DOCUMENT RESUME

ED 030 284 EF 003 356

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Pub Date Apr 69

Note-14p.. A paper presented at the meeting of the American Association of Collegiate Registrars and Admissions Officers, Dallas, Apr 20-24 1969

EDRS Price MF-$0.25 HC-$0.80

Descriptors-Campus Planning, Computer Science, *Facility Utilization Research, *Higher Education, *Research Methodology, *Scheduling, *Space Utilization

Ten units in higher education employing computer techniques which used a key measure relecting the relative degree of flexibility available to an institution for scheduling its instructional program are reported upon. Other measures which have been employed are described in the form of a short history of space utilization in higher education and the consequences of earlier studies are discussed. (FPO)

The Impact of Academic Program Structure on Instructional Space Utilization*

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A Paper Given at
the Meeting of the American
Association of Collegiate Registrars
and Admissions Officers

Dallas, April 20-24, 1969

*The research reported in this paper was supported in part by a grant from the ESSO Education Foundation

PART I: AN OVERVIEW

1. A Short History

In the organized instruction program of a college or university, students enroll in courses to work with faculty members in learning about a particular field of knowledge. The courses they take in any one term are more or less determined by the requirements of the degree program they are pursuing, plus a variety of other influences. "Students enrolling in the courses offered by the faculty" seems a simple enough matter. However, several hundred or several thousand students--each registering for several courses, each having need for different mixes of courses from term-to-term--create an enormous number of possible combinations by which instructional activities may be scheduled. This complexity is compounded by the need to order the use of faculty instruction time, and it is further compounded by the need to schedule course activities into available instructional rooms of appropriate size, type, and location.

In a simpler age, the college curriculum was less diversified, more extensively prescribed, and more homogeneous; the classroom and teaching laboratory facilities were simpler; rates of growth were slower; the pace of academic life was more leisurely. A particular professor had his particular lecture room or laboratory outfitted with the maps, charts, or apparatus needed for his customary mode of teaching. Students signed up for his course with the registrar (or even directly with the professor, himself) primarily as dictated by curriculum requirements. The schedule of when and where the course was to be taught was largely determined by the preferences of the individual professor. The coordination of schedules to minimize time conflicts between required courses

was worked out over time, and scheduling was as much a matter of habit as anything else. There was no acute scheduling problem, and nobody worried about rates of room utilization or student station occupancy.

The explosive growth of higher education after World War II shattered that golden era. Acute growth in size, complexity, and diversity of academic programs has made the tasks of registration and scheduling extremely difficult. At the same time, rapid growth demanded such massive increases in capital outlay for higher education facilites that concern for more efficient space utilization has become almost a national fetish.

The bulge of enrollments under the G.I. Bill of Rights after World War II made us acutely aware of the problems of assigning large numbers of students into courses and scheduling courses into limited and fixed-size facilities. As the G.I. enrollments subsided, the higher education community turned its attention in the early 1950's to "The Impending Tidal Wave of Students."[1] Projections indicated a doubling of college enrollments in the coming decade, the combination of high postwar birthrates, growing demand for education beyond high school, and the massive expansion of research and graduate functions.

These forecasts of unprecedented growth led to a rash of statewide higher education surveys and institutional self-studies to plan for meeting the expanding demand. Since capital expenditures were the most obvious and definable needs, many of these studies focused on improving the utilization of existing space as a device for easing the burden of cost. The notion that colleges and universities were guilty of serious under-utilization of space became widespread among legislators, foundations, trustees, and the interested public. Within institutions, shortages of office, research, and other kinds of space led administrators

to seek more intensive utilization of classrooms so the surplus could be converted to other uses while the long process of building new buildings was launched.

Landmark studies, such as the California and Western Conference Cost and Statistical Study and the Restudy of the Needs of California in Higher Education,[2] advanced the technology of measuring space utilization and developing standards for facilities planning. John Dale Russell and James I. Doi applied their methods of assessing space utilization in New Mexico, and other states followed their leads. In 1957, under the auspices of the American Association of Collegiate Registrars and Admissions Officers, Russell and Doi published their Manual for Studies of Space Utilization in Colleges and Universities.[3]

In most of these studies, while other types of space were included, the utilization of classrooms and teaching laboratories -- scheduled instruction facilities -- captured the focus of attention. Even though space inventories showed that these instructional facilities were as little as 5 to 10 per cent of the total nonresidential floor area of an institution, the fact that scheduled classroom use and student station occupancy were relatively easy to measure caused unwarranted weight to be given these measures, especially by state legislatures seeking ways of easing the burden of setting priorities for capital expenditures. The measure became the message!

