arguments.

Consider an objective function $y = y(z)$ to be maximised subject to $g(z) = o$. A point z^* is defined to be an efficient input-output point if observing $g(z) = o$, it is impossible to locate another point $\bar{z}$ such that (assuming differentiality for purposes of exposition):

$$\bar{z}_i \varepsilon \bar{z} \geq z^*_i \varepsilon z^* \quad \text{for } y'_i \geq o,$$

$$\bar{z}_i \varepsilon \bar{z} \leq z^*_i \varepsilon z^* \quad \text{for } y'_i \leq o,$$

and

at least one $\bar{z}_j \varepsilon \bar{z} > z^*_j \varepsilon z^* \quad \text{for } y'_j \geq o$

or

at least one $\bar{z}_j \varepsilon \bar{z} < z^*_j \varepsilon z^* \quad \text{for } y'_j \leq o$

This definition corresponds to that of Pareto optimality. Setting constant all $z_i \epsilon z$ for which $y_{z_i} < o$(inputs), the set of all efficient points containing those constant values defines the output transformation surface which is the boundary of the feasible set determined by the constant inputs and the constraint $g(z) = o$. Similarly, setting constant all $z_j \epsilon z$ for which $y_{z_j} > o$ (outputs), the set of efficient points generated therefrom defines the input transformation surface.[3/]

Much efficiency analysis goes on under the rubric "cost-effectiveness analysis". Inputs are fixed and efficient output sets are sought or outputs are fixed and sets of efficient input combinations are sought.

1.2.3. Optimality analysis

In optimality analysis, we suppose that we have a well defined objective function whose arguments are known and whose form and coefficients are specified. In this case, rare in the analysis of social or economic systems, the analyst's task is to seek the global optimum of $y = y(z)$ subject to $g(z) = o$.

1.2.4. Kinds of systems analysed

Much early systems analysis was performed on systems for which rather simple unitary goal systems were postulated. This made possible the specification of well defined objective functions whose optimisation was sought. Thus, economic theorists

adopted profit maximising and utility maximising postulates for their theories of the firm and household.[4/] Operations researchers have sought to minimise costs of operating inventory systems or to maximise the tonnage of material carried through a submarine blockade.[5/]

As systems analysis spread to less technical systems, the problem of specifying objective functions became more difficult. Military systems analysis reached this stage when it began to consider alternative enemy reactions and complex tradeoffs among offensive and defensive capabilities.[6/] Management scientists discovered that the postulate of profit maximisation was frequently inadequate. Welfare economists have long grappled with systems involving multiple objective systems.[7/]

1.2.5. The scope of university systems analysis

Universities present the analyst with a broad spectrum of systems problems. In some lower order problems (e.g., inventory control, maintenance and replacement of equipment, heating plant design) it is possible to formulate objective functions and conduct optimality analysis. As one moves from operating problems to planning problems, the difficulties of specifying objective functions increases. With increased difficulty goes increased potential payoff from successful

applications of analysis.

1.3. The Health Science Faculties of the University of Toronto

The systems analysis described in this paper is being conducted in support of planning for the health sciences faculties of the University of Toronto. These eight faculties, schools, and departments constitute the domain of the Vice President, Health Sciences.[8/]

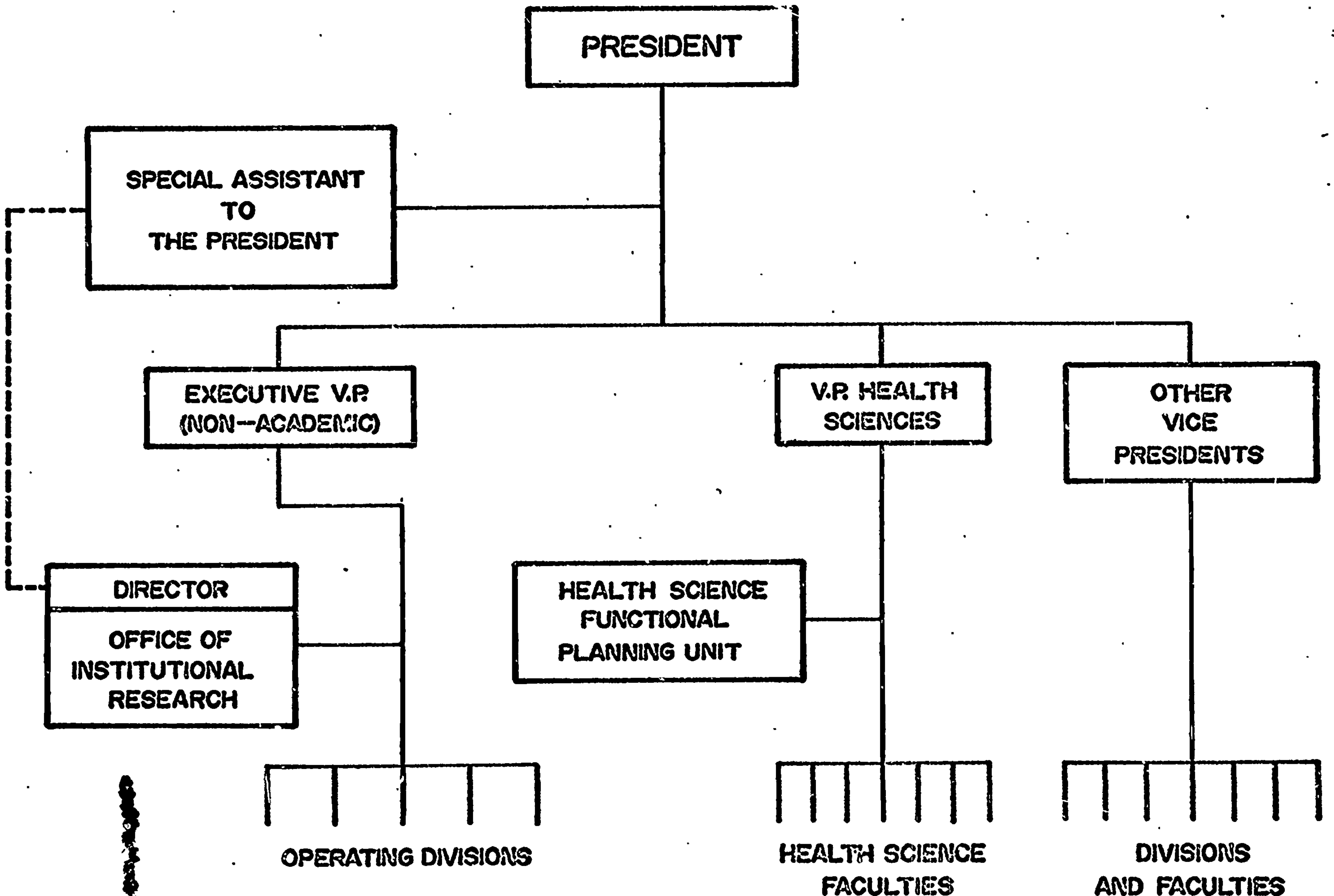
Because most of the work to date has concerned the Faculty of Medicine, the bulk of this paper is directed towards that Faculty.

The Faculty of Medicine consists of 19 departments.[9/] Associated with the Faculty of Medicine are eleven hospitals where clinical instruction is given to undergraduate medical students in the fourth, third, and part of the second medical years.[10/] Graduate training and research are also conducted. Each of these hospitals, except for Sunnybrook, is governed by its own board of trustees. (Sunnybrook, formerly a veterans' hospital, was presented to the University of Toronto on October 1, 1966.) Most of the hospitals are located in close proximity to the main campus of the University of Toronto.[11/] Basic data describing the eleven hospitals is provided in Table 1.

The association of the University and the Toronto General

Fig. 0.1

STRUCTURE OF SYSTEMS ANALYSIS GROUPS
AT THE UNIVERSITY OF TORONTO



Hospital is defined by the Toronto General Hospital Act. This Act specifies that the professor and head of each university department is entitled to a service in the Toronto General Hospital. An amendment to this Act specifies that there shall be only service in medicine and surgery; the professor of these departments is by inference the Chief of Service at the Hospital. The remaining heads of clinical departments are also chiefs of service of their respective divisions at the Toronto General Hospital, except for the Department of Paediatrics (Hospital for Sick Children) and the Department of Psychiatry (The Clark Institute). The relationship of the University to the other teaching hospitals and the mechanism of appointments of chiefs of service is not defined by formal agreement.

2. THE HEALTH SCIENCES FACULTIES AS A SYSTEM

We choose to regard the health sciences faculties with all their faculties, departments, and associated hospitals as a system. It is a complex system with multiple inputs and outputs. Distinguishing between inputs and outputs is often difficult. A symbiosis among instruction, research and service create problems of joint outputs. A multiple goal structure is determined by the organisational autonomy of the teaching hospitals and the clinical departments. Our objective is to employ systems analysis to improve the planning and operation of this system.

