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William G. Shepherd,

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OPERATIONS RESEARCH IN EDUCATION*

William G. Shepherd
Vice President, University of Minnesota

Paul Grambsch in inviting me to speak to you this noon probably assumed that because my background was engineering physics I was knowledgeable of the field of operations research. Let me quickly dispel any such illusion for the rest of you. I am strictly a seat of the pants pilot in the company of those who, through mathematical modeling techniques attempt to provide for informed judgments about courses of action in complex systems. I hope word of my confession does not have too wide a circulation among my colleagues who will regard it as a confirmation of their worst suspicions.

Operations Research and Management Science have achieved respect for their accomplishments in applying mathematical statistical methods to decision-making processes. I need not tell you that these techniques have been applied successfully to intricate and involved systems. The very wide range of your concerns is reflected in the journals you read which report studies of such diverse matters as compact book storage in libraries, the surveillance of a region by detection and tracking operations, and development planning in underdeveloped countries. And, not surprisingly, it has been suggested that education provides a fertile field for management scientists and operations analysts. In fact, in 1961, at the first joint national meeting of this organization, William J. Platt of the Stanford Research Institute presented a very provocative paper entitled "Education—Rich Problems and Poor Markets." Rich problems, as he says, in that the issues are non-trivial and complex—poor in the market sense, he implies, because education is regarded as sacrosanct and hence ought not to be subjected to scrutiny in the way that business operations are. As a university administrator, I am all too aware of the non-trivial and complex character of the problems of education. As one trained in the analytical attack, I can also attest to the difficulties which one faces in attempting to apply analytical methods to situations which involve some of the intangibles of the mind and spirit. But despite the disproportion between education's need for operations analysis and the scope of its present effort, it would not be a fair presumption that there has been no attempt to apply these methods to the problems of education. Moreover, I believe that educational planners would welcome an increase in the aid of analysts, and that these efforts can have great significance if we can clearly define their purpose. As one you may justifiably regard as a layman in your discipline but understanding of your techniques, I shall want to identify in a few minutes a few of the contexts in which I believe operations research can be useful. But first I should like to talk with you about some of the difficulties inherent in planning for higher education.

*Talk delivered October 9, 1964 at the TIMS-ORSA meeting in Minneapolis.
Our educational process in the United States is clearly one of the most complex of the systems which affect our lives. To appreciate this we need only note that our children are involved in formal schooling for periods ranging from 13 to 23 years. We demand first and foremost that the system provide training in basic skills for all. It is expected to prepare young men and women for a wide range of vocations and professions, as well as giving them opportunities to develop a cultural background which will make them intelligent, interested and effective citizens.

If we think of the educational process as an analogue of an industrial operation, we begin to realize the intricacies of orderly educational planning. Education must operate with raw material which varies widely in quality and, one might add that the raw material seems at times to actively resist processing. Those responsible for processing the raw material also vary widely in quality and preparation and are in continual short supply. The plants in which they carry on their activities are generally too small for the operations and are uneven in their facilities. The working material may be arbitrarily and unexpectedly withdrawn from the production line at various stages and conversely it may be arbitrarily fed into other plants for further processing. The various plants operate semi-autonomously with different techniques and varying goals for their finished products. At a fixed stage in the processing, the working material itself enters into the decision concerning its final form and has a voice in choosing the plant where the finishing touches are to be imposed. Finally, when the product is released to the world, it frequently returns to the plants for retreading and the plants are expected to understand these new needs and provide the machinery to meet them. The plants operate under highly decentralized management with very loose coordination—Stockholders (PTA's, Alumni Organizations) freely and continuously offer advice on techniques and goals.

It is hard to believe that a planner in his right mind would accept an industrial planning position given equivalent ground rules. And yet, our educational system, imperfect as it appears to be, does work, and effectively trains men and women like you to make decisions rationally and wisely.

