A pilot System Dynamics model to Capture and Monitor Quality Issues in Higher Education Institutions: Experiences Gained

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Abstract

This paper describes and reports on a system dynamics (SD) model, developed as a pilot study in order to assess the feasibility of modelling the complex, interdependent set of variables concerned with the various aspects of managing quality in higher education.

The quality of higher education delivered is a major concern for students, institutions and government departments, particularly as the "unit of resource" continues to decline. Quality issues impinge on all aspects of an institution's planning, students' and staff performance, administration and finance.

The initial set of influences were based on relationships identified by researchers in the field of quality standards in higher education. This initial structure was validated and calibrated for this School by incorporating academic and research staff perceptions. These were captured through a survey, subjected to statistical analysis, and were incorporated in the model. Currently, the model contains over 100 variables. A number of runs were made at an average of 25 seconds per run on a Pentium 266 MMX with 126 MB RAM in a Windows NT environment. The model is simulated over an eight-year period.

From the results of this pilot study, it would appear that Higher Education departments may obtain useful insights into the likely impact of educational policies on the attainment of quality related objectives, through the use of such a model. It is emphasised that these results are reported as the first stage of a long-term project. The author would welcome comments from these with an interest in the field, particularly those interested in some form of continuing dialogue or collaboration.

Introduction

This paper reports on a pilot study in developing a system dynamics (SD) model, designed to assist in policy analysis in respect of quality issues by the School of Computing, Information Systems and Mathematics (SCISM) at South Bank University. The project acted as a feasibility study in identifying those factors that SCISM should consider when developing a quality management system within the Department. Under the supervision of the Author, the questionnaire design, administration, interpretation and the modelling simulation and analysis, was carried out by A. Mania with assistance from D. Williams.

As reported in a companion paper (Kennedy, 1998), Quality has been an issue of concern for many organisations in their efforts to achieve their corporate objectives. For higher education institutions, the aim is attaining high quality standards of education and scholarly activities. The main objective of this empirical study was to gauge the impact of educational and managerial policies on quality through the use of a SD simulation model. This initial model focuses on assessing various aspects of quality in the University: administration, staff development, organisation effectiveness, funding, student performance, staff morale and motivation and research.

The model was also used to assess the usefulness of SD in exploring quality issues and funding linked problems in higher education departments and to explain how best to deal with those problems. The initial findings suggest that a SD model may provide insights and support exploration of the process of achieving high quality standards. Such a model may accommodate a non-linear and iterative view, define new boundaries to the development process so as to include hard and soft issues, consider the University's strategic objectives, and acknowledge changes in the education environment.

Reviews of courseware and plans, assessment methods, course structure, quality of units and staff commitment to teaching influence the quality of teaching, which in turn influence student and staff performance.

With the use of influence diagrams, these factors were further broken down into the key variables, which influence quality management in higher education departments. These key variables were further refined by adding performance tables. This process enabled the determination of negative and positive influences. When the model was simulated, fuzzy sets came up with scores of overall quality of the process. Integrating fuzzy concepts into SD models was another achievement of this project, although the main objective was to develop a quality management model.

Quality is a fuzzy concept. It could be graded as High, Medium or Low. The system then uses this information in assessing the overall quality performance. A typical rule conceptually takes the form of IF-THEN-ELSE. Such a model is efficient in determining the level of quality over time. At run time, the block of rules interacts to determine the mean average score of a particular attribute over time. Statistical control methods can be used to control upper and lower limits in a quality performance problem. The third step was used to collect and analyse data to test the model. Simulation runs were performed to test the limits of the model to determine whether it can provide an insight and understanding of the quality management problems.

The analysis of the Quality Management process permits experiments with different scenarios while reflecting the behaviour of expected performance. This will help both management and staff to investigate the impact of specific policies before actually implementing them in the real system. For example, the management would be able to gain insights on the effect of increasing class sizes on research, student performance and staff performance. This study shows a potential role of SD in explaining some of the current phenomena in ever-reducing resources and demand for high quality standards in higher education in the UK.

