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Education Quality Control Based on System Dynamics and Evolutionary Computation

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1. Introduction

Today, virtually all strategic planning involves the identification of indicators that will be used to monitor progress and often the setting of quantitative targets. As part of a results based management approach, some reward or penalty can be attached to achieve the targets. However, rarely is there an attempt to link explicitly the policy actions with the results, tracing through exactly how a given set of policy actions is expected to lead to the final outcome. The ideas regarding what needs to be done and how to proceed are usually implicit and buried within the minds of policy makers.

The quality management principles have varied greatly from the researchers' point of view. According to (Harris & Baggett, 1992), they classified them into three main principles. The first of them focused on the customer by improving the service quality through improving and training workers. The second principle concentrates on the workers themselves through improving their contribution to increase the education effectiveness. The third principle deals with the contracted service and aims to achieve the standards agreed upon. That could be done through the main factors that can be measured in the education process.

In (Williams, 1993), on the other hand, he stressed on the necessity to have quantitative measures for performance. That can help the organization to measure how far is the achieved progress by applying the quality management program from the point of view of the provided service compared to the service expected from customers. He believed that there are another two directions for the quality management. The first direction provides a tool for the management to increase the productivity and provide customer satisfaction while reducing the unnecessary expenses. The second direction provides a tool that can be used to improve the way we are doing our work.

While in (Michael & Sower, 1997), they considered quality as the quality from the point of view of customers especially in higher education. As the product of the higher education institutes is not visible, the end product can't be analyzed or checked against defects. Thus, when customers are happy with the service provided from the education institute, the quality is acceptable.

Based on an extensive review of literature on Total Quality Management (TQM) in higher education, in (Tribus, 1986), it was proposed a specific definition of "customer" and

developed a comprehensive TQM model that is comprised of eight steps. The definition of "customer" and the TQM model developed can serve as a basic foundation for colleges and universities to follow when implementing TQM at their respective institutions. He also recommended a list of things to do and problems to look for when implementing a TQM project. While in (Motwani & Kumar, 1997), they looked at the applicability of TQM in education and some of the concerns addressed in the literature. They explored the different approaches used by several educational institutions in implementing TQM. They also suggested a five-step programming model that any university can use for implementing TQM.

Oregon State University implemented TQM in nine phases: exploration; establishing a pilot study team; defining customer needs; adopting the breakthrough planning process; performing breakthrough planning in divisions; forming daily management teams; initiating cross-functional pilot projects; implementing cross-functional total quality management; and setting up reporting, recognition, and awards systems as shown in (Coate, 1991).

On the other hand, in (Taylor & Hill, 1992), they examined the emerging paradigm of TQM and summarized its implications for higher education. Rather than prescribing a set of generic implementation steps, they suggested that there are other, more significant, factors to be considered related to the timing of the initiative rather than where it should begin. They discussed four necessary issues: the removal of abstraction from the concept of quality in higher education; organization-wide understanding of the customer; the importance of assessing the current quality level; and the need for strategic quality planning. Also they cited classical organizational facets such as structure, culture, human resource management and leadership as being among the determinants of TQM success. Concentration on these key matters attenuates the importance of the method of implementation. They argued that to disregard these harbingers of success is to risk long term damage to the organization and considerably reduce the likelihood of sustained and self generating organizational improvement.

In producing indicators of institutional quality in Ontario universities and colleges: options for producing, managing and displaying comparative data, the Educational Policy Institute (EPI) assessed the information needs of Ontario's postsecondary system, what types of comparative quality indicator data are currently available, and how effective common higher education data architecture could be structured. EPI found that a wide variety of potentially comparable data existed in Ontario, though not in a centralized or easily accessible format. Examples of this data include Common University Data Ontario, the National Survey of Student Engagement, and commercial institutional rankings. After reviewing several potential models for common data architecture, EPI suggested that an "Open Access Model" would best serve the needs of Ontario postsecondary stakeholders. Such a model would be collaboratively developed and maintained, striving to meet the informational needs of government, institutions, and students as presented by (Educational Policy Institute, 2008).

Despite many approaches became available, Education Quality Control (EQC) is considered a difficult task, as few policy-makers have adequate tools to aid their understanding of how various policy formulations affect this complex, socio-technical system. The impact of EQC is far-reaching, impacting the regional economy, environment, and society through many interactions. The effect of a policy meant to improve one aspect of education quality is not

always known a priori, and the interactions of that policy with other policies are seldom understood well. Additionally, there are not always clearly-defined objectives that all policy planners use as described in (Barski, 2006).

Thus, the goal in this chapter was to develop a proof-of-concept model of the EQC, extended to include the different resources and utilities of the education institute, which can be analyzed to provide insight to policy-makers by comparing the relative effectiveness and interactions across policies.

Once the model was developed and tested, a system optimization was performed. Thus, this chapter aims to better understand the interactions and behaviours of the effect of the resources distribution on the total quality achieved, and to understand and quantify tradeoffs that must be made when choosing a final policy to be implemented.

2. Computer simulation

Simulation is a powerful tool used to study complex systems. It is the development of a model of a complex system and the experimental manipulation of that model to observe the results. Models may be purely physical, such as a wind tunnel; a combination of physical objects under software control, such as flight simulator; or logical, as represented in a computer program.