In spite of the pleas and warnings of the wiser spacemen, instructional space utilization became a major criterion for ranking institutions and projects according to need in the allocation of resources for higher education facilities.

In the meantime, the harried registrar was struggling to get growing volumes of students and courses scheduled into a relatively

constant schedule week and a relatively shrinking supply of rooms (thanks to improving utilization and tardy construction). By the late 1950's, the advancing arts of data processing and computers were being looked toward as the source of salvation. Extensive machine records programs were developed for registration and student course record processes. Especially in institutions that had large-scale computers, experiments were started to find ways of using the computer to section students into courses and to find better methods of schedule-building. The objectives of these efforts typically were to use the power of the computer to manage the complex problems of sectioning students to achieve their programs with a minimum of conflicts and to plan course schedules to achieve more efficient utilization of instructional facilities.[4]

2. The Consequences

Although much progress has been made in the development of sophisticated computer sectioning systems it is fair to say that much work needs to be done at this point before computer scheduling has reached a workable and fully satisfactory level.

It is not insignificant that one of the early manifestations of contemporary student unrest was the bending of IBM cards. We are a long way from synthesizing the rigorous demands of computerization with the individual human needs and values of the student and faculty member. One of the serious problems of many modern student sectioning systems is the difficulty of accommodating shifting student demand to relatively inflexible faculty resources and quite rigid facilities.

Most student sectioning systems work with a pre-established schedule of courses, which defines the times and days of the week in which the course will meet and the location of its meeting. The numbers

of sections to be offered depends on faculty resources available. The sizes of sections are limited by a combination of pedagogical definitions of maximum class size or, more often, the number of spaces available in the room in which the class section is scheduled. Students select the courses they want to take from the predetermined schedule of courses, presumably avoiding time conflicts in the process. Their course requests are fed into the computer and matched against the available capacity in the sections. The individual student course schedule is produced in the process. When course request demand gets out of phase with available capacity, large numbers of unfilled requests result. Given the temper of the times, this is viewed as another manifestation of the evils of a bureaucratic and dehumanized educational system.

As the result of increasing tendencies of colleges to move away from highly prescribed curricula toward more open elective systems, and as the result of the student search for the meaning and relevancy of education to their personal lives, unpredicted shifts in student interest have been manifested in many institutions. Since physical facilities are very difficult to modify quickly (in spite of efforts to create more flexible facilities) and because faculty resources cannot be easily shifted overnight, it is almost inevitable that this somewhat unstable student demand will be out of phase in some degree with available resources.

There is growing evidence that <u>excessive</u> instructional space utilization will compound these difficulties and will incur costs that significantly outweigh the savings in floor space and capital outlay gained by high scheduled utilization. If there is at least a modest surplus of available rooms of various sizes, classes often can be shifted

to accommodate unexpected demand. If the distribution of room sizes allows a reasonable excess of station capacity, additional student demand can be accommodated without incurring the cost of setting up additional sections (a cost which includes both additional faculty and the possibility that an instructor added at the last minute will not be fully satisfactory).

The usual response to the foregoing argument is that if colleges will make better use of early morning, late afternoon, evening, noon hour, and Saturday for scheduling, more scheduling time will be available and better hourly utilization can be achieved. When it is argued that students won't take courses and many faculty won't teach at those hours, a coercive response that "they ought to be forced to" is sometimes heard. That is no longer a tenable position.

Donovan Smith, conducting a cost-benefit study at the University of California, reports evidence that increased operating costs (due mainly to small class sizes) substantially offset the assumed saving of higher room utilization achieved by scheduling at unpopular hours.[5] Who knows what other inefficiencies are incurred when sleepy students or a tired instructor are forced to engage in stimulating intellectual exchange at 8 a.m. or 4 p.m.?

We are just beginning to learn how to assess the other costs associated with facilities utilization. We are just beginning to describe facilities utilization in its proper context, in terms of the space and time resources required for the effective accomplishment of the academic program objectives of the institution. Thanks to the emergence of program planning, the concepts of systems analysis, and cost-effectiveness analysis, we are beginning to see ways in which facilities planning can follow program planning, instead of the reverse.[6]

Hopefully, as a result, we may begin to find ways of establishing utilization goals that flow out of the programs of the particular institution. As it is now, we are using or trying to use space utilization "standards" that were developed mainly in the early 1950's for other institutions.