2.1. Outputs of the System

Without reference to objectives, it is impossible to distinguish inputs from outputs. Because we are dealing with multiple objective functions, there may be no general agreement on what belongs on the input side of the ledger and what constitutes the outputs.[12/] We avoid this issue here and simply list those things which are regarded as outputs by some objective function operating in the system.

2.1.1. Education of health science personnel

A major objective of the University is the education of health science personnel. This means, presumably, addition to

the stocks of knowledge and skill of this set of people. Measurement of these stocks and increments thereto is very difficult. Discussion of problems of measuring outputs is deferred until section 4.3; until then, the question is begged by treating the number of students processed through the system as an index of output.

Educational outputs may be grouped into four groups: (1) Undergraduate education of students of Medicine and the other faculties, (2) Graduate training in the basic sciences, (3) Career training of clinical specialists, and (4) Continuing medical education. The levels of educational activities are described in Appendix A.

2.1.2. Patient care

The eleven hospitals associated with the Faculty of Medicine contain more than 6,500 beds. In 1966,120,192 patients were admitted for treatment and the number of patient days of care numbered 1,612,321.

2.1.3. Research

Research is recognised as an important independent objective of the health science faculties. In addition, research facilities are regarded as a means of attracting and retaining staff of high calibre.[13/]

2.2. Inputs to the System

A variety of inputs flow into the system. What appears as inputs to some may seem to be outputs to others; for example, patient care appears to the University as an input to the teaching and research processes while it seems to be an important output to the associated hospitals. Avoiding such difficulties, we proceed to list a number of the inputs to the system.

2.2.1. Uneducated or partially educated individuals

Students at all stages of their training invest their time in the health education process. A student at the beginning of year t makes the input of one man-year and arrives at year t + 1 with his stock of knowledge increased. The physical input is the student's time and part of the social opportunity cost of that input is the value of alternative employment that he might have had were he not in school.

2.2.2. Academic and non-academic staff

Faculty, residents, demonstrators, technicians, and other specialists contribute their services to the health science education and research processes.

2.2.3. Facilities and materials

The most varied kinds of facilities and materials are used by the system. Lecture halls, seminar rooms, theatre clinics, study spaces, library facilities, laboratories, offices,

eating facilities, living quarters, television equipment, and animals are but a few of the facilities and materials used in the teaching and research process. In some cases, materials are consumed in the process of use; in others, the input is reckoned in units of capacity per time interval.

2.2.4. Patients

Health science students must be exposed to normal and abnormal patients in all age groups and of both sexes. They must see patients undergoing acute and chronic care including convalescent and ambulatory care. To adequately provide for clinical research, there must be a plentiful supply of normal and abnormal patients. Both teaching and research require the input of patient "services".

This list of inputs could be extended almost indefinitely. Enough items have been enumerated to indicate the main categories into which inputs are classified. No mention has been made of money because of a desire to concentrate attention on the physical resources which are input into the system. Money, as generalised purchasing power, is command over physical inputs of diverse types. Our approach is to deal first with resources in physical units and to convert to monetary units afterwards. Furthermore, the appropriate valuations to be placed on many systems inputs often are not to be found in the

market-place; some more subtle definitions and estimations of real opportunity costs are necessary.

2.3. Major Problems Confronting Decision Makers of the System

A number of major problems now confront decision makers in the University of Toronto health sciences system.

2.3.1. Expansion of enrolment in medicine

The first major problem arises from a planned expansion of the undergraduate medical program. In 1964, after considering alternative ways of increasing the number of medical specialists, a special committee of the University's Board of Governors recommended an expansion of the medical faculty to accommodate 250 students in the entering class rather than approximately 175 accepted at the present time.[14/] The increased enrolment is to be handled by an expansion of the existing basic science departments on the main University campus and by expansion of the activities at each of the major affiliated teaching hospitals.

The Committee anticipated substantial economies of scale as a result of the enlargement of the proposed facilities on campus and at the teaching hospitals. It estimated that those economies would be substantial when compared to the cost of constructing comparable facilities in a new university medical centre for an equivalent number of students. The Committee

anticipated that the increased number of graduates would be turned out three to four years earlier than from an independently developed new medical school. Furthermore, it was expected that academic staff might be recruited more readily into the existing framework of the well recognised Faculty of Medicine than to a new school.[15/]

The Board of Governors Special Committee recognised that the enlargement of the entering class to 250 students posed special problems for maintaining and raising standards of education in the Faculty. It reasoned that the main difficulty would be experienced in the clinical training of medical students. But the Committee delivered the opinion that: "If the clinical departments can be developed to a uniformly high standard at three or more major teaching hospitals, clinical instruction of 250 students per class could be satisfactorily handled by sub-dividing classes into three or more smaller groups each affiliated with one teaching hospital."[16/]

2.3.2. Curriculum changes

Early in 1967, after several years of discussion, the Faculty of Medicine agreed in principle to a basic re-design of the undergraduate medical curriculum.[17/]

The Curriculum Committee's basic recommendation was

that: "the Faculty conduct a co-operative experiment in correlated system-oriented teaching." This recommendation, spelled out in more detail in the Committee's Proposed Plan, reflected considerable dissatisfaction with the traditional curriculum based upon the conventional departmental divisions (i.e., Anatomy, Surgery, Medicine, etc.). The organisation of instruction by human physiological systems was expected to facilitate the teaching of basic science, pathophysiology and clinical aspects of patient care by teachers with common interests but with differing points of view.

The Curriculum Committee proposed that the curriculum should be structured on the basis of the following three inter-related periods of study:

Period I - Normal biology of man

Period II - Disease in terms of altered human biology

Period III - Patients in relation to altered biological processes

Period I would be spent largely on campus, Period II partly on campus and partly in teaching hospitals, and Period III largely in teaching hospitals.

Beyond this parcelling into periods and some general recommendations about the organisation of each period, the Curriculum Committee did not go. In particular, it did not attempt to specify particular lectures, seminars, laboratories, etc.,

their times or places, their sizes or topics, or even the number of students who would participate in each of the teaching hospitals during periods II and III. The responsibility for detailed curriculum planning was delegated to a Committee of the Heads of Departments. This Committee was empowered to appoint a "period committee" for each of the three curricular period. Each period committee consists of:

(1) a period coordinator

(2) Chairmen representing each system and/or departmental discipline being taught in the period.

Each period committee is charged to:

(1) plan the curriculum and examinations in its period: and

(2) submit the plan for approval to the Committee of the Heads of Department.

2.3.3. Increase in research

The Special Committee of the Board of Governors, in its 1964 Report, recommended a major expansion of the level of research in the Faculty of Medicine. Its reasons for this recommendation were threefold:

(1) Increased medical knowledge is a good thing and, therefore, medical research is an independent and autonomous objective to be pursued.

(2) The scope of medical knowledge is so great that only by being involved in research can a medical teacher maintain the high quality of his teaching.

(3) To attract and retain high calibre staff it is necessary to offer good research facilities and create an atmosphere conducive to continuing academic achievement.

The first of these reasons is autonomous while the second and third are induced by a concern for achieving the instructional objective.

2.3.4. Expansion of graduate studies

The need to produce physician-scientists and future teachers was considered by the Special Committee of the Board of Governors to warrant considerable expansion in graduate studies. This includes M.A. and Ph.D. studies, career training of clinical specialists, and continuing medical education.

The training of clinical specialists has formerly been a hospital rather than a University responsibility even though Faculty staff members were involved. It is now proposed that the University's Faculty of Medicine assume explicit financial and academic responsibility for the education, training and supervision of interns and residents.

2.3.5. Staffing policy

The departments of the Faculty of Medicine and the other health sciences faculties employ staff members who provide services of instruction, service, research and administration to the system.

Changes in the levels and mixes of the main system outputs carry implications for staff resources.

At the present time, the Faculty of Medicine depends heavily on (1) staff members paid wholly or principally by granting agencies outside the University and (2) voluntary staff in the clinical departments who receive little financial or academic recognition from the University. This latter group consists largely of clinical practitioners who, at least in the past, derived some advantage from their association with the teaching hospitals.[18/]

There is a concern that the existing staff mix of teacher-practitioners is an unsteady base for the desired quantitative and qualitative expansion of the Faculty. Teaching may be given a residual priority by a teacher-practitioner who is very busy with his private practice. The desired development of research in the Faculty is inconsistent with a staff mix favouring teacher-practitioners; research demands teacher-researchers.

Finally, many fear that the Faculty will be unable to attract enough staff members of high calibre if it relies on part-time, voluntary teacher-practitioners.