Computer simulations have been used to help in decision making since the mid-1950s. Building computer models of complex systems has allowed decision makers to develop an understanding of the performance of the systems over time. How many tellers should a bank have? Would the materials flow faster through the manufacturing line if there were more space between stations? What is the weather going to be tomorrow? Where is the optimal place to put the new fire station? We can gain considerable insight into all of these questions through simulation.

Although the definition of systems implies that their objects interact, the more interactions that exist in the system, the better it is as a candidate for simulation as explained in (Pidd, 1994). Thus, the best systems suited for simulation are the dynamic and complex ones. Their characteristics may be understood and captured in mathematical equations, such as the flight of a missile through nonturbulent atmosphere. Alternatively, their characteristics may be partially understood and the best way to simulate them is to use statistical representation, such as the arrival of people at a traffic light.

The keys to construct a good model are to choose the entities to represent the system and correctly determine the rules that define the results of the events. Pareto's law says that in every set of entities, there exist a vital few and trivial many. Approximately 80% of the behaviour of an average system can be explained by the action of 20% of the components. The second part of the definition of simulation gives us a clue where to begin:" and experimenting with that model to observe the results. "Which results are to be observed? The answers to this question give a good starting point to the determination of the entities in the real system that must be present in the model. The entities and the rules that define the interactions of the entities must be sufficient to produce the results to be observed as shown in (Shannon, 1998).

Therefore, the essence of constructing a model is to identify a small subset of characteristics or features that are sufficient to describe the behaviour under investigation. So, a model is an abstraction of a real system; it is not the system itself. Therefore, there is a fine line

between having too few characteristics to accurately describe the behaviour of the system and having more characteristics than you need to accurately describe the system. The goal is to build the simplest model that describes the relevant behaviour.
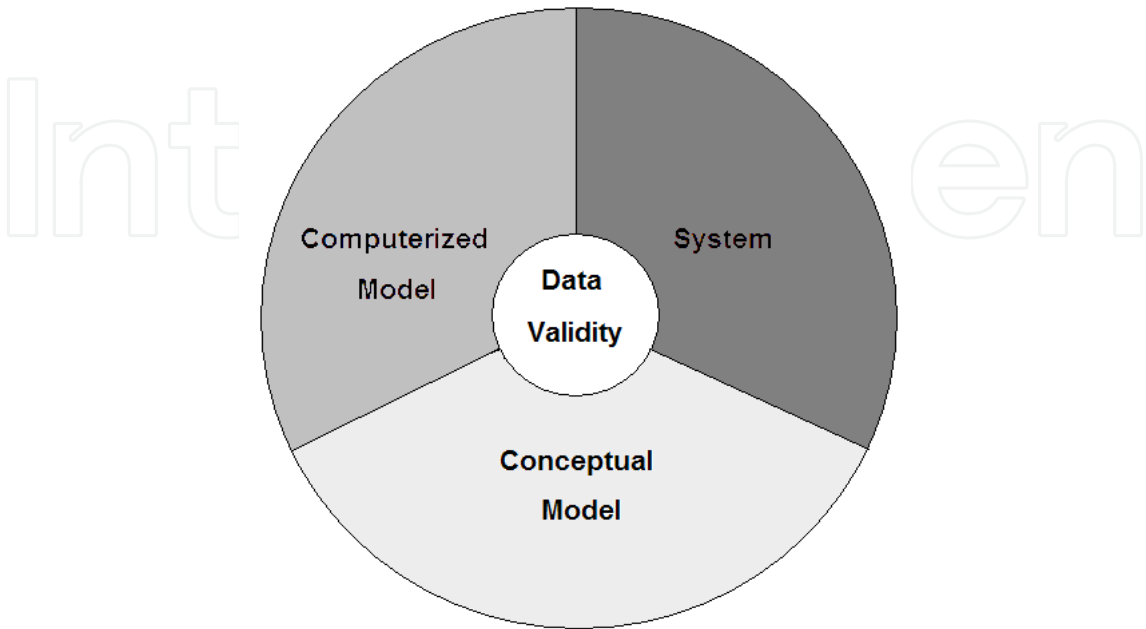

Fig. 1. The modelling process

Because a computer program implements an abstract model, we can consider the simplified version of the model development process as shown in fig. 1. The problem entity is the system, idea, situation, policy, or phenomena to be modelled; the conceptual model is the mathematical/logical/verbal representation of the problem entity developed for a particular study; and the computerized model is the conceptual model implemented on a computer. The conceptual model is developed through an analysis and modelling phase, the computerized model is developed through a computer programming and implementation phase, and inferences about the problem entity are obtained by conducting computer experiments on the computerized model in the experimentation phase. Conceptual model validation is defined as determining that the theories and assumptions underlying the conceptual model are correct and that the model representation of the problem entity is "reasonable" for the intended purpose of the model. Computerized model verification is defined as assuring that the computer programming and implementation of the conceptual model is correct. Operational validation is defined as determining that the model's output behaviour has sufficient accuracy for the model's intended purpose over the domain of the model's intended applicability. Data validity is defined as ensuring that the data necessary for model building, model evaluation and testing, and conducting the model experiments to solve the problem are adequate and correct as explained in (Robert, 2007).

