RISK ANALYSIS OF TRAINING PROGRAMS IN EMERGING OCCUPATIONS*

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ABSTRACT

Programs which train people for jobs in emerging occupations face risks (1) of failing to train enough people to fill jobs in the occupation and (2) of wasting resources on training more people than are needed. The lack of information, the growth, and the change in an emerging occupation create significant forecasting errors and raise risk. The reduction of risk requires a training program structure and educational resource management which can adapt quickly and which reduce can reduce the need for highly accurate forecasts. In this paper a simulation model representing the job market in an emerging occupation, forecasting of jobs, resource management, and a two-year training program is analyzed in order to highlight the sources of risk and suggest ways to reduce risk. Results highlight the risk of failing to fill jobs when the traditional methods of forecasting job opportunities are used. Results also show the riskiness of relying upon the traditional two-year training program as the only training vehicle.
Typically an educational institution designs a new program by copying existing educational programs. A secondary vocational school offers a two- to four-year program during the day for teenagers and employs full-time faculty. A community college or technical institute designs two-year full-time programs for high school graduates using full-time faculty. When the manpower needs in an occupation are well-known, copying existing programs can be effective design. However, in an emerging occupation the number of people needed in five to ten years is difficult to estimate. Estimates can be wrong by a factor of two-to-five. With such great uncertainty, design of the education program by tradition may create large economic risks.

This paper employs a simulation model which represents the job market for a single emerging occupation in a large metropolitan area and a single traditional two-year training program which attempts to fill the needs for trained people in this occupation. The model emphasizes the information flow and the policies by which the resources of space, teachers, and equipment are managed in response to the demand for trained technicians in the occupation. It explicitly represents the interactions between the training program and the job market and it shows the financial consequences of the actions taken. The purpose of the paper is to show how simulation models can be used to analyze the risk of training programs. Using such simulation models one can design (1) information flow, (2) resource control policies and (3) the basic structure of the program in order to reduce risk in the environment of uncertainty and change which characterizes training for emerging occupations. To illustrate the process, a traditional two-year program for a technician is examined. The results show that this tra-
ditional two-year program is risky. It either wastes resources or fails to meet
the demand for manpower.

Risk occurs because resource commitments are based upon forecast of man-
power needs which in emerging occupations are likely to contain significant
error. The error is large, both because of the uncertainty of the character-
istics and need for people in an emerging occupation and the length of looking
ahead required of the forecast. The forecast must estimate the demand for
students when they graduate. Consequently forecasts must look ahead to a time
equal to the length of the education program plus the time required to acquire
resources. A five-year forecast is required to make decisions for adding
buildings for a two-year program when the building planning and construction
time is three years.

Errors in forecasting impose two kinds of risk upon educational management.
The first kind of risk is the one most easily understood, the most frequently
discussed, and the easiest to measure. It is the risk of supplying more gradu-
ates than needed. When some graduates are unable to find jobs using the
skills for which they have been trained, there has been a waste of space, teachers,
equipment materials, and students' time. The second kind of risk is failing to
supply enough graduates to fill needs. Jobs will go begging which reduces
economic growth in the nearby region if technicians are critical to an industry.
In addition, some people will be denied careers due to a lack of appropriate
training. However, failure to satisfy demand is hard to perceive because
there is seldom readily available data on unfilled jobs. The extent of the
failure to fill demand is even harder to perceive since not all of the manpower
needs will be expressed in jobs that employers are actively trying to fill. Employers who have failed to fill existing jobs become discouraged and do not invest in equipment, space, and organization to create all the jobs they want filled in the given occupation.

Three elements contribute to risk in an educational program for an emerging technology. The first is error in forecasting. Risk is less with perfect forecasting because resources and graduates could be perfectly aligned with manpower needs. Unfortunately, the uncertainty of the future always exists. However, there are different techniques for forecasting and some are better than others. Inappropriate forecasting techniques create unnecessary risk. The second element contributing to risk are the policies by which resources are managed. For example, the aggressiveness of the policies will influence the type of risk, excess resources or too few graduates, which is likely to occur. The third contributing element to risk is the program design itself. Program design is made up of (1) the length of the program, (2) skills to be taught, (3) the type of students entering the program, and (4) the resources devoted to the program. The length of the program and the time to acquire resources determine the forecasting time which affects risk. The commonness of resources used and skills taught among a cluster of programs affects the speed of acquiring resources and the ability to use them in other programs if need falls. When resources are acquired faster or can be used elsewhere risk is reduced.