For these reasons, a major shift in the composition of the Faculty staff is contemplated. In the clinical departments

the proposal is to shift the staff mix from one favouring teacher-practitioners to one favouring teacher-researchers.[19/]

2.4. The Need for Analysis

From this brief survey of five major decision areas confronting leaders of the Faculty of Medicine, the need for analytical staff work is apparent. Major questions for analysis are:

2.4.1. How many teaching hospitals should there be in the new system and what should be the nature and extent of involvement of each?

2.4.1.1. How many students should be at each teaching hospital in Periods II and III?

2.4.1.2. What research activities should be geographically located at each teaching hospital?

2.4.2. What will be the specific design of the new curriculum?

2.4.2.1. What resource requirements will the new curriculum generate?

2.4.3. What are the combined input implications of the expanded graduate and undergraduate programs, more research activity, and a shift from teacher-practitioners toward teacher-researchers?

2.4.4. What facilities should be built on campus and at the teaching hospitals? And when?

2.4.5. What are the financial implications of the proposed changes? If the government refuses to foot the entire bill, what "second-best" plans should be formulated?

Early in 1967, the Health Sciences Functional Planning Unit was formed with financial assistance from the Federal and Ontario governments. The Unit is placed organisationally under the Vice President, Health Sciences. Its mission is to develop and apply system analytic techniques to assist policy planning in the Health Sciences.

A principal objective of the Unit is to develop models which quantitatively assess the resource implications of alternative plans for expanding and improving health science programs. This is what we previously termed "input-output" analysis, and the next section describes some current work in this field.

3. INPUT-OUTPUT ANALYSIS OF THE HEALTH SCIENCES SYSTEM (The JCL3W Model).

To illuminate the resource implications of alternative answers to questions such as those mentioned in section 2.4., the H.S.F.P.U. has developed several input-output models.[20/] One of these, the"JCL3W" model, is discussed below.

The JCL3W model accepts technological descriptions of the system (or component sub-systems) and output levels; it proceeds to compute the quantities of inputs "required" to produce the outputs.[21/] In the terms of section 1.2.1. it resembles the system (1.3.) displayed on page 4 of this paper.

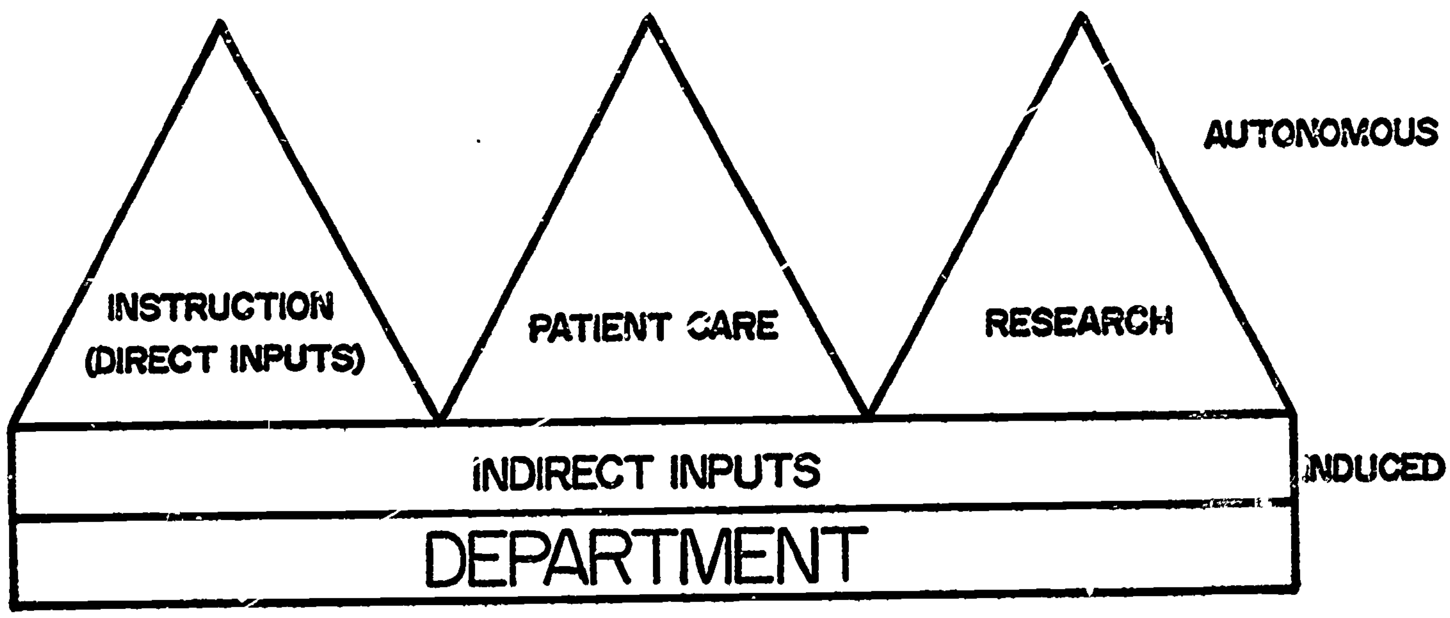
3.1. Departmental Workloads

Because the departments provide most of the inputs to the health science system, the JCL3W model was designed to compute the input resource requirements at the departmental level of detail. The loads upon a department may emanate from several different sources as illustrated in Figure 1.

3.1.1. First is the load generated by the teaching function itself. This is handled by decomposing each curriculum into basic modules called "activities" in such a manner that certain direct input requirements can be associated with a "unit" of that activity. Direct input resource requirements are things such as academic staff, lecture halls, seminar rooms, patients, etc.

Fig. 1

DEVELOPMENT OF LOADS ON A DEPARTMENT



3.1.2. Induced resource requirements result from the necessity to support and sustain the academic system. They can be viewed as "induced" by the existence of students in the system. Of these, administrative requirements are relatively obvious. Service (i.e., patient care) is necessary in order to have patients available as an input for the medical educational system. Well equipped research units are thought to be necessary to attract and retain qualified academic personnel. All of these place loads on the typical department in addition to, and as the result of, the teaching function.

3.1.3. Autonomous resource requirements are those which are necessary whether or not a teaching function is performed. Patient care is an autonomous objective. For example, some research activity is independent of the number of students present in the system.

3.2. The JCL3W Model[22/]

The basic building block of the JCL3W model is the "activity". An activity is one unit (usually one hour) of a literal activity (e.g., pathology lecture, surgery seminar) involving a group of students and a set of input resources. All academic activities which engage health science students are described according to type, size of student group involved, and specifications of inputs required to carry out the unit level of the activity (including the type of input, the department from

which it comes, the cost-centre to which the input is to be dedicated, and a code denoting the nature of the functional relationship between the activity and inputs required per unit level). Figure 2 displays the Activity Record Sheet on which this information is recorded.

Activities are combined into sets called curricula. Each curriculum is compiled by assembling activities and indicating the fraction of the class to be engaged in this activity and the number of hours per week that each activity is to operate. Figure 3 , displays the Curriculum Recording Sheet used to collect the curriculum specifications.

Students are "moved" through the system from state to state by a Markov chain. Some leave the system, others drop out and re-enter, others proceed directly through the system to graduation. As they are moved through the system by the program, they engage in activities as directed by the curricula. The types and levels of activities generate input requirements. These are dumped onto magnetic tape from which they may be arranged in thousands of possible combinations by the Report Generator.[23/]

The model can handle time units of flexible length in a series of up to 65 units (five years if each unit is four weeks in length; somewhat more than one year if units are a single week). A typical five-year case for the Faculty of

Fig. 2

ACTIVITY RECORD SHEET

(Revision 1, June, 1967)

Description of Activity: Bed-Side Clinic, Medicine

Item	Entry	Card columns	Code
Card Code		1–2	0 7
Sequence Number		3	1
(2 Blank Spaces)		4–5	
Activity Code (A)		6–8	0 0 1
Activity Type (B)	Bed-Side clinic	9–10	0 5
Maximum Group Size		11–13	1 0
Desired Group Size		14–16	1
(3 Blank Spaces)		17–19	
First (Fourth, Seventh) Resource			
(2 Blank Spaces)		20–21	
Department (C)	Medicine	22–23	0 7
Resource Code (D)	Lecturer	24–26	0 1
Dedication Level (E)	University & Dept.	27–28	0 1
Proportional Unit (F)	One per group	29–30	0 2
Quantity		31–36	1.0
Second (Fifth, Eighth) Resource			
(2 Blank Spaces)		37–38	
Department (C)	Medicine	39–40	0 7
Resource Code (D)	Patient, hospitalized	41–43	1 1
Dedication Level (E)	Institution & Dept.	44–45	0 3
Proportional Unit (F)	One per group	46–47	0 2
Quantity		48–53	1.0