3. System dynamics and model implementation

System dynamics, created during the mid-1950s by Professor Jay Forrester of the Massachusetts Institute of Technology, is considered a way of thinking about the future which focuses on 'stocks' and 'flows' within processes and the relationships between them, the system dynamics approach forces policy-makers to acknowledge upfront if there is uncertainty and to identify where this uncertainty lies as shown in (Zhang et al., 2008). This acknowledgment may make it easier to get people to buy-in to the more systematic approach that is considered in this chapter.

Cutting a system up into bits often destroys the system you are trying to understand. This, of course, is a matter of connectedness: if you break the connectedness of a system, you break the system itself. Rather more subtly, many systems show characteristics that are not properties of any of their constituent parts. It therefore follows that no study, however exhaustive, of any individual constituent part will ever identify the existence of these system-level characteristics, let alone how they behave as explained by (Sherwood, 2002).

It is important to note that the system dynamics approach for monitoring and evaluation does not only consist of the modelling of a complex problem, rather it should be conceived more as a process in which various things occur. First, at the policy-making level, one must specify how a particular target will be reached. That is, one specifies a structural model underlying the achievement of the target. System dynamics tools can help develop such structural models. Second, one must identify exactly what information is needed to ensure that one is on track to achieve the desired results. Third, there should be an on-going review of a program's outcomes, comparing expected outcomes to actual outcomes and, if actual outcomes fell short of expected outcomes, why this occurred. The expected outcomes may not have been achieved because the planned policy actions were not carried out. Or it may be the case that the actions were carried out, but certain key parameter values were mis-estimated. If the actions were carried out and the key parameter values were, indeed, correct, it may be that the underlying structural model was incorrect and needs be reconsidered. With the system dynamics approach, the model is constantly being reconsidered and appropriate modifications and adjustments are expected in the course of one's work as shown in (An et al., 2004).

As one can imagine, taking a more structural approach through system dynamics is much more intensive in the use of information and requires more work than with a reduced-form approach. Although collecting information and allocating the necessary human resources all involve significant burdens, there are certainly ways of reducing these information costs. For example, by identifying the key drivers of desired outcomes within a given system, one can focus efforts on generating the necessary data only for those particular areas. This also helps to reduce the financial costs of collecting information which can be considerable. In doing this, one can thus develop a work program which concentrates work efforts only in certain areas.

It is possible to perform good system dynamics work with many different tools, including spreadsheets and programming languages, though this is not usually practical. There are few software programs that were designed to facilitate the building and use of system dynamics models. DYNAMO was the first system dynamics simulation language, and was originally developed by Jack Pugh at MIT. The language was made commercially available from Pugh-Roberts in the early 1960s. DYNAMO today runs on PC compatibles under

Dos/Windows. It provides an equation based development environment for system dynamics models as shown in (Kasperska et al., 2006).

The Stella software, originally introduced on the Macintosh in 1984, provided a graphically oriented front end for the development of system dynamics models. The stock and flow diagrams, used in the system dynamics literature are directly supported with a series of tools supporting model development. Equation writing is done through dialog boxes accessible from the stock and flow diagrams. Parallel to that, in the mid 1980s the Norwegian government sponsored research aimed at improving the quality of high school education using system dynamics models. This project resulted in the development of Mosaic, an object oriented system aimed primarily at the development of simulation based games for education. Powersim was later developed as a Windows based environment for the development of system dynamics models that also facilitates packaging as interactive games or learning environments. Another language that originally developed in the mid 1980s for use in consulting projects Vensim was made commercially available in 1992. It is an integrated environment for the development and analysis of system dynamics models. Vensim runs on Windows and Macintosh computers as discussed by (Eberlein, 2009). On the other hand, MapSys from Simtegra's flagship systems thinking and system dynamics is another software that allows for the drawing of causal loop diagrams or stock & flow maps using simple drag and drop operations. It can export system diagrams to popular applications such as WORD or simulate it and view the results using a powerful graph editor.

In addition, there are a number of other modelling and simulation environments which provide some support for building system dynamics models and one of these is NetLogo which is a programmable modelling environment for simulating natural and social phenomena. It was authored by Uri Wilensky in 1999 and is in continuous development at the Centre for Connected Learning and Computer-Based Modelling. NetLogo is particularly well suited for modelling complex systems developing over time. Besides being able to use the system dynamics tool integrated into the software, modellers can give instructions to hundreds or thousands of "agents" all operating independently. This makes it possible to explore the connection between the micro-level behaviour of individuals and the macro-level patterns that emerge from the interaction of many individuals as explained in (Wilensky, 1999).

The remainder of this chapter will discuss the proposed methodology to model and assess the education quality system. The model will be further optimised to find the solution that gives recommendations for the best resources distribution that increase the quality.