There is and has been planning in education but there is no question that the planning process can be improved and no question that there is an imperative need for improvement when we consider the staggering demands on education in the modern world. We live in an increasingly complicated society, which is moving forward at a pace which requires the training of a greater proportion of the population to higher levels. A Presidential Commission has proposed that 49% of our high school graduates could benefit from two years of collegiate experience and 32% of high school graduates could benefit from four years. This proposition comes at a time when the college age population is at an all time high. The total number of degrees granted during 1962-63 was the greatest in history. During the 12 month period ending in June, 1963, approximately 410,000 bachelors degrees were conferred. To meet the needs of education and industry, universities are being asked to serve graduate populations as large as the undergraduate populations of two decades ago. In 1962-63, 40,000 first professional degrees, 91,400 masters degrees, and 12,800 doctors degrees were conferred. Moreover, rapid advances in science make continuing education essential if we are to avoid professional obsolescence. At the opposite end of the educational spectrum, we are faced with the need for new educational methods to train those of the lowest intellectual ability so that they may make a useful contribution to our economy in an age when automation has almost eliminated the demand for unskilled labor.
The sum total of these educational demands involves the expenditure of great sums, the construction of new facilities and the development and deployment of more and more educators. Clearly we must make some determination of priorities. The fact that higher education will be involved in crisis in the coming years because of shortages in faculty and facilities is evidence of inadequacy in both our earlier planning and decision making. We have failed in enlisting the support which would have made it possible to prepare more adequately for the situation ahead in part because we have not had the analyses which would spell out the consequences of various courses of action. The result may well be that we will not only fail to reach our stated national goals but find it impossible to serve the coming generation as well as we served their predecessors.

I can, therefore, only applaud the interest of management scientists and research analysts in the problems of education. We have, however, developed our present system of education in response to convictions developed by our society which are fundamental to its health. It is not easy to quantify these and fit them into a mathematical model. We should proceed with an awareness of them.

In an analytical study there is an inevitable tendency to design models where cause and effect relationships are clearly demonstrable. Thus a real concern of educators which creates resistance to the rigid application of analytical techniques is that the economic impact of the professional schools is generally clearly measurable but that this is less easily done for the social sciences and done with very great difficulty indeed for the arts and humanities. And yet the greatest and fastest growing demand at present in higher education occurs in the Liberal Arts areas. And we need only look at the world about us to see how desperately we need a greater understanding of the social forces which control our behavior and a greater understanding of our own purposes. How do we weight these factors in our analysis?

We have attempted national planning in an effort to strengthen our position in science and technology. We have not been completely unsuccessful but the results have not been all that was hoped. Notably we observe that, in spite of an emphasis on the importance to our national welfare and security of science and technology and a concentration of our national resources in supporting the educational activities in these fields, there has been both an absolute and relative decline in the numbers of students seeking careers in them. The effects of our planning efforts have benefited the scientific and technological fields in universities but have had side effects—and one need only review the histories of universities since World War II to demonstrate this. In this period those segments of a university which seem to affect directly our economic welfare, health, or security have flourished while those whose contribution has been less apparent have declined. The college units now facing the most severe demands are now the least healthy. You may say, and probably correctly, this this is a consequence either of lack of analysis or of bad strategy or both. The fact remains that strategies which aim at meeting crash needs can and have distorted our educational institutions so that they are less well prepared to meet expressed demands.

Some of the resistance to planning which Platt mentions arises as a consequence of the scars which educational policy makers have incurred in trying to arbitrate between external pressures to meet national goals and internal pressures to meet needs expressed by student interest. The point I am stressing is that a strategy which is based on the economic effects of education may ignore that fact that man does not always behave or wish to behave as an "economic man." I note that you have already heard talks intriguingly titled, Problems in Message Selection: On the Stubbornness of Horses, and Stochastic Learning in Mice, Men and Machines. These
titles remind me of Dostoevsky’s lucid and ironic discussion of science, man’s choice, and free will in his *Notes From Underground*. Time is too short to do justice to his thesis, but it is in effect this—man is so stubbornly human a creature that he will, if necessary, refuse to behave in his own best interest in order to retain his sense of his own humanity. Let me quote an especially trenchant part of this for you: “It is just his fantastic dreams, his vulgar folly, that he will desire to retain, simply in order to prove to himself (as though that were so necessary) that men still are men and not piano keys, which even if played by the laws of nature themselves threaten to be controlled so completely that soon one will be able to desire nothing but the calendar. And after all, that is not all: even if man really were nothing but a piano key, even if this were proved to him by natural science and mathematics, even then he would not become reasonable, but would purposely do something perverse out of sheer ingratitude, simply to have his own way. And if he does not find any means he will devise destruction and chaos, will devise suffering of all sorts, and will therefore have his own way,” Dostoevsky is I suppose more pessimistic than most of us but I think we should not dismiss his message or his warning. An analytical approach to education must involve a compassionate understanding of man and a compassionate assessment of man’s goals.

My next word of caution is triggered by Platt’s apparent regret that the U.S. educational network is so dispersed that it offers few targets for research analysts. He comments that “fortunately, several leading states, faced with pressures for expanding higher education, are beginning to organize and coordinate their plans” and that “the commissions charged with these planning responsibilities represent logical markets” for operations research. This is indeed true and on one week ago the American Council on Education devoted its annual meeting to discussions of the problem.