How many states have "borrowed" the space utilization standards of the California Restudy? How many have selected a utilization target from the Doi-Scott normative utilization tables (which were based on 217 space utilization studies conducted between 1956 and 1959) without really understanding what utilization at the 80th percentile means?[7] How many building projects containing essential faculty offices, laboratories, and libraries, have been deferred because their standing in the rank ordering of classroom utilization among institutions put them down on the state priority order? How many student programs have been warped because of schedule conflicts and closed sections affected in part by an inadequate supply of instructional facilities of the right sizes? How much precious time and effectiveness is lost because of disjointed class schedules of students and faculty members? From another point of view, what is the cost of increasing potential student-course conflicts caused by compressing the effective schedule week between 9 a.m. and 3 p.m., Monday through Friday, due to student and faculty time preferences?

We cannot begin to deal with these kinds of problems until we have a much better understanding of the relationships between our academic programs and the space and time resources they consume. This study is an illustration of, and, we believe, a significant contribution to, the kinds of analyses needed to begin placing instructional facilities scheduling and utilization in its proper context as resources of the instructional program.

PART II: THE STUDY

The study used data from ten educational units in the Rochester area.* The student course request files from each of these educational units were the source of the data, with the student identification number and a course or course section identification number serving as input to the model. Although the data were derived from real institutional course request files, they are treated in the model simply as different sets of numerical data representing the interaction between students and courses.

These data were processed by a series of computer programs which measure certain dimensions of the structure of the academic programs as they relate to the scheduling and utilization of time and space resources.

The key measure of scheduling utilization capability is a space-time index derived from the interaction of students enrolling in courses. This measure is called mobility. It is a measure which reflects the relative degree of flexibility available to an institution for scheduling its instructional program. This measure is derived from the application of a graph model resolved by an algorithm based on the map-coloring algorithm of topological mathematics. F. W. Arcuri of the University of Rochester will describe the method more fully in a forth-coming publication of the detailed results, to be sponsored by the ESSO Education Foundation.

*These were composed of (1) the undergraduate program and (2) the Eastman School of Music of the University of Rochester; (3) the day program and (4) evening program of Rochester Institute of Technology; (5) St. John Fisher College, a four-year liberal arts men's college; (6) Nazareth College, a four-year liberal arts women's college; (7) Monroe Community College, a large, urban junior college; (8) Le Moyne College, a small men's liberal arts college; and (9 and 10) two regional high schools which were experimenting with computer block scheduling.

The following hypotheses were generally confirmed from the study:

(1) As the average course load per student increases the degree of scheduling difficulty increases.

(2) As the average course or course sections size increases, the degree of scheduling difficulty increases.

(3) The higher the degree of prescribed curriculum in the program (or greater the extent to which students were taking similar course patterns) the easier the scheduling problem becomes.

Each of these measures -- average section load, average section size, and the degree of prescribed or lock-step curriculum -- are descriptive of the general structure of the academic program of the different institutional units. One of the most powerful influences among these variables proved to be the degree of prescribed or lock-step curriculum. Affinity measures the degree to which groups of students are taking the same courses in common patterns. For example, the Rochester Institute of Technology day program showed a measure of extraordinarily high affinity due to the prescribed nature of their program. R. I. T. showed by far the lowest density of course conflicts and a high average mobility. Therefore it should have a more flexible scheduling capability. The effect of a lock-step curriculum substantially offsets the opposing effects of high student course loads and high average class sizes.

The average course load of the student also proved to be a significant factor. The University of Rochester's full-time undergraduate program is a four-course program compared with the typical five or six courses per full-time student in the other units. This lower average course load significantly offset the fact that the University of Rochester has a highly unprescribed and open curriculum.

The study also applied these measures of affinity and density to the detailed instructional program of the University of Rochester. The results of these data clearly show that the density of the course conflicts radically rises as the average class size of the course increases. The study also showed that as the level of the course advances from freshmen through graduate level, affinity rises and density decreases. Affinity rises primarily because students enrolled in undergraduate level courses have much more diversified programs, but as the level of the course advances, the upper division and graduate concentration creates a higher degree of common course patterns among advanced students. At the same time as the level of the course moves from lower division to graduate, the average section size is declining; thus the movement toward smaller section size and the movement toward greater course affinity from freshmen to graduate level courses compound to radically reduce the density of the course conflict matrices among courses at the higher levels.