3.1. Causal loop diagram

Fig. 2. Cause and effect relationship

Casual Loop Diagram (CLD) is considered the first step in system dynamics and it enables complex systems to be described in terms of cause-and-effect relationships. CLD is a visual method of capturing the system complexity providing a powerful means of communication, and its use can ensure that as wide a community as you wish has a genuinely, and deeply, shared view. This is enormously valuable in building high-performing teams and can also help you identify the wisest way of influencing the system of interest. As a result, you can avoid taking poor decisions, for example decisions that look like quick fixes but are likely to backfire.

The way in which real systems evolve over time is often bewilderingly complex. System dynamics enables us to tame that complexity, offering an explanation of why a system behaves as it does, and providing insights into the system's likely behaviour in the future. The key is to understand the chains of causality, the sequence and mutual interactions of the numerous individual cause-and-effect relationships that underlie the system of interest. These chains of causality are captured in a causal loop diagram, in which each cause and effect relationship is expressed by means of a link represented by a curly arrow as shown in fig. 2.

Links are of only two types: positive links and negative links. If an increase in the 'cause' drives an increase in the 'effect', then the link is positive; if an increase in the 'cause' drives a decrease in the 'effect' then the link is negative.
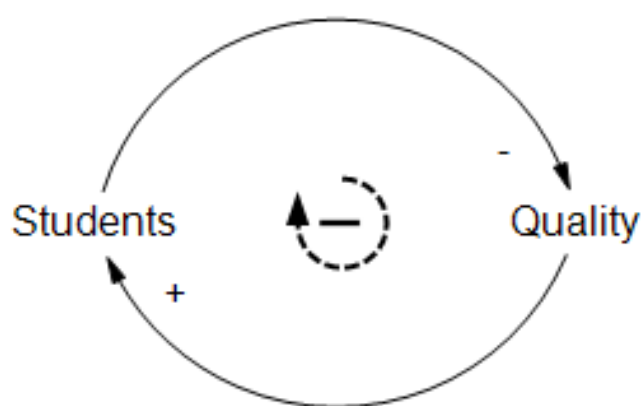

Fig. 3. CLD loop (balancing loop)

CLDs of real systems are composed primarily of closed, continuous chains known as feedback loops. There are only two fundamental types of feedback loop: the reinforcing loop and the balancing loop. Reinforcing loops are characterized by having an even number of minuses around the loop (with zero counting as an even number); balancing loops have an odd number of minuses as shown in fig. 3. The action of a reinforcing loop is, as its name implies, to amplify the original effect on each turn. Reinforcing loops therefore behave as virtuous or vicious circles, depending on the circumstances. The action of a balancing loop is quite different: The system seeks to achieve or maintain a target or a goal. For example, the action of a thermostat in a heating system maintains the ambient temperature at a constant level; likewise, the objective of many budgeting systems is to steer the corporation toward a set of pre-determined goals.

All real systems are composed of interlinked networks of reinforcing loops and balancing loops, often in conjunction with a (usually small) number of dangles, which represent items

that determine the boundary of the system of interest, such as the output of the system or the targets or goals that drive it.

Compiling a good CLD for a real system requires deep knowledge of the system. It also encourages the explicit articulation of relationships that we all know are present but are rarely talked about, and the recognition of fuzzy variables, which are important but difficult to measure, such as the effect of having good staff on attracting and retaining customers.

The original intent for the education quality model was to model large scale regional behaviour and pin point the different factors that affect quality. Some of those factors are naturally the ones set by the standardisation committees responsible for ranking the educational organizations. Other factors are equally important such as students and employees satisfaction and even they are not very tangible, they can definitely guide the optimisation of the budget distribution.

Costs in the quality requirements are attributed to salaries and expenses and include building and facilities, courses, marketing, counselling, libraries and information centres, students' services, legalism and morals, research and environmental services, and scientific evaluation. The total budget is therefore the sum of these costs.

Design factors	Effective weight
Building and facilities	14%
Courses	15%
Marketing	5%
Counselling	5%
Libraries and information centres	8%
Students' services	8%
Research and environmental services	10%
Legalism and morals	5%
Scientific evaluation	5%
Staff level	15%
Management	10%

Table 1. The design factors along with their weights contributing to the university accreditation