Fig. 3

CURRICULUM RECORDING SHEET

(Revision 1, June, 1967)

Field	Columns	Entry	Note
Card Code	1, 2	0 6	
3 Blanks	3, 4, 5		
Faculty	6, 7	1	
Curriculum Number	8, 9, 10	0 1 3	Fourth Year Med (66-7)
Activity Code	11, 12, 13	0 0 1	Bed-side Clinic, Medicine
Hours per Week	14, 15, 16	8	

Field	Columns	Entry	Note	Columns	Entry	Note
Sequence Number	17			47		
Institution	18, 19	0 7	TGH	48, 49	1 1	NMS
Percent of Class	20, 21	5 0		50, 51	1 0	
Other Faculty*	22	2		52	2	
One Blank	23			53		
Institution	24, 25	0 8	TWH	54, 55		
Percent of Class	26, 27	1 5		56, 57		
Other Faculty	28	2		58		
One Blank	29			59		
Institution	30, 31	0 9	SMH	60, 61		
Percent of Class	32, 33	1 5		62, 63		
Other Faculty	34	2		64		
One Blank	35			65		
Institution	36, 37	1 0	Wel	66, 67		
Percent of Class	38, 39	1 0		68, 69		
Other Faculty	40	2		70		

Medicine might involve 18 different curricula, 250 unique activities, 29 resource codes and 152 cost-dedication centres on the campus and in the teaching hospitals. Less than two minutes time on the IBM-7094II is required per run. Figure 4 displays the flow by which the JCL3W model takes the Activity Records, Curriculum Records, and other input information and produces the reports on input requirements by institution and/or department for each input type.

The Faculty of Medicine inputs currently being calculated directly by the simulation programs are the following:

Staff (Faculty of Medicine staff, resident staff, demonstrators, other non-university staff)

Patients and Supplies (ambulatory patients, hospitalised patients, autopsy patients, biological specimens, neurological specimens, newborn babies)

Space (lecture rooms, didactic labs, elective research space, sit-down round rooms)

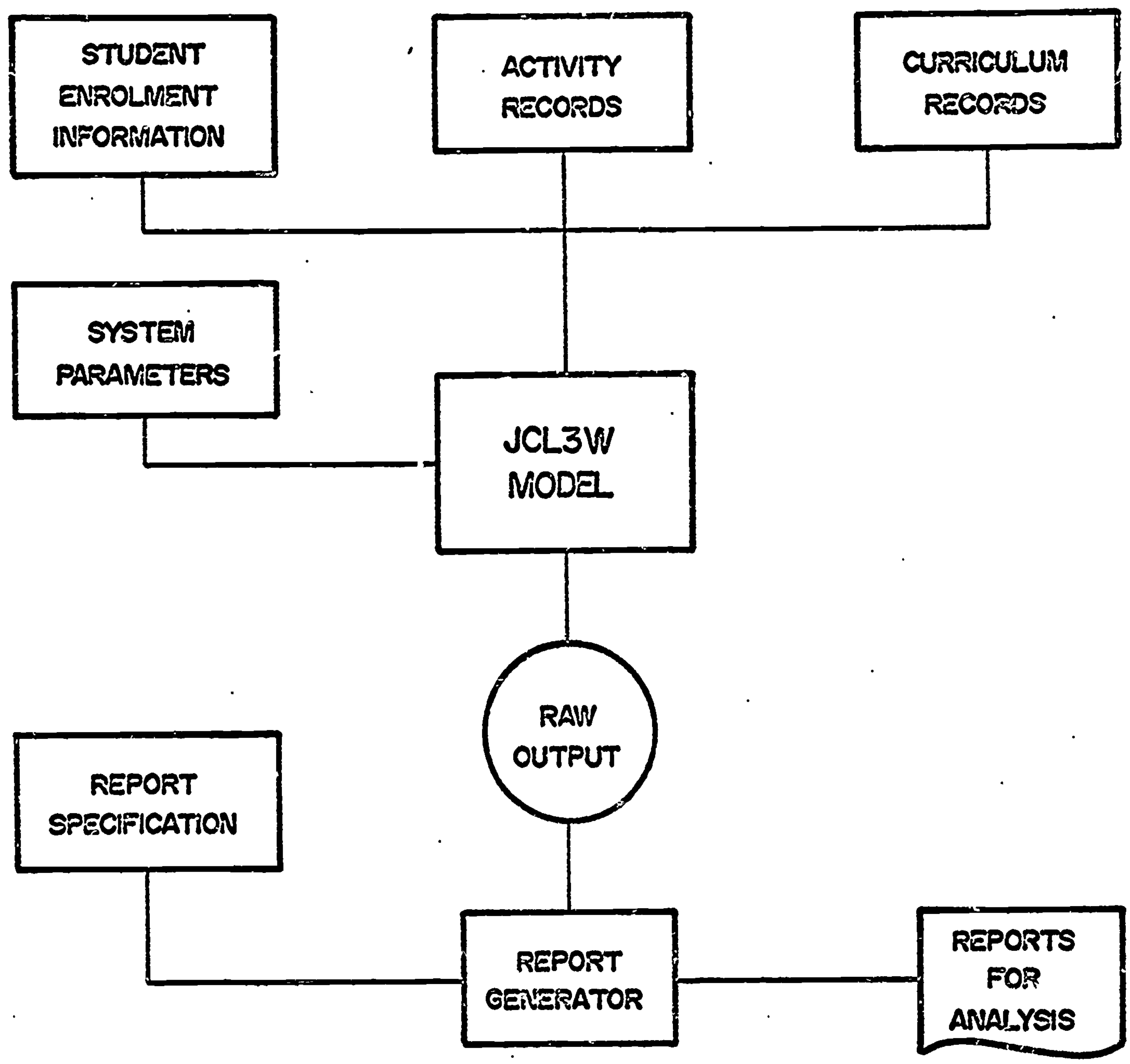
Two of the particular resources, academic staff and lecture rooms, are decomposed by type of teaching activity (for the academic staff) and by number of student stations (for lecture rooms). This direct resource list can easily be modified or extended.

3.3. Use of the Model's Output

A great value of computerised input-output models for

Fig. 4

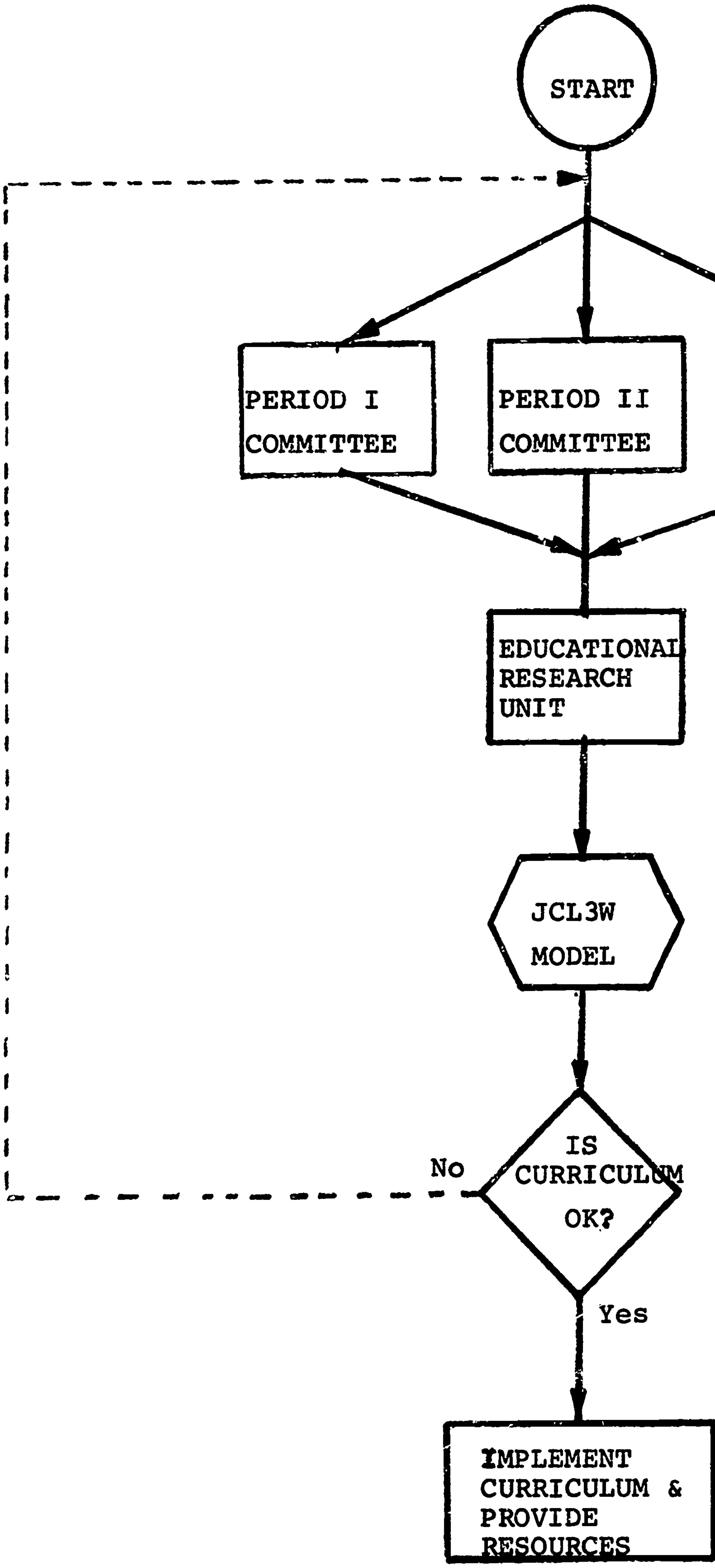
STRUCTURE OF THE HEALTH SCIENCES JCL3W MODEL