The model was calibrated using data captured from a survey of staff members within SCISM. Initial results of the analysis indicate that contemporary university departments can explore quality control procedures and gain an understanding into the likely impact of such policies. Many simulation runs were made at an average of 25 seconds on a Pentium 266 MMX with 126 MB RAM in a Windows NT environment. The ability of SD to deal with compression of time and space provides the opportunity to help managers understand their problems and find solutions for them in the shortest possible time. The model contains over 100 variables and further work to expand the scope and model calibration is under way.

The strength of the SD is its ability to handle as well as the ‘harder’ quantitative factors some of the ‘soft’ quality issues. Although the development of this first model was relatively straightforward, we had some difficulty with incorporating academic and research staff perceptions about quality. A survey was conducted of all staff teaching and researching in the school and their perceptions and management’s desired performance over time was captured and incorporated in the model. An area where the model needs extending, is in the student perception of quality issues in the university.

However, the current model at this stage provides some insights and is helpful in explaining some of the dynamic structure identified. The model is simulated over eight years of the school’s management information system’s life cycle. Current plans are to employ a full-time research staff to extend and calibrate further the existing model. This experience shows yet another potential of the initial SD model, both as training and policy analysis in the context of quality control in higher education in the UK.

Higher Education Quality Management Factors

Quality Management in Higher Education can be seen to consist of the various processes or activities within the institution. Some processes are interrelated and their occurrence depends on other activities. Based on the work of Cortada (1995), Ashworth and Harvey (1994) and O'Neil (1994), the author suggests the figure (below) to represent the main issues addressed in Quality Management in Higher Education.