The design vector for the model consists of the budget shares for each of the design factors which in turns offer regulatory actions for the education quality. The nine design factors chosen along with another two factors (staff level and management that are not optimized in education quality model) are shown in table 1 (based on the Arabian business schools association), with their percentage contribution to the accreditation quality for each variable as shown in (ARADO, 2009).
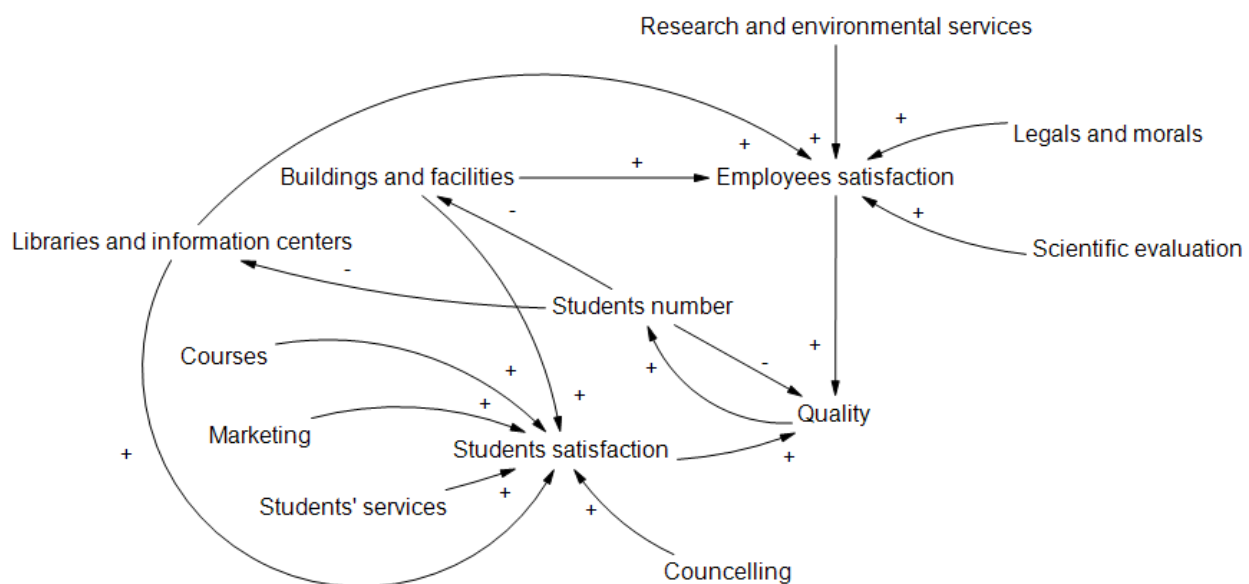
Fig. 4. The education quality control model CLD

The model based on a view of the EQC has been represented and simplified in Fig. 4. In this model the main factors affecting the quality are included for optimization. The quality is mainly affected by both the students' satisfaction and the employee's satisfaction. In addition, the students' number that join the institute can increase or decrease depending indirectly on the education quality. Both the students' satisfaction and the employees' satisfaction are affected by different factors that are improved and maintained by allocating suitable financial resources. The spending can be scheduled on a yearly basis to maximize the total quality of the institute and is based on the effective weight of each factor on the quality improvement. As accreditation is considered another way of evaluating the institute performance, the accreditation criteria plays an important role of weighing the importance of the different institution spending. That spending need to keep the institution facilities within a certain value if not increased. In other words, if some facilities such as libraries and information centres are not improved consistently, they will be obsolete and decrease in value with time. The number of students affects as well the effective value of the libraries and information centres as its increase will definitely decrease their effective value. On the other hand, buildings can increase in market value when lands and building materials goes up. In that sense many institutes directs their initial attention toward buying lands that are suitable for future expansion. The diagram was designed in a way that combines students and employees satisfaction with the accreditation factors in order to improve the over all quality of the institute.
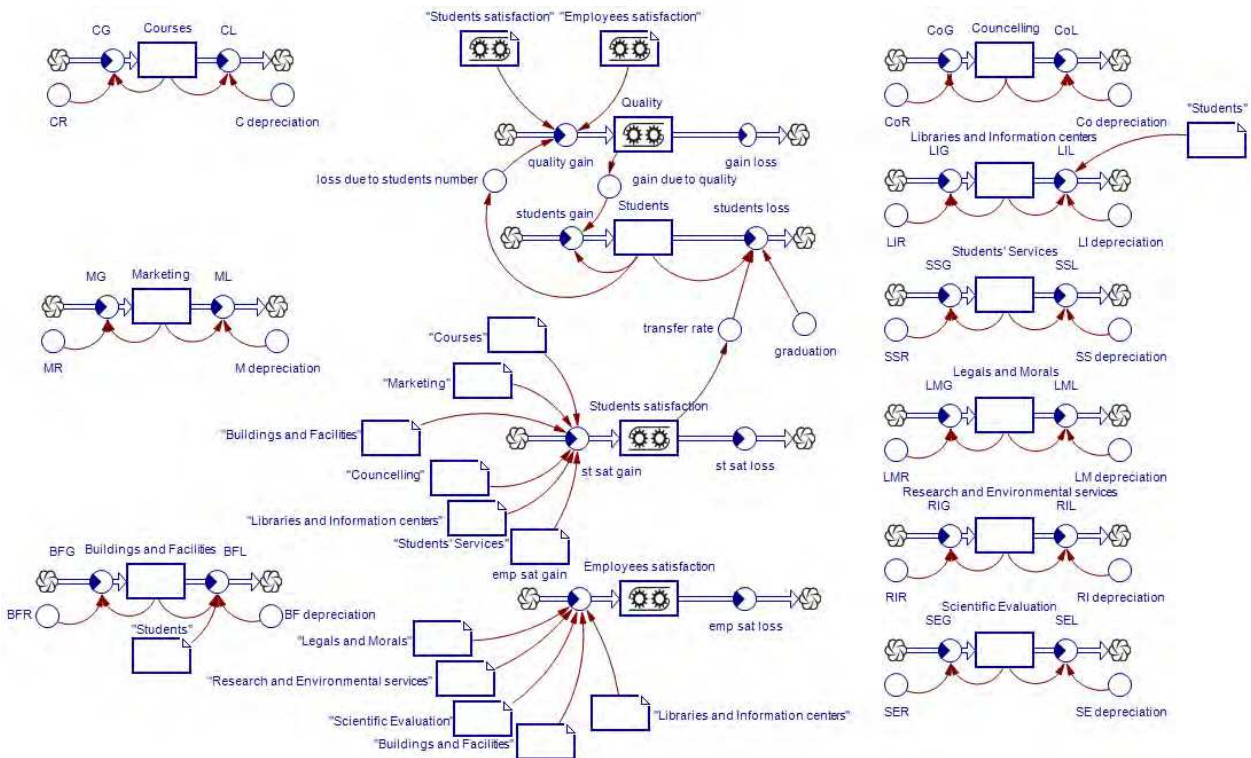
3.2. Stock-flow diagram