health sciences planners is the ease with which they permit comparative evaluations between alternative plans and programs. Such comparisons, in the detail available from the JCL3W model and its reports, can illuminate the input-output implications of alternative policies or plans under consideration. It is this feedback between simulation runs under different conditions and health sciences decision-makers trying out new alternatives that moves this input-output analysis toward efficiency analysis.

The Health Sciences Functional Planning Unit is working closely with the curriculum period committees described above to assess resource requirements under various proposals that they might consider for the new curriculum, enrollment expansion and hospital involvement of this expansion. Figure 5 displays the flow of information among these groups. Proposed syllabi are generated in the Systems and Topics committees. These are reconciled and coordinated for each period by the Period Committees. Singularly or jointly, the proposed period curricula are: (1) Tested for timetable feasibility by the Educational Research Unit, and (2) Submitted to the JCL3W model for an estimate of their resource input requirements.

Reports on timetable feasibility and resource requirements go back to the Period Committees and to the Curriculum Committee for further consideration. Figures 6-9 show selected summary



1. The three systems committees generate a curriculum.

2. Curriculum is specified in detail and checked for timetable feasibility.

3. Resource input requirements estimated. These estimates retained in case curriculum is approved.

4. Pedogogic benefits and resource input requirements evaluated by Curriculum Committee, Departmental Chairmen and Faculty Council.

UNIVERSITY OF TORONTO

FACULTY OF MEDICINE

FLOW OF INFORMATION IN CURRICULUM PLANNING

Fig. 5

graphs comparing alternative curricula and enrollment levels.

3.3.1. Scale effects

Figures 6 and 7 illustrate the impact of retaining the existing curriculum and expanding the enrollment per class from 175 to 250 medical students. The impact is shown for only two departments (Medicine and Surgery) and two resources (Faculty contact hours per week - Figure 6, and Hospitalised patient contact hours per week - Figure 7.) Similar information for all departments and many resource types is provided to the Period Committees.

Additional illustration of scale effects is provided by Figures 8 and 9. The comparison here is between a single stream of 250 students proceeding in lock step through the sub-periods of Period II and four separate streams (of about 63 students each) taking the same material in staggered order. When this experiment was designed, it was expected that staggering would avoid some of the severe peaking between the first 20 weeks and the last twelve; it was expected that the economies realised from staggering would reduce the total contact hours required. Instead, the diseconomies of smaller scale swamped the economies from better phasing. An exception was noted only in weeks 25-32 for didactic labs with twelve student stations of capacity.

3.3.2. Effects of curriculum change

Figures 6 and 7 illustrate the implications of changing

Fig. 6.

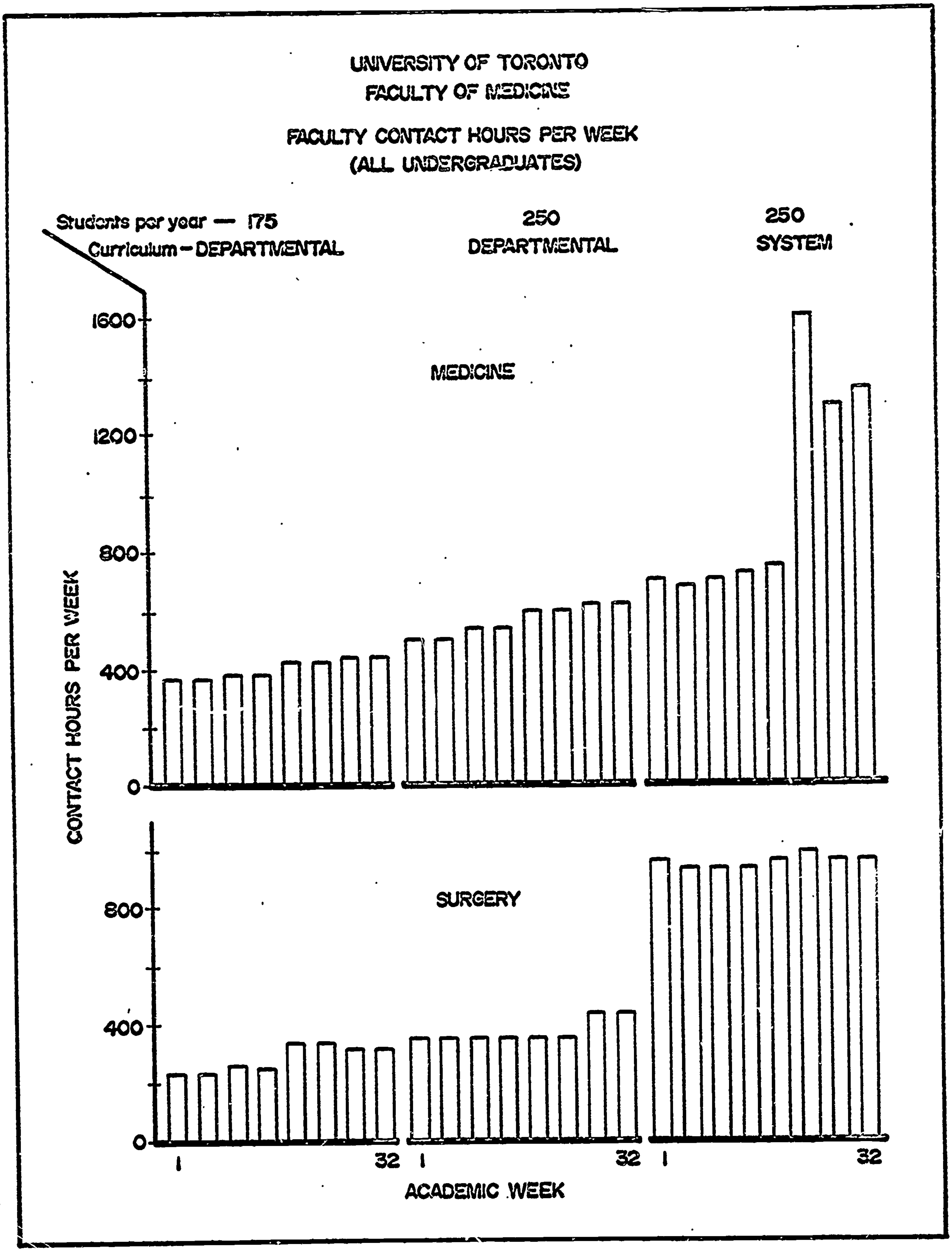

UNIVERSITY OF TORONTO
FACULTY OF MEDICINE
FACULTY CONTACT HOURS PER WEEK
(ALL UNDERGRADUATES)
Students per year — 175
Curriculum — DEPARTMENTAL
250
DEPARTMENTAL
250
SYSTEM
MEDICINE
SURGERY
CONTACT HOURS PER WEEK
1600
1200
800
400
0
800
400
0
1
32
1
32
1
32
ACADEMIC WEEK

Fig.7.