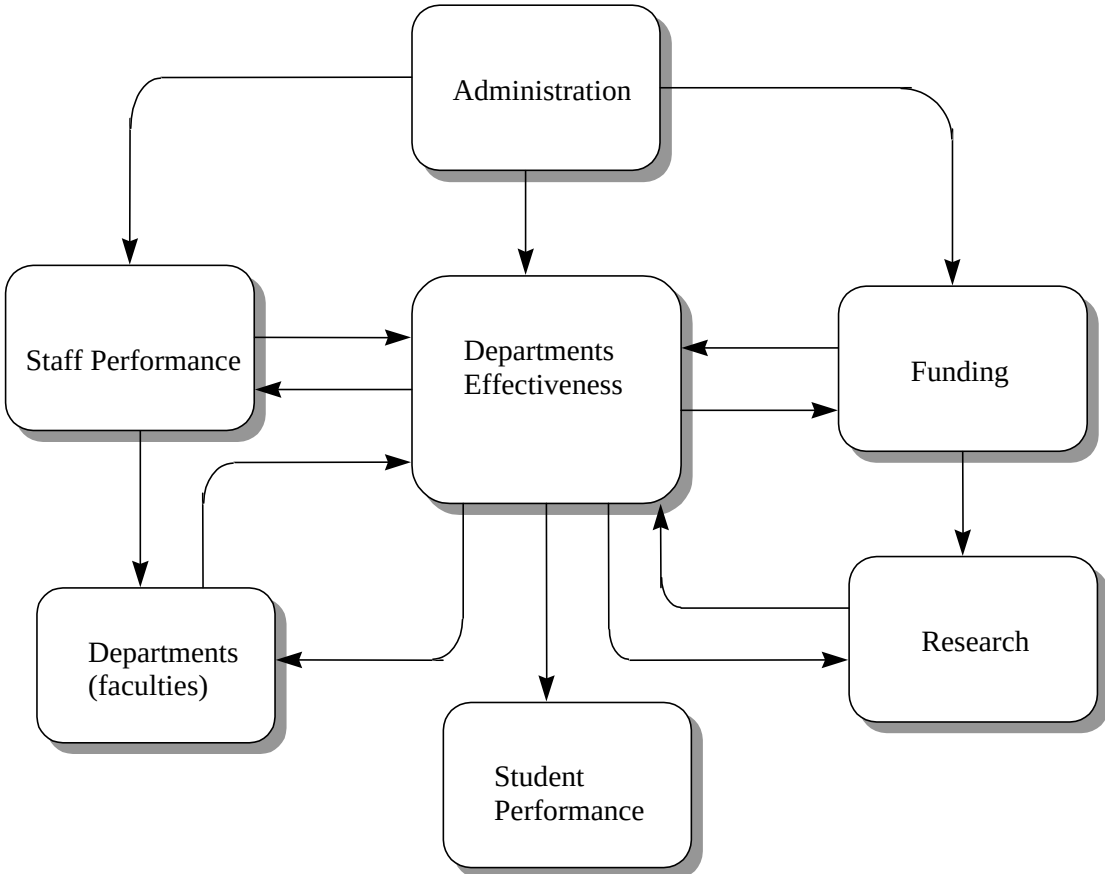

Figure 1: Higher Education Quality Management Factors.

The above diagram gives a schematic view of the main activities affecting quality management of Higher Education institutions from a high level perspective. These factors are examined in great detail in the companion paper (Kennedy, 1998).

In order to measure the quality of institutions of higher education, it is important to assess the various factors that contribute to its overall performance. These include (Ashworth and Harvey, 1994):

- organisation and resources;
- students and their support;
- teaching and learning;
- curriculum ;
- funding;
- research;
- management and quality control policies.

Stages in the Development of the Model

There are three main steps involved in the development of the model:

The first step is to have a good understanding of the main attributes affecting the University as a whole and formulating their relationships with one another. Influence diagrams were used to explain the main influences showing whether they are a positive or a negative influence.

The second step is to build a prototype model using the information obtained from the influence diagram.

The third step will include the collection of data required to finish the model. This data was obtained from the questionnaire of SCISM staff members. Simulation runs will be performed to validate the results throughout the whole model-building process.

Step 1: Influence Diagram

The six key performance indicators of the level of quality identified are quality of Research, Teaching, Professional activities, Administration support, Units and Student performance. The relationship of the variables was captured using system qualitative analysis technique. Influence diagrams can be used to explain main influences and the direction of such influences.