Fig. 5. The stock flow diagram for the education quality control model

As can be seen from the view in fig. 4, the EQC model must encompass many factors in order to provide useful data to policy planners. In addition to the more apparent factors such as students' satisfaction, employees' satisfaction and policy planning, a good model must consider the regional economics, supply chain management, and environmental assessment.

To address these issues, a modular model that encompasses the factors listed above has been implemented into the stock-flow diagram as shown in fig. 5. At the highest level, we have a quality module that contains the direct factors that affect its values, such as the students' satisfaction, the employees' satisfaction, and the students' number. At a lower level, we have multiple modules that model a particular aspect such as the courses, marketing, buildings and facilities, counselling, libraries and information centres, students' services, legal and morals, research and environmental services, and scientific evaluation with their effect on both the students' satisfaction and the employees' satisfaction while additional modules can be added if needed.

The quality, the students' satisfaction and the employees' satisfaction are all treated as conveyers while the students' number and the rest of the factors are treated as stocks. Stocks are accumulations. They collect whatever flows into them, net of whatever flows out of them. While in the conveyer, material gets on and rides for a period of time, and then gets off. The transit time can be either constant or variable. That selection was done to be close to the nature of the system as variables that need to keep track of previous values were modelled with stocks while variables that can change periodically independent on the previous values were modelled with conveyors.

3.3. Model equations

Stock and flow diagram only offers us the connection between variables but the real relations are realised behind the scene with equations. Those equations can be a simple equality or a table that connects two variables. The following figure (fig.6) shows a sample of the equations linking the different variables in the stock and flow diagram.
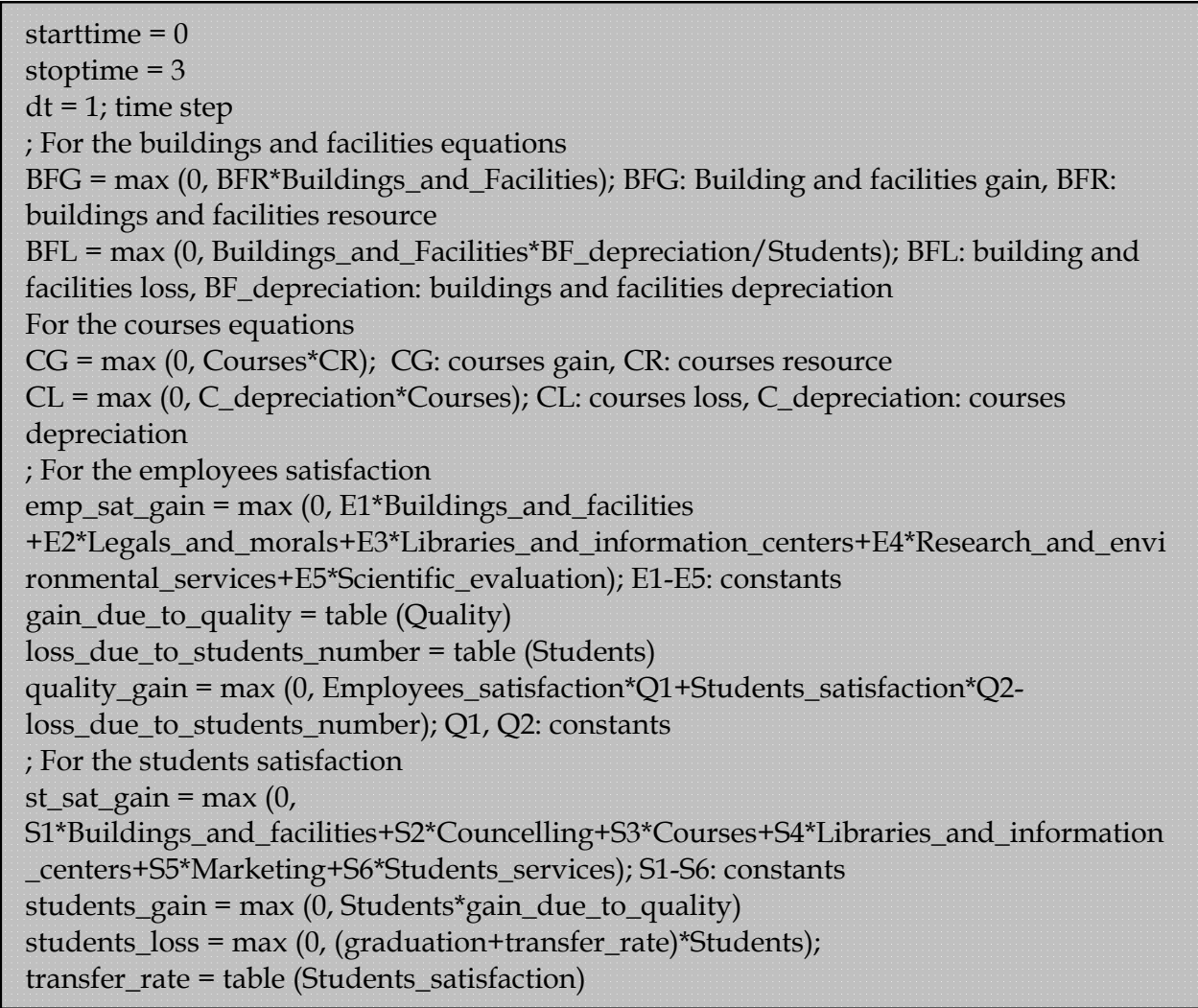
```
starttime = 0
stoptime = 3
dt = 1; time step
; For the buildings and facilities equations
BFG = max (0, BFR*Buildings_and_Facilities); BFG: Building and facilities gain, BFR:
buildings and facilities resource
BFL = max (0, Buildings_and_Facilities*BF_depreciation/Students); BFL: building and
facilities loss, BF_depreciation: buildings and facilities depreciation
For the courses equations
CG = max (0, Courses*CR);  CG: courses gain, CR: courses resource
CL = max (0, C_depreciation*Courses); CL: courses loss, C_depreciation: courses
depreciation
; For the employees satisfaction
emp_sat_gain = max (0, E1*Buildings_and_facilities
+E2*Legals_and_morals+E3*Libraries_and_information_centers+E4*Research_and_envi
ronmental_services+E5*Scientific_evaluation); E1-E5: constants
gain_due_to_quality = table (Quality)
loss_due_to_students_number = table (Students)
quality_gain = max (0, Employees_satisfaction*Q1+Students_satisfaction*Q2-
loss_due_to_students_number); Q1, Q2: constants
; For the students satisfaction
st_sat_gain = max (0,
S1*Buildings_and_facilities+S2*Councelling+S3*Courses+S4*Libraries_and_information
_centers+S5*Marketing+S6*Students_services); S1-S6: constants
students_gain = max (0, Students*gain_due_to_quality)
students_loss = max (0, (graduation+transfer_rate)*Students);
transfer_rate = table (Students_satisfaction)
```