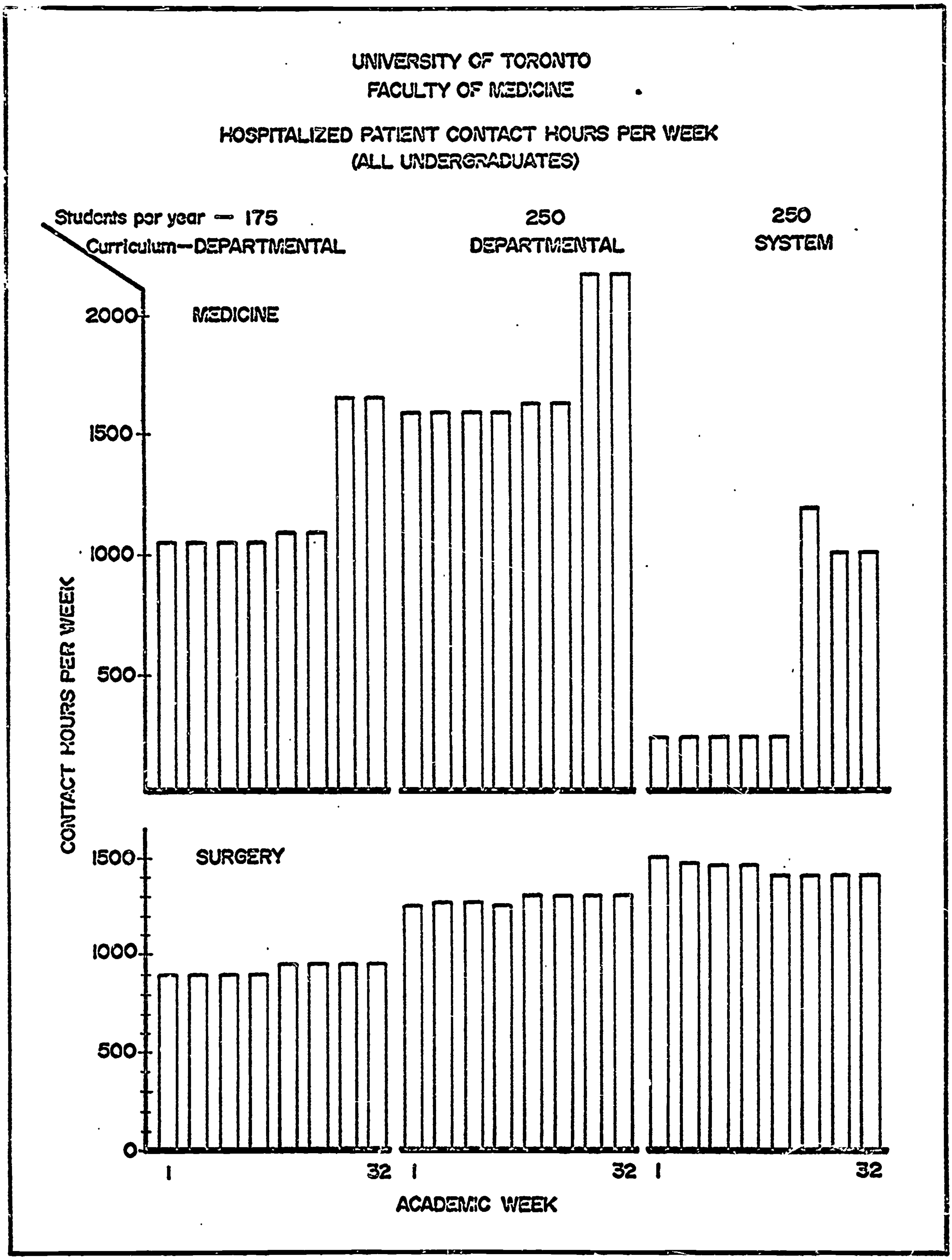

UNIVERSITY OF TORONTO
FACULTY OF MEDICINE
HOSPITALIZED PATIENT CONTACT HOURS PER WEEK
(ALL UNDERGRADUATES)
Students per year — 175
Curriculum—DEPARTMENTAL
250
DEPARTMENTAL
250
SYSTEM
MEDICINE
SURGERY
CONTACT HOURS PER WEEK
2000
1500
1000
500
0
1
32
ACADEMIC WEEK

Fig.8.

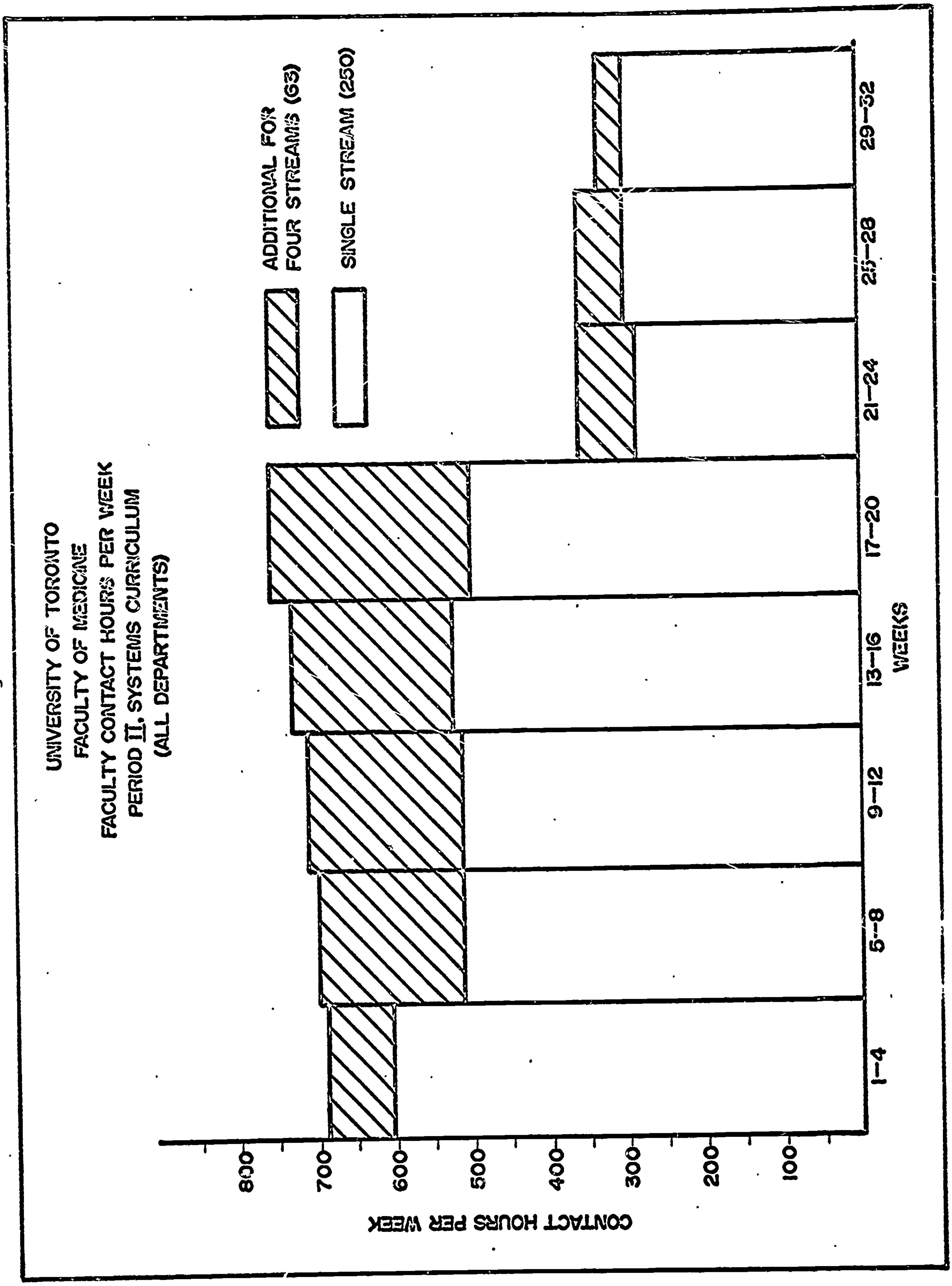
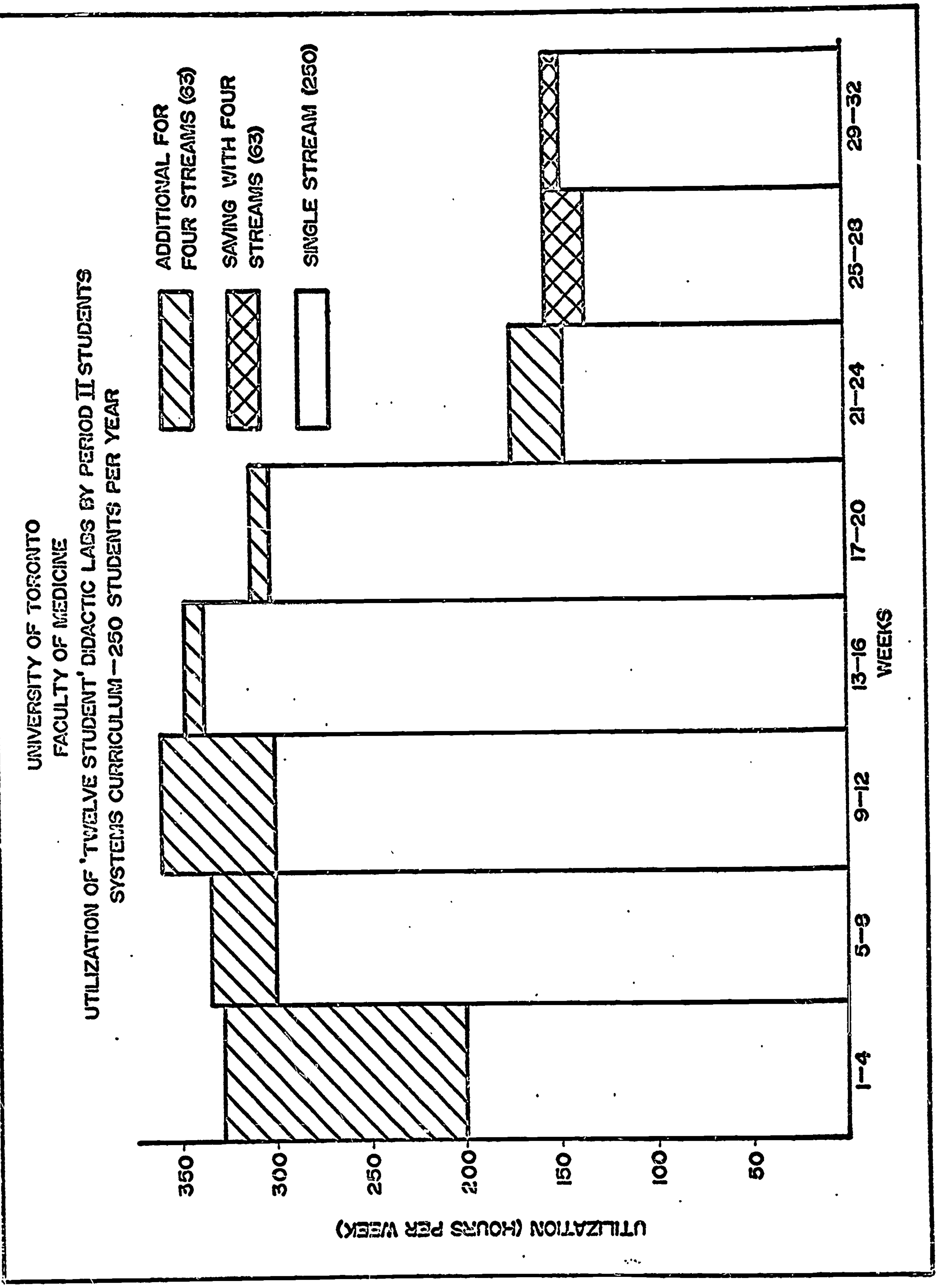