These results are in some degree logically deterministic in the model as a function of the fact that the more courses a student enrolls in, the more other courses he is likely to bring into conflict with each other. The more students enrolled in a single course, the more other courses are brought into conflict with that course, and so on. The quantitative data derived from the ten educational units and the in-depth study of the University of Rochester program confirmed the hypotheses.

The most important conclusion to be drawn from this is that the study demonstrates the extent to which differences in the structure of academic programs of different institutions significantly affect the degree of scheduling capability and, hence, the level of utilization

which may be achieved by a given institution. By-and-large, the smaller institution may expect a more difficult scheduling problem. This is confirmed in the normative utilization data produced by Doi and Scott, which showed that smaller institutions generally utilize their classroom and teaching lab facilities at lower rates than larger institutions do.[8] The larger institutions have a great deal more flexibility in facilities and courses than smaller institutions.

In terms of policy implications, this study confirms that the allocation of capital resources should not depend on the homogeneous ranking of different institutions and their building projects according to these simple measures of instructional space utilization.

The methodology points toward the possibility that we may be able to discover ways of weighting space utilization according to the utilization capability of the institution as a function of the structure and characteristics of the institution's academic program.

The method, above all, demonstrates the power of mathematically modeling program activities as a means of deriving better understanding of the relationships between program structure and composition and the resource requirements of higher education.

FOOTNOTES

1. Ronald B. Thompson, The Impending Tidal Wave of Students (Columbus,O.: American Association of Collegiate Registrars and Admissions Officers, 1954); see also Thompson's College Age Population Trends, 1940-1970 (Columbus, O.: Ohio State University, 1953).

2. California and Western Conference Cost and Statistical Study for the Years 1954-55 (Berkeley: University of California Printing Department for the Fund for the Advancement of Education, n.d.); A Restudy of the Needs of California in Higher Education, T.C. Holy, et al., (Sacramento: California State Department of Education, 1955).

3. John Dale Russell and James I. Doi, Manual for Studies of Space Utilization in Colleges and Universities (Athens, O.: Ohio University for the American Association of Collegiate Registrars and Admissions Officers, 1957).

4. James Blakesley and associates pioneered computer applications to sectioning and scheduling at Purdue University. The efforts of Robert Holz and associates at MIT toward the development of GASP -- Generalized Academic Simulation Program -- received much attention. See Judith Murphy and Robert Sutter, School Scheduling by Computer: The Story of GASP (New York: Educational Facilities Laboratories, Inc., 1964). Since then many successful computer systems for sectioning students have been developed. For example, see W. A. Douglas and D. C. Hirt, "Computer Sectioning at the University of Colorado," College and University, 42 (Spring, 1967), pp. 264-276. The annuals of AACRAO and the Machine Records Conferences are filled with stories of great ambitions and some successes of schedule-building and sectioning programs.

5. Donovan Smith will report of these studies at the annual meeting of the American Association of Collegiate Registrars and Admissions Officers, April, 1969. Harlan Bareither of the University of Illinois also will give a paper on a similar subject at the same meeting. See Smith's earlier paper pointing up the difficulties of achieving high station occupancy in classroom utilization; Donovan Smith, "Mathematical Models of Space Utilization," in Clarence H. Bagley, Design and Methodology in Institutional Research, Proceedings of the Fifthe Annual National Institutional Research Forum, May 3-4, 1965, pp. 125-128.

6. I have argued elsewhere that in the absence of effective program planning in institutions, facilities planning has served to organize long-range thinking about program development, that program planning results from the demands for decisions regarding enduring facilities. See Thomas R. Mason, "An Inverse Relationship -- The Uses of Facilities Planning for Institutional Research," in Clarence H. Bagley, ed., Research on Academic Input, Proceedings of the Sixth Annual Forum of the Association for Institutional Research, May 2-5, 1966, pp. 81-86.

7. James I. Doi and Keith L. Scott, Normative Data on the Utilization of Instructional Space in Colleges and Universities (American Association of Collegiate Registrars and Admissions Officers, July, 1960), esp. Table 3, p. 6.

8. Ibid.