Fig. 6. Sample equations for the education quality model

3.4. Simulation

	Estimated quality	Real quality
Year 1	0.42	0.45
Year 2	0.46	0.51
Year 3	0.52	0.54

Table 2. The estimated qualities of the model along with the real qualities

In order to verify the accuracy of the model, real data that cover three years has been used. That limited duration was chosen as the adoption of new techniques may require a special set of data that is difficult to be obtained in a longer time frame. The model performance is shown in table 2 and illustrates the simulated results for the quality along with the real quality values achieved by the policy makers with traditional methods. It can be derived from the results that the trend of improvement for both the real and the estimated qualities are similar for the three simulated years. That in turns reflects the potential of the model to capture some details that can be of great importance in the planning process.

4. Evolutionary computation and model optimization

Evolutionary computation is a general term for several computation techniques which are all based to some degree on the development of biological life in the natural world. Currently there exist several major evolutionary models. The genetic algorithm, by far the most common application of evolutionary computation, is a model of machine learning taking inspiration from genetics and natural selection. In natural evolution, each species searches for beneficial adaptations (species optimizations), which arise through mutation and the chromosomal exchange and recombination of breeding. The two key axioms underlying the genetic algorithm are that complex nonbiological structures can be described by simple bit strings (analogous to the "genetic code" of chromosomes), and that these strings could be improved, according to a particular measure of fitness, by the application of simple transformation functions (just as living species may be "improved" through mating). Evolutionary strategies simulate natural evolution similarly to the genetic algorithm. Like genetic algorithms, evolutionary strategies are most powerful while comparing populations of data, as opposed to individual samplings. Differences between the two lie in their application; evolutionary strategies were designed to be applied to continuous parameter optimization problems seen in laboratory work, while the genetic algorithm was used originally in integer optimization problems. Evolutionary programming is a stochastic optimization function, similar in many ways to the genetic algorithm. However, evolutionary programming places emphasis on the behavioural link between parent and offspring, as opposed to the genetic algorithms attempt to model the exact code transition as seen in nature. Evolutionary programming follows a general process with obvious similarities to natural evolutionary progression. An initial population of trial solutions is selected at random from a coding scheme. A chosen mutation factor is applied to each solution, generating a new population. Because evolutionary programming resembles biological evolution at the level of reproductive populations of species, and there is no genetic recombination between species, evolutionary programming transformations take place without crossover- combination of two parent member's genetic code. The offspring species' members are weighed for overall fitness; the best are kept while the rest are eliminated, and the algorithm repeats with the new, fitter population. The learning classifier system's purpose is to take in input and produce an output representing a classification of that input. They have undergone and continue to go through multiple minor changes of name and scope, but the enduring foundation originates in J.H. Holland's Adaptation in Natural and Artificial Systems, wherein he envisions a cognitive system capable of classifying and reacting appropriately to the events in its corresponding environment. This most obviously parallels the inherently intelligent behaviour seen in all macro- and