UNIVERSITY OF TORONTO
FACULTY OF MEDICINE
FACULTY CONTACT HOURS PER WEEK
PERIOD II, SYSTEMS CURRICULUM
(ALL DEPARTMENTS)
ADDITIONAL FOR
FOUR STREAMS (63)
SINGLE STREAM (250)
CONTACT HOURS PER WEEK
800
700
600
500
400
300
200
100
1-4
5-8
9-12
13-16
17-20
21-24
25-28
29-32
WEEKS

Fig. 9.


UNIVERSITY OF TORONTO
FACULTY OF MEDICINE
UTILIZATION OF 'TWELVE STUDENT' DIDACTIC LABS BY PERIOD II STUDENTS
SYSTEMS CURRICULUM—250 STUDENTS PER YEAR
ADDITIONAL FOR FOUR STREAMS (63)
SAVING WITH FOUR STREAMS (63)
SINGLE STREAM (250)
UTILIZATION (HOURS PER WEEK)
350
300
250
200
150
100
50
1-4
5-8
9-12
13-16
17-20
21-24
25-28
29-32
WEEKS

from a "departmental" to a "systems" curriculum (with 250 students per class). Only the effects on the departments of Medicine and Surgery are shown here.

The Health Sciences Functional Planning Unit is attempting to achieve a one week turn-around between the expression of interest in a curriculum by a period committee and the delivery of a report containing summary and detailed analysis of the resource implications of that curriculum.

3.4. Extensions of the JCL3W Model

The existing version of the JCL3W model produces direct output requirements in "resource hour" units, e.g., faculty contact hours (by type of staff), space utilisation hours (by type of space), and patient contact hours (by type of patient).

A necessary extension, one that is presently being made, is to convert these resource hours to physical hours. Simultaneously, a calculation of indirect input requirements must be made.

Computation of indirect inputs and conversion to physical units requires more information about the "technology" of the system. This is done by specifying values for policy parameters such as:

(1) teaching load per staff member, administrative-clerical support per student and staff member.

(2) office space per staff member and administrative-clerical worker.

(3) research facilities per staff member.

(4) beds per staff member (for private patients).

(5) teaching contact hours sustainable per teaching patient (observing constraints on quality of care)

(6) patient care staff and facilities per teaching patient.

These parameters reflect decisions of the departmental chairmen, the hospitals, and the deans of the faculties. It will, of course, be possible to study the resource input consequences of alternative sets of these policy parameters.

3.5. Additional Models

The JCL3W model is useful for input-output analysis of health science education by structured curricula. It is not suitable for specialty training and patient care. Models to facilitate input-output and efficiency analysis of these health science systems operations are now under development at the H.S.F.P.U.

A master model is being designed which will accept inputs from the JCL3W and other models and permit input-output and efficiency analysis of interaction within the system. This analysis will help develop answers to such questions as those listed in section 2.4.(p.20).

4. SOME DIFFICULTIES AND THE NEED FOR MORE RESEARCH AND DEVELOPMENT

Six years ago, W.J.Pratt wrote an article entitled "Education - Rich Problems and Poor Markets".[24/]

The problems to-day are richer than they were in 1961 and the markets are no longer so poor.

At the macro-level of national or state planning, there is growing awareness that explicit analysis is required if society is to reap a good return from its intellectual resources and its educational investment.

At the micro-level of school systems and universities, decision-makers are feeling a growing need to make the most efficient use of the resources put at their disposal. Very much can be done to improve efficiency, and educational administrators are increasingly willing to try systems analysis and related techniques if they show reasonable promise. The University of Toronto is now investing very substantial resources in systems analyses of itself. A most prominent systems analyst is now President of the University of California and much good work is being done there. Other universities are entering the field.

From a richness of problems and a poverty of markets, educational systems analysis is moving to confront the vastness of need and the difficulties of implementation. Some of the difficulties mentioned below may be unique to the University; in various degrees most are probably common to many other universities.

4.1. Pressure

Systems analysis to increase efficiency in educational resource allocation was begun too late. Not too late to do any good, but too late to contribute what it might have to the enormous educational expansion of the late 1950's and 1960's.

Hundreds of universities are in the advanced stages of educational investment programs whose returns will be far less than they could have been. But contemplation of the missed opportunities is depressing and our gaze should be directed ahead.

Some university administrators now perceive how valuable can be the better information that systems analysis can provide. The result is that systems analysis groups, where they exist, are under tremendous pressure to produce results fast. Each day's delay agonizes those who must feel that decisions must be made yesterday. There is a tremendous thirst for information.

Some remedies for this are the following:

(1) University decision makers need help in setting future targets for the completion of facilities and implementation of programs. When this has been done, target dates for major decisions can be rationally established. Critical path networks can be established for the information gathering and analytic activities leading up to major decisions.

(2) More financial support should be allocated to systems analysis for educational efficiency. The payoff is very great.

(3) Systems analysis groups must be partially insulated from the pressures of to-day's decision-making so that they may forge better analytical tools for tomorrow's problems.

4.2. Multiple Goal Structures

Most of to-day's systems analytic tools were developed to support decision-making in organisations with unitary goal structures. Industry and the Department of Defense are organised as hierarchies and most people in those systems accept the existence of a dominant objective function, i.e., that of the top management or the Commander in Chief.

Universities are loose-knit organisations with multiple objective functions and diffused power. Deans, departments, professors with tenure and even students may harbor objectives that conflict mutually and with the objectives of the university administration, the board of trustees, alumni groups, and the government.

Conflict is mixed with commonality of interest in universities and truly useful systems analysis must take account of this. Some tools, devised for hierarchical systems, are less useful in this unfamiliar environment. This is notably true of optimising models.

Systems analysis for university decision-making can benefit from political and sociological organisational analysis.[25/]

4.3. Difficulties of Measuring Outputs

If goals and objective functions are extraordinarily difficult to specify, outputs inevitably must be difficult to identify and measure. There are many problems to whose resolution systems analysis will be better able to contribute when we have better criteria for measuring the output of our universities.