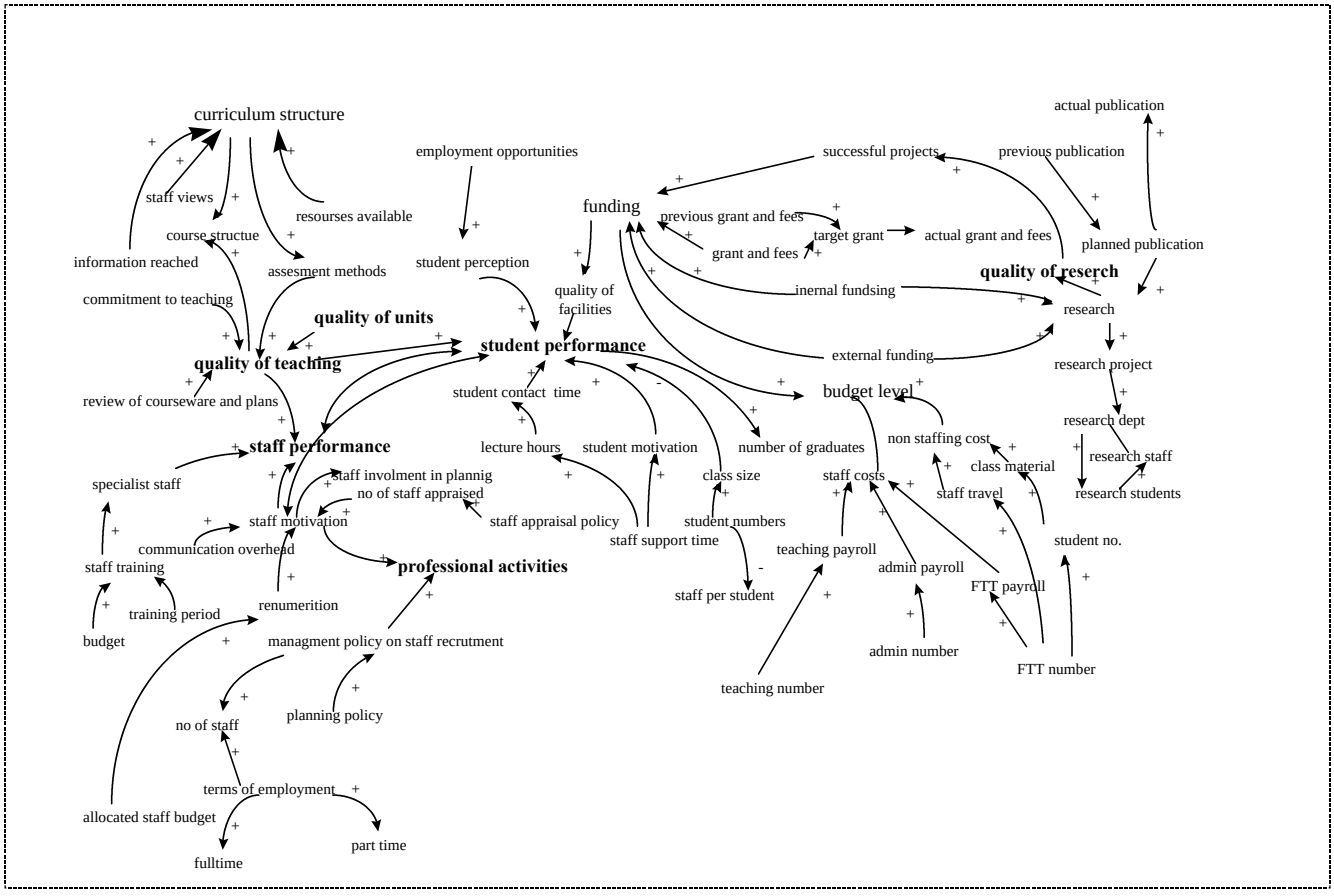

Figure 2: Influence diagram of Key Performance Indicators

From the figure 2 above, it may explain that funding (both internally and externally), previous publications and the research budget influences Quality of Research. This then influences the number of research projects, increase in both research staff and students, funding for more projects, and an increase in publications.

Student performance is influenced by student motivation, quality of facilities, student perception of employment opportunities, quality of teaching, staff performance, student contact time, class size and staff motivation. Student performance then influences the number of graduates completing courses and in turn increases both staff motivation and performance.

The number of specialist staff, staff motivation, staff involvement in professional activity influences staff performance, quality of teaching and student performance. This in return influences student performance.

Staff motivation is influenced by communication overhead (communication lines with management), remuneration (fringe benefits and salaries) and student performance. This increases staff involvement in professional activities though this is also dependent on management policy on staff recruitment.

Constant review of courseware and plans, assessment methods, course structure, quality of units and staff commitment to teaching influence quality of teaching. This in return influences student performance and staff performance.

Step 2: A Prototype Model

The second step was to build a prototype model using information obtained from the influence diagram.

The model building process took a top-down approach. There was a need to identify broad quality areas and their feedback loops.

The model has 7 sectors:

- Staff performance and productivity
- Budget
- Funding
- Student Performance
- Quality of Research
- Quality of Administration Support
- Equipment

Such a model above is efficient in determining the level of quality over time. At run time the block of rules interact to determine the mean average score of a particular attribute over time. Statistical control methods can be used to control upper and lower limits in a quality performance problem.

This results in the sectors of the Simulation model as shown in Figure 3 (below)