Let me parenthetically remark that I do not want you to think that I am being critical of Mr. Platt. His article is a stimulating challenge and it is clear enough that he is not unaware of the concerns which I want to stress today. What does give me concern in the statement of this view is that it seems to overlook the possibility that the dispersal and diversity of our educational opportunity has some real values in spite of the difficulties this poses for the planning process. The ideal situation for planning would be one in which there were uniform goals and uniform measures for standards of performance. Clearly there is a need for coordination of effort and wise decision making in the allocation of resources. We must, however, guard against yielding to pressures which will enforce too rigid a pattern on education. The desire to simplify and unify our educational system so that it will more readily lend itself to a common analytical attack could be a most stultifying force. It would tend to restrict innovations, encourage conformity and lead to mediocrity. What we least want in a vigorous society is a standard man. Moreover, the very diversity of our educational system has always provided us with the best safeguard against the fears of any single source of control of education. Not only is our system itself diverse, but it serves diverse needs and a glory of our educational system has been the multiple chances which it has provided. Many who sincerely express fears that we are wasting scarce teaching resources on marginal talent lose sight of the fact that the dedicated interest in education and the broad base of support for education in the United States stems from the fact of its general availability. Its independence should not be jeopardized lightly.

I cannot too strongly emphasize the importance which I attach to the availability of multiple opportunity in any system of education which we plan. Europe,
in the past, has succumbed to the logical classification of students according to their
demonstration of ability at an early age. Fortunately, we have been more com-
passionate and wiser in recognizing that rate of progress is a normal variant affected
by the cultural background of parents, economic condition and sheer knowledge
of opportunity. What has made the United States a land of opportunity is the general
availability of education and our willingness to bend over backwards to avoid in-
justices by the provision of second chances. Let us not in our planning close the
gates of opportunity.

I have spent so much time in raising warning flags that you may have come
to the conclusion that my earlier invitation for greater analytical participation in
education was given with tongue in cheek. Let me turn now to some of the issues
in which operations research methods can be of great assistance in educational
planning. One of these certainly is analysis to help us plan sensibly the relationship
between our need for teachers and scholars to the potential supply, and to relate
the implications of such planning to the way we organize instruction and research.

One of the most sacred criteria we have used to judge the quality of institutions
of higher education has been the student-faculty ratio. The ultimate ideal has always
seemed to be one student to one faculty member or perhaps better one student seated
on one log facing one faculty member. It has never been entirely evident to me that a
one to one ratio was ideal. Indeed one of the most terrifying discoveries for a young
teacher is that, although he may be the intellectual superior of any single student, the
group stimulation forces him to deal with an apparent IQ much higher than he antic-
pipated. We have much to learn about the ideal class size for various types and levels of
instruction, and the effects of various patterns on our students. We have much to
learn about human learning in general if we are to effectively deal with the rising
demands for education. I have earlier made reference to the goals set for higher
education. We must deal not only with a larger population but also with a larger
percentage of the population seeking college experience. Concurrently, we are ex-
pected to provide for increasing numbers at the graduate level. We have raised
the level of instruction to the point that we need a larger and larger fraction of our
faculty trained to the Ph.D. level. In 1959, a master plan survey team in California
estimated that their state alone would need an average of more than three thousand
new faculty per year during the next fifteen years. This estimate includes all
educational needs and does not therefore mean 3,000 Ph.D.'s per year, but it does
point up, I think, the order of magnitude of the problems we face.

If we insist on maintaining traditional instructional methods and in particular
make a fetish of the student-faculty ratio, we face an impossible situation. It has
been estimated that the maintenance of our present student-faculty ratio and standards
would mean that for the next few years one-half of our total Ph.D. production
would have to seek careers in teaching. In the face of all the other demands this
is totally unrealistic. We must then be prepared to give on standards of faculty
quality or on the student-faculty ratio.

In a witty article entitled "Meager Means and Noble Ends," Economics Professor
George Stigler remarks "I think it is fair to say that the technology of college teaching
is not among the most dynamic branches of modern life. The last really notable
advance in college teaching in recent times was the invention of the printing press."
It is true that academicians are a conservative lot and slow to change the techniques
of their profession. There are refreshing signs of change and we begin to see in-
creasing recognition of the need to adopt some of the principles which have made

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possible the increased productivity in industry. Experiments on the use of closed circuit TV and particularly the use of taped lectures have extended the audiences of the master scholar. In some fields professors have discovered that these techniques make it possible to share experiences with large groups of students which were earlier impossible. Some of the most dramatic examples are in medicine, and particularly in surgery. We have begun to study the strategy of the learning process and applied the findings in improved instructional devices such as programmed texts and teaching machines.