Computer Simulation

The methodology for analyzing risk proposed here is system dynamics (Forrester, 1). The assumption is that forecasting, resource management, an educational program, and the job market form a complex feedback system in which the unaided human mind cannot identify the sources and magnitude of risk. How-
ever, this gap in the capacity of the human mind can be filled by a computer simulation model. The human mind, perhaps aided by statistics, is capable of choosing the elements and relationships between the elements in complex situations which matter. But the human mind is unable to describe the dynamic behavior which is created by the complex system. More importantly, the human mind cannot describe the effect upon behavior of changes in a complex system such as changes in forecasting techniques, resource management policy or educational program design. However, the elements and relationships that matter in a complex situation are easily translated into the language of a computer simulation model (Pugh, 3). Computer simulation quickly and inexpensively can show the effect upon dynamic behavior of any change once the theory of what matters has been specified. Thus this approach to understanding what matters in a complex situation, such as the sources of risk, and to designing improved performance draws upon the ability of the human mind to identify relevant elements and relationships in a situation and upon the ability of computer simulation to show the effects of changes in the system upon dynamic behavior.

The Model

The concepts which underlie this model have been stated above, but here they are re-iterated. Risk of educational programs in an emerging occupation comes from the failure of programs to meet demand for manpower or from the expenditure of excess resources and the training of a surplus of graduates to meet demand for manpower. The sources of risk lie in the elements which determine the response of the program to demand. These elements are the forecasting techniques, the resource management policy, and the program design. Riskiness is determined by seeing how the educational program responds to a number of
different patterns of growth of demand for manpower. If the response is good for different patterns of growth, then risk is low. For an example of similar concepts applied to corporate growth see Swanson (4) and Wright (8).

Figure 1 shows the sectors of the model. These are the job market, forecast techniques, resource management policy, and the educational program itself. Let us look at each of these in turn.

The job market sector represents the creation of jobs and the movements of people skilled in the occupation. Jobs are created as employers invest in space and equipment, make organizational changes and actively seek people to fill them. But jobs are not demand for manpower. Demand is the number of jobs which would exist if there were people available to fill them. Employers will not create a job, even though they need the person if they believe the job will not be filled. For example, if an organization needs five people and has already created two jobs which it cannot fill, it will not create the space, make the investments, and change the organizational structure in anticipation of finding three additional people. The job sector also portrays the dynamics of the total labor force in the occupation. Employment and unemployment both of alumni of the educational program and of others skilled in the occupation is shown. Depending upon the unemployment rate, people migrate into or out of the region represented in the job sector. The attrition of people from employment due to death, retirement, promotion, or disillusionment is represented by a fraction leaving each year.

The forecast sector takes information from the job market to predict manpower needs in three years and to forecast the number of people available in three years if there were no graduates from the educational program. In the runs that follow, two techniques of forecasting manpower needs are used. One of them
FIGURE 1: Flow Diagram of the Simulation Model of Resource Management of a Training Program in an Emerging Occupation
is a linear extrapolation of the number of jobs three years into the future. The second is a perfect three-year forecast of demand. Available supply in three years is forecasted by subtracting from the labor force the attrition over three years caused by death, migration, promotion, etc.

The resource management policies use the forecast of manpower needs, the forecast of labor force supply, and information of resources available in order to determine the acquisition (reduction) of resources in the educational program. Tests of two resource management policies -- one aggressive, one conservative -- are shown below. Space, teachers, and equipment are the resources which are managed. In this model finances do not enter the resource policies. However, the financial consequences of the resource decisions are calculated using typical costs.

A program design of two years is examined. In the model the two-year program is represented by the first- and second-year students and attrition of students each year. For this program design, it is assumed that space must be ordered two years ahead of time, equipment is ordered one year ahead of time, and it is assumed that plans are well-enough known one year ahead that the correct number of teachers are available to fill the enrollment needs. It is also assumed that the number of teachers and the amount of equipment can be reduced but that space once constructed for the program cannot be used for other purposes.

This model contains assumptions about attrition rates of students, the ability to reduce resources, costs, the ease of reducing the number of teachers, and other assumptions which differ from specific situations. These differences will make some computer simulation runs unrealistic for specific cases. However, the methodology illustrated is general. Correct representations of specific situations could be made, which would allow proper risk analysis and design of
information flow, management policies and the program for the specific situations. The conclusion that a two-year educational program which utilizes inflexible resources is risky is also generally valid.

Simulation Runs

The purpose of the three simulation runs that follow is to illustrate how one might evaluate the riskiness of a program design. In this case, it is a two-year program which uses inflexible space. It is called inflexible because it takes two years to acquire and has no alternative use. Certain tenured faculty also have these characteristics. We look at how well the educational program responds to ten-year growth in demand for manpower from ten people to 400 people. This growth in demand for manpower appeared typical for an emerging occupation such as bio-medical technicians in a large metropolitan region. Response to this demand is tested for two different forecast techniques and two resource management policies. If performance is always poor for different forecasting techniques and different resource policies then risk lies with the program design.