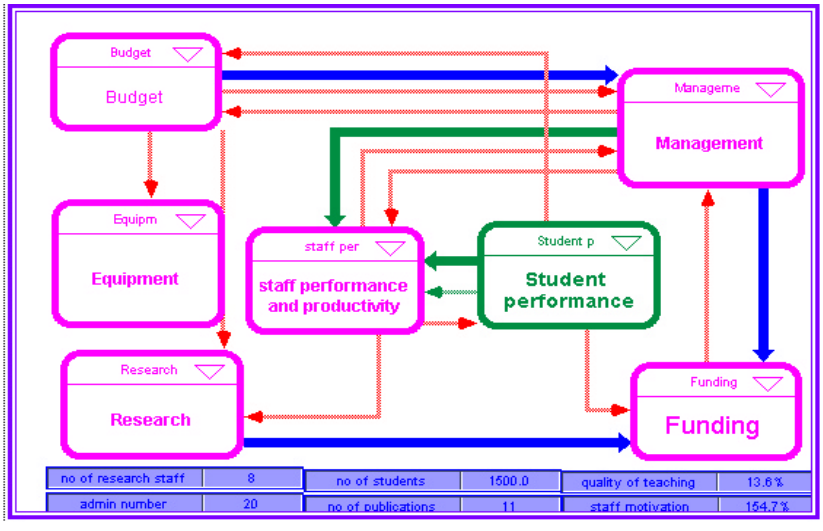

Figure 3: Simulation Model Sectors

Step 3: Data Analysis

The third step was used to collect and analyse data to test the model. Simulation runs were performed to test the limits of the model to see whether it can provide an insight and understanding of the quality management problems.

Many simulation runs were made at an average of 5 seconds on a Pentium 90 with 32 MB RAM. The ability of System Dynamics to deal with complex time and space provides its ability to help managers understand their problems and find solutions for them.

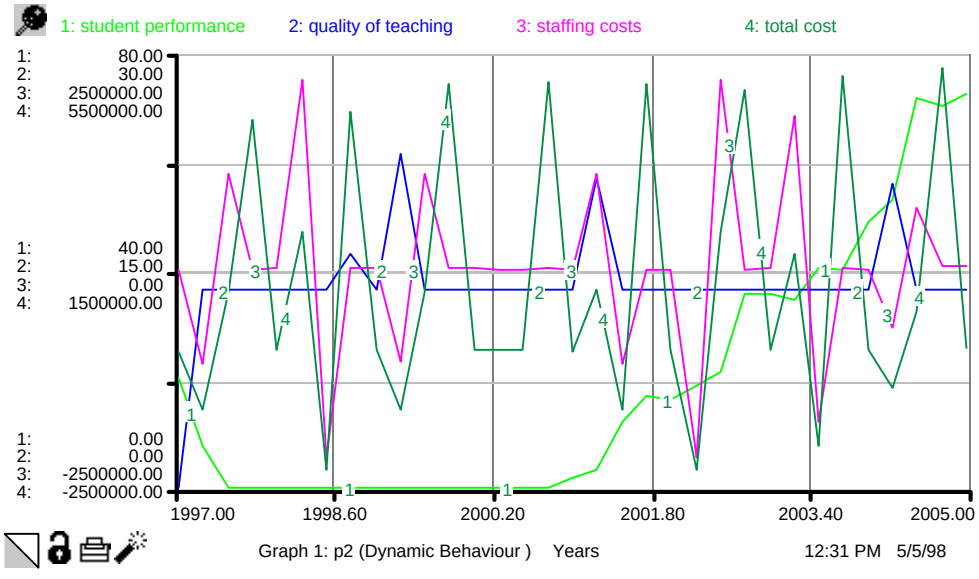

Figure 4: Simulation Results

Figure 4 above shows the simulation results of: quality of teaching, students' performance, staff costs and total costs, based on the model assumptions, over the simulation period.

Summary

The analysis of the 'Quality Management Process' at South Bank University's School of Computing (SCISM) gave the team a starting point to the model building process. The team was able to obtain some, but not all, the data needed to use in the model through the use of a questionnaire to SCISM staff and figures obtained from the Dearing report (1997). One main drawback was that there were no past data records to help gain an insight on the progress made earlier to solve this problem using other methods. Through the use of the questionnaire results, the team was able to identify the main problem areas facing the SCISM in achieving high quality standards of education. The main key issues that needed to be addressed were staff performance, student performance, research, teaching and learning, administration support and funding. The team therefore concentrated on modelling these issues. Due to the fact that this pilot project was carried out during the summer vacation, the team was not able to capture data on student perceptions on quality issues, which would have an impact on the model.

The use of System Dynamics approach would enable the construction of a model that allows interactive 'Process Flight Simulation'. It permits experimentation with different scenarios, and while reflecting the behaviour of the real system, there is no risk of disrupting it. This will help both management and staff to investigate changes to the system before actually implementing them. For example, the School management would be able to gain insights into the effect of increasing class sizes on research, student performance and staff performance.

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