This partial list of difficulties points the way for future work. The market is no longer poor, it is buoyant.

APPENDIX

TABLE 1

Selected Statistics of Eleven Hospitals Associated with the Faculty of Medicine, University of Toronto

Institution	Type of Hospital	Number of beds as of 31 Dec. 1966	Number of patients admitted in 1966	Number of patient days of care in 1966	Number of paid hours of work in 1966 (millions)	Per cent of paid hours of work devoted to medical education in 1966	Number of medical specialists graduated (excluding doctors) in 1966	Gross Operating Costs in 1966 ($ millions)	Percent of revenue from the OHSC.
Toronto General Hospital	general	1,391	27,116	425,290	7.2	4.8	108	20.7	90
Toronto Western Hospital	general	851	18,556	251,998	4.3	4.8	63	12.4	92
St.Michael's Hospital	general	894	19,154	289,841	4.7	3.8	162	12.2	93
Wellesley Hospital	general	454	6,980	103,339	1.9	6.8	46	5.8	95
Princess Margaret Hospital	Cancer Institute	120	2,677	38,244	1.2	2.3	4	5.4	99
New Mount Sinai Hospital	general	373	10,938	113,257	1.7	5.6	58 (a)	5.9	96
Sunnybrook Hospital	general (formerly veterans)	987	n.a.	41,638	0.8	3.6	2	2.5 (b)	75 (b)
Sick Children's Hospital	Paediatric	848	26,224	234,958	5.2	4.5	61	15.5	94
Clark Institute of Psychiatry	Psychiatric	206	264	12,886	0.4	1.0	n.a.	n.a.	n.a.
Women's College Hospital	general	280	8,088	83,327	1.4	2.4	51	3.8	98
Lyndhurst Lodge Hospital	spinal rehabil-itation	50	195	17,543	0.2	0.1	n.a.	0.5	75
Total		6,554	120,192	1,612,321	29.0			(84.7)	

a. Includes Nightingale School of Nursing

b. From October 1, 1966 only.

Source: Ontario Hospital Services Commission. 1966 Annual Report, (Statistical Supplement), Toronto, 1967.

TABLE 2.

Undergraduate Enrolment in Medicine
University of Toronto, 1949/50 - 1966/67

	First year	Second year	Third year	Fourth year
1949/50	165	-	-	-
1950/51	164	158	-	-
1951/52	156	152	169	-
1952/53	157	149	162	170
1953/54	150	150	155	160
1954/55	131	146	154	152
1955/56	163	125	145	151
1956/57	149	151	124	140
1957/58	161	149	147	123
1958/59	168	153	140	147
1959/60	154	158	148	144
1960/61	149	152	152	146
1961/62	152	144	148	150
1962/63	175	143	133	147
1963/64	161	166	129	133
1964/65	176	147	159	127
1965/66	161	182	134	157
1966/67	155	177	181	133
1967/68*	160	178	168	179
1968/69*	160	183	169	166
1969/70*	225	183	173	167
1970/71*	225	247	173	171
1971/72*	225	247	234	171
1972/73*	225	247	234	232

Source: J.W.Steiner, K.Arakawa, M.L.Chipman, and G.C.Crawford; Studies on Medical Education, 1947-1966, University of Toronto (Mimeograph), 1966, pp.147-159.
Presidents Report, University of Toronto, 1966.

* Projected.

FOOTNOTES

1/ E.S.Quade; *Military Systems Analysis*, RAND Corporation, RM-3452-PR, January, 1963, p.2.

2/ R.N.McKean; *Government Efficiency Through Systems Analysis*, Wiley, 1958.

3/ The isoquant, so familiar to economists, is an input transformation surface and the production possibility curve is an output transformation surface in two-dimensional space. Obviously it is possible to generate many types of transformation surfaces (efficiency frontiers) by setting constant different combinations of $Z_i \epsilon Z$. The "production function" is defined as an efficient mapping of inputs into outputs. What we have called "efficiency" analysis corresponds to "suboptimisation" as defined by Hitch and McKean. See C.A.Hitch and R.N.McKean; *The Economics of Defense in the Nuclear Age*, Harvard, 1960.

4/ P.A.Samuelson; *The Foundations of Economic Analysis*, Harvard, 1947, Chapters III - IV.

5/ P.M.Morse and C.E.Kimball; *Methods of Operations Research*, MIT Press, 1951.

6/ H.Kahn and I.Mann; *Techniques of Systems Analysis*, RAND Corporation, RM-1829-1, June, 1957.

7/ E.J.Mishan; *Welfare Economics*, Random House, Chapter 1.

8/ Included are the faculties of Medicine, Dentistry, Pharmacy, and Food Sciences, the schools Nursing, Hygiene, and Physical and Health Education, and the Banting and Best Department of Medical Research.

9/ The departments are Anaesthesia, Bacteriology, Biochemistry, Institute of Bio-Medical Electronics, Medical Biophysics, Medicine, Obstetrics and Gynaecology, Ophthalmology, Oto-Laryngology, Paediatrics, Pathological Chemistry, Pathology, Pharmacology, Physiology, Preventive Medicine, Psychiatry, Division of Rehabilitation Medicine, Surgery, Therapeutics, Art as Applied to Medicine. See Faculty of Medicine Calendar for 1967/68.

10/ The eleven institutions are Toronto General Hospital, Toronto Western Hospital, St.Michael's Hospital, Wellesley Hospital, Princess Margaret Hospital, New Mount Sinai Hospital, Sunnybrook Hospital, The Hospital for Sick Children, The Clark Institute of Psychiatry, Women's College Hospital, and Lyndhurst Lodge Hospital. Each of these hospitals, except for Sunnybrook, is governed by its own board of trustees. Sunnybrook, formerly a veterans' hospital, was presented to the University of Toronto on October 1, 1966.

11/ The Toronto General, New Mount Sinai, Sick Children, and Women's College hospitals are within two blocks of the corner of College St. and Avenue Road, i.e., in immediate proximity to the medical science buildings on the main campus. The Clark Institute is five blocks from the intersection. Toronto Western, St.Michael's, Wellesley, and Princess Margaret hospitals are within one and one-half miles of the campus. Lyndhurst Lodge is about two and one-half miles from the campus

and Sunnybrook is about six and one-half miles distant.

12/ For example, clinical service to patients is considered by the hospital boards of trustees and the clinical staff to be a main, if not the sole, output of the system. But the University's Board of Governors' Special Committee on the Future Development of the Faculty of Medicine mentioned as objectives only education and research, i.e., service was excluded. Presumably, then, patient care was considered by the Special Committee to be an input to or a by-product of the education and research processes. See the Report of the Board of Governors' Special Committee on the Future Development of the Faculty of Medicine, May 1964 (mimeograph).

13/ Ibid., P.11.

14/ Ibid., pp.27-28.

15/ Ibid.

16/ Ibid., P.28

17/ "A Proposed Plan for an Undergraduate Medical Curriculum", Recommendation of the Curriculum Committee, January 3, 1967.

18/ Approximately 700 members of the Faculty of Medicine hold University appointments. Of these only about 200 hold full-time appointments and nearly all of these are members of the basic science departments; the number of full-time members of clinical departments is very small. This information is supplied by the Academic Service Unit.

19/ See the Report of the Special Committee of the Board of Governors, op.cit., pp.17-20.

20/ The first of the models (the CAMPUS model) developed at the University of Toronto was described in R.W.Judy and J.B.Levine, A New Tool for Educational Administrators, University of Toronto Press, 1965. This model is now being implemented and tested by the University's Office of Institutional Research. The model described in this paper is an extension of the CAMPUS model to a very disaggregative level.

21/ These are not input-output models in the Leontief sense although they are of the same family.

22/ It is called the JCL3W Model because it was designed by R.W.Judy, S.Centner, J.B.Levine, R.Wilson, J.Walter, and W.Wolfson. For a more technical description of this Model, see S.Centner and W.Wolfson; Simulation and Rational Resource Allocation in the Health Science Faculties", a paper presented at the meeting of the Institute of Electrical and Electronics Engineers Conference, March 22nd, 1967, New York, N.Y.

23/ A special report generator was written for the JCL3W Model and other models under development at the H.S.F.P.U. See C.A.Burgess; A Report Generator Program, Unpublished M.A.thesis, Department of Computer Science, University of Toronto, October, 1967.

24/ Management Science, Vol.8, No.4, July, 1962, reprinted in Martin K.Starr, Executive Readings in Management Science, Macmillan, 1965, pp.298-308.

25/ See, for example, C.March(ed.), Handbook of Organisations, Rand McNally, 1965, and J.C.March and H.A.Simon, Organisations, Wiley, 1958.