Extrapolation Forecast

The first simulation is of a typical situation. The forecast of manpower needs is a three-year linear extrapolation of the recent growth in jobs. Linear extrapolation of jobs appears to the authors to be a realistic representation of how manpower needs are forecasted. While the Bureau of Labor Statistics (7) uses more complicated techniques, the underlying assumption is the continued linear movement of changes. Similarly the projection techniques of the Technical Education Research Center assume that changes in the recent past will continue (6).
For the first simulation run, an estimate of labor supply in three years is subtracted from the linear extrapolation of jobs to arrive at manpower requirements. Then resources are acquired in order to fill the estimated manpower requirements. However, the resource management does not start a program until it sees a need for ten graduates a year. Program size is limited to thirty graduates per year. In this simulation it is assumed that the average length of time a person stays in the occupation is three years, i.e., 33 percent leave the occupation each year.

Figure 2 is the plotted output of 162 months, or 13.5 years of computer simulation. The top half of the plots shows job market variables: demand for manpower, jobs, employment and the number of alumni. Scales for the variables are to the left of the plot and cover the range from zero to 500. The bottom of the plot shows variables of the educational program: total enrollment and first-year enrollment are measured in numbers of students and the scales range from zero to 200 for the full plots. Space and equipment are normalized for students and are measured in student requirements and thus has the same scales as enrollment. The number of teachers is shown. The scales for teachers range from zero to 13.33 in order to normalize students and teachers for the student-teacher ratio of 15 assumed in the model. The final variable plotted is the budget which is the monthly cash outlay including both operating and capital expenses. The scale ranges from zero to $40,000 per month over the graph.

Figure 2 shows the poor performance and thus the high risk for typical policies and a two-year program design when faced with rapid growth in demand for manpower. Demand is not filled. For example, at Month 30, potential demand is fifty-five jobs, the educational program is in its first year, and only
Figure 2  Basic Run
eighteen jobs have been created of which seven are filled by the in-migration of skilled people. Throughout the run, jobs are far less than demand and employment is only about two-thirds of jobs. A coupling together of the forecasting technique and program design is the cause of this dismal failure to meet demand. The forecast is based upon the current number of jobs. But the number of jobs depends upon availability of trained people which is determined largely by the graduation rate of the program. We find a vicious circle. The growth in jobs is held down due to the relatively slow increase in the size of the educational program. The forecasting is linear projection of the recent past growth rate in jobs which has been slow. Thus the slow growth is forecasted for the future which continues the slow growth of the program and the failure to meet demand.

Criticism for this poor performance should not be laid upon the forecasting technique. Any forecasting technique which projects jobs based upon past history of jobs will fall into the same trap we have seen here. Since demand, as defined in this model, cannot be measured, almost any forecasting technique will use data about jobs or employment and will then project jobs in the future by some momentum technique. However, both resource management policies and program design can be changed. Specifically, the program design bears heavy blame for this poor performance. Notice the continued large gap between employment and jobs. It is always clear that there is a great need for people in this occupation. The failure to fill need is due to the two years it takes to acquire space in order to increase the size of the enrollment and the two years it takes to graduate a student once he has been admitted. If space could be acquired more quickly, the size of the educational program could increase more rapidly
which would allow employment and jobs to grow faster and fill manpower needs better. In addition, a shorter program could graduate more students with the same resources in order to fill demand more completely.

**Perfect Forecast**

In addition to testing risk under realistic forecasts, one should also test with perfect forecasts. If behavior is poor with perfect forecasts, then forecasting is not the source of risk. When a perfect forecast of manpower needs is assumed, the deficiencies of the resource management policies of the two-year program and of inflexible resources are revealed. Accompanying the perfect forecast is a resource management policy similar to that in Figure 2, i.e., resources and enrollments in educational programs are controlled in order to graduate enough students to fill the gap between demand and supply of people in three years. However, there is no limit on the program size. In addition, this simulation run assumes a more realistic twelve-year longevity than assumed in Figure 2.