Parenthetically I might remark that some of the early predictions that programmed learning and teaching machines would produce a revolution in education are now being tempered. Those who have pioneered in this field are beginning to speak more cautiously about evolution in recognition that the human learning process is far from simple and does not yield easily to uniform techniques. Research on human learning gives promise of being one of the most exciting and rewarding activities in education. The joining of vigorous research in human learning to equally vigorous analysis of curricular models which will relate our instructional resources most effectively to our instructional needs is a direction of effort urgently needed in higher education. Let me continue with brief identification of other specific areas in which I think significant contributions to educational planning could be made by operations analysts and management scientists.

We badly need careful studies on the optimum size of collegiate units—weighing the advantages of the collective interaction of faculties, i.e., the critical mass, against the disadvantages that they may become so preoccupied with their internal interaction that their external interaction is neglected.

We need careful analyses which would bear on these questions—at what stage should we undertake to replicate institutions? And what demographic considerations should influence this decision?

We need to know in detail and in depth what the local and regional effects of institutions of higher learning are. We need to bring rational data to bear on the question of what mixtures of institutions are needed to serve the needs of a region. We ought to attempt to determine an optimum strategy to govern institutional cooperation.

There are also very real and unresolved problems faced on a less macroscopic scale. For example, how should the internal resources of a large educational institution be deployed? I don't want to imply that this is now done without any kind of operations analysis, although some of you may have suspected this. In reality we have brought to bear the best analytical resources we have available to direct our resources in ways consistent with the structure and purposes of our institution. But I do mean that the allocation of large resources must often be done quickly, and prudence demands that quick action be supported by efficient plans for bringing relevant and accurate information to bear on the decision making process, including information on the consequences of all allocations. As other examples of problems internal to an institution: How can we analyze the effects of different models of disciplinary groupings on the effectiveness and efficiency of our instructional and research programs? What is the optimum distribution of any given faculty in terms of age, rank, and distribution of activity? In an institution the size of the University of Minnesota, how can we estimate the amount of overstaffing for internal operations needed to accommodate the increasing levels of activity by our staff in institutions and programs, domestic and foreign, external to our structure?
Conclusion

I have outlined, all too briefly, a number of the planning questions we face in higher education which might be susceptible to operations analysis. Together we could quickly extend the list. None of these questions is susceptible to easy analysis; all of them seem to invite analysis on a grand scale. But I should like to caution against any preoccupation with the use of operations analysis directed only toward large problems faced by the whole of higher education. The University of Minnesota is, in itself, an institution of sufficient size and complexity, concerned with a sufficiently discrete population and mission, so that the application of operations analysis to the details of our own enterprise would be useful. Indeed, small scale analyses which could be directly used in reference to our internal problems of resource allocation, building priorities, the planning of curricular patterns, and the like might be the best grand strategy for making operations analysis a sufficiently sophisticated and flexible instrument for widespread use in higher education.

Education is in a period of crisis, and we need wise planning. We need skilled help in the development of planning strategies and techniques, and I hope that some of you will join with those of us who carry heavy responsibility for planning in the development of these strategies and techniques.

The successes of education seem sometimes like those of the Sorcerer's apprentice; we seem almost to be creating needs and demands for more and more education more rapidly than we can answer these needs and demands, so that the harder we run, the farther we fall behind. The answer in such a situation is, I am sure, not a retreat from our problems, but rather, an increased willingness to use the instruments that intellect has given us in an attack on the problems that the demand for knowledge has generated.

Text of Talk on Industrial Management Available

The opening lecture at the "Escuela Tecnica Superior de Ingenieros Industriales" of the University of Barcelona was given, this year, by Dr. J. Torrens-Ibern, Professor of Applied Statistics and Operations Research, Dean of the Branch of Organization and Economy at the School.

A substantial part of the lecture—titled "Algo sobre los Metodos cientificos de Gestion Industrial" (Something about Scientific Methods in Industrial Management)—was devoted to the control of decision-models by charts of cumulative sums.

A copy of the published text can be obtained on application from "Seminario de Estadistica Aplicada e Investigacion Operativa" Escuela Tecnica Superior de Ingenieros Industriales, Barcelona (14) Spain.

Argentina Strong in IFORS

Members of TIMS are aware of the interest in Operations Research in most of the countries mentioned below. However, many members of TIMS may not be aware of the great interest in the subject in South America as indicated by the following:

IFORS, International Federation Operations Research Societies, reports voting power of member Societies:

Argentina 11; Australia 9, Belgium 5, Canada 11, Denmark 7, France 14, Germany 11, India 9, Italy 7, Japan 12, Netherlands 7, Norway 7, Spain 5, Sweden 12, United Kingdom 18, U.S.A. 35.

Reported by: J. Chapiro

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