Figure 3 is the plotted output of the simulation run. For this plot, the scales of the educational program variables have been doubled from those of Figure 2 while the scales on the job market variables have not changed. As one would expect, demand is filled quite well with perfect forecasting. The difficulties lie in the concept of a two-year program and inflexible resources to fill the needs of the emerging occupation. There are two sources of demand for manpower in an occupation which is growing rapidly. One source of the demand is the need to fill newly created jobs. This is a major source of demand during the rapid growth in the occupation. The second source of demand is to replace those people who leave the occupation because of death, retirement, promotion, or disillusionment. When the length of time on average that a person
Figure 3  Long Occupational Longevity and Unlimited Enrollment with a Perfect Estimate of Potential Demand.
stays in an occupation is long, the replacement needs for manpower is far less than the needs when jobs are growing rapidly. This is shown by the very rapid rise, peaking out, and then the fall in enrollment in the program. The peak in enrollment is approximately three times the enrollment needed to replace those that leave the occupation. The problem is that a two-year program requires more space, teachers, and equipment than a shorter one for the same rate of graduates. Thus when inflexible resources such as special space and tenured teachers are acquired the eventual downturn in enrollment creates waste. The excess space and teachers probably would keep enrollments greater than needed, resulting in graduates having difficulty finding jobs. Thus we see that under ideal conditions, perfect forecasting and a commitment to meet the needs for manpower, a two-year program with inflexible resources at first involves budget demands, $70,000 per month, when the program is growing and later waste occurs when manpower requirements decline.

Needed is a program design which makes a more efficient use of resources during the growth in demand in order to reduce costs. Short-term retraining programs for adults may provide such an answer. Secondly, the inflexible resources are shown to be inappropriate. Neither depreciation of space nor the reduction of tenured faculty by death or retirement could track the decline of enrollment to one-third of its peak value in eight years. Either space which can be used for a variety of programs or rented space would be more efficient in the long run. Similarly an untenured or part-time faculty or one which can be used in other programs is a more efficient faculty.

Conservative Policy

An alternative way to reduce the large budgets and waste in Figure 3 is to adopt a more conservative resource policy. A more conservative policy is shown
in Eq. [1].

\[
\text{desired graduation rate in 3 years} = \frac{2}{3}\left(\frac{\text{estimated labor force in 3 years}}{\text{estimated occupational longevity}}\right) + \frac{1}{4}\left(\frac{\text{forecast manpower needs in 3 years} - \text{estimated labor force in 3 years}}{\text{estimated labor force in 3 years}}\right) \tag{1}
\]

This declares that the educational program will take only two-thirds of the burden of providing skilled manpower and will attempt to fill in one year only one-fourth of the gap between jobs and expected employees available. It attempts to avoid the sharp rise and fall of enrollment caused by the policy in Figure 3 which attempted to fill the gap between jobs and labor force in one year. In every other way the situation is identical to that of Figure 3, i.e., there is a perfect forecast of potential demand, people stay an average of twelve years in the occupation, and resources are the same.

Figure 4 shows the behavior resulting from the conservative policy. The scales are identical with those in Figure 3 which means that the scales for the educational program variables are double those of Figure 2. We see in Figure 4 that resources are more efficiently utilized but the demand for manpower has not been filled adequately. This simulation run and that of Figure 3 point out the riskiness in the program design. It runs the risk of high cost and heavy cash demands if demand is satisfied but while conservative management reduces waste, expense, and cash flow, the risk of not filling demand rises. New program designs are required in order to fill demand while avoiding heavy start-up costs and the eventual waste shown in Figure 3.

Conclusions

The use of simulation to analyze risk has been illustrated. The conclusions of these few tests is that a traditional two-year educational program using in-
Figure 4. New Policy with Unlimited Enrollment and a Perfect Estimate of Demand.
flexible resources is very risky. With typical management, demand for manpower was not filled. Then under more ideal conditions, problems persisted.

These same simulation techniques can be used to find the mix of forecasting techniques, resource policies, and program design which will perform well for a wide variety of patterns of demand growth. Two directions of program design appear promising. One is for an educational institution to develop a cluster of programs which require similar facilities, and can use the same teachers and instructional material. Consequently, resources can be acquired quickly when manpower requirements soars by borrowing from programs where resources are not so urgently needed and when requirements slacken, resources can be quickly used elsewhere. The other way to make program design better appears to mix different paths of training for the same emerging occupation such as full-time adult retraining, night schools, and full-time secondary and post secondary education. In addition, the use of part-time teachers and short-term rental space yields very desirable flexibility in resources.

Accurate forecasting is always difficult. Simulation modeling could find the accuracy of forecasts needed for low risk. It is likely that forecast error can be high and risk can still be low with proper management policies and program design. An important extension of this work is to find the program designs and management policies which are effective with normal errors in forecasting.

Research and applications in business management can provide a methodological guide (Forrester, 1) and can give hints about improved forecasting techniques, management policies and program design (Nord, 2), (Swanson, 4), and (Swanson, 5).
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