microscopic living creatures. Though there are certainly other forms of evolutionary computation, the above offers a brief summary of the most established and useful evolutionary techniques as discussed in (Floreano, 2008).
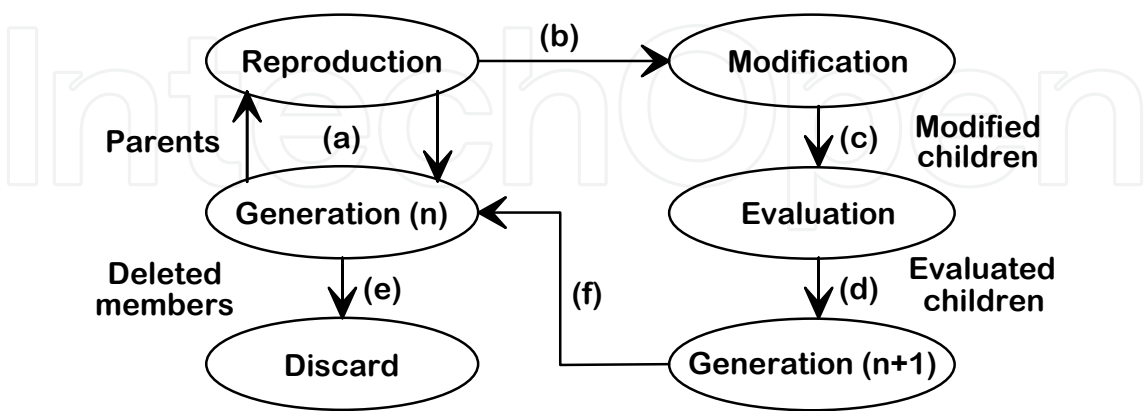
4.1. Genetic Algorithms

Fig. 7. Genetic algorithm cycle of reproduction. The algorithm uses (a) reproduction to select potential solutions (b) genetic operators to modify the solutions (c) evaluation against the objective function (d) new generation produced, which replaces the old solutions (e) while the other solutions are deleted.

In this research the basic features of genetic algorithms were used to optimize the spending for each of the nine variables that controls the design factors mentioned in table 1 in order to maximize the education quality. Genetic algorithms use the evolutionary process of natural selection as a metaphor for what is essentially a hill-climbing search without backup. Genetic algorithms search for an optimal solution or a global maximum among an enormous set of data. That can be achieved by computationally modelling the alteration, recombination, and propagation of genes that forms the basis of biological evolution. To achieve this, certain complex biological details of evolution must be abstracted in favour of more relevant principles.

Genetic splitting and pairing, as well as phenomena such as crossover and mutation, are modelled probabilistically. Assuming that parameter encoding, population size, propagation iterations, genetic operators, and a fitness function have been chosen. The 'target-size' sets the length of the binary sequence (zeros and ones) that must be found. This sequence can be thought of as the optimal genetic information (genome) for a particular environment. The 'population-size' sets the number of individuals that can try out their own genomes in that environment. The genetic algorithm runs through the following sequence of events that are summarised in fig. 7:

(a) A population of given size is initialized.

(b) For a specified number of generations:
1) Assign each individual node a fitness level according to the fitness function.
2) Probabilistically select a specified number of pairs of individuals according to fitness levels. Higher fitness levels increase an individual's chance of being selected.

3) Apply the specified genetic operators to these chosen pairs to produce new individuals.
4) Randomly select individuals from the population. Replace them with the newly produced individuals.

(c) Return the individual with the highest fitness level as the output.

A careful choice of genetic operators can improve the efficiency of the genetic algorithm or enable it to find otherwise inaccessible solutions. Crossover switches two subsequences of two parent strings; the goal is to place two fit sequences on the same string. Subsequences are selected probabilistically.
Mutation introduces "genetic diversity" into the population by randomly altering one character of an individual string. Mutation provides a way to help the genetic algorithm avoid the situation in which the system fixates on a local maximum after repeatedly propagating a particular character as discussed in (Tian, 2008).
The optimization problem in this research is a maximization problem which aims to maximize the total quality of the institute.

4.2. Variables selection
A single objective has been used for the optimization analysis of the model as the basis of optimization. The objective has been selected to reflect the task of EQC with long-term sustainability in mind: to maximize the quality of the institution as a function of the design vector calculated over a predetermined number of years.
The System Dynamics Modeller in NetLogo allows for drawing a diagram that defines "stocks" and "conveys", and how they affect each other. The Modeller read the EQC diagram and generated the appropriate NetLogo code: global variables, procedures and reporters. The next step was to optimise the model using genetic algorithm on the proposed model. Genetic algorithm is then implemented in the NetLogo environment to search for a quasi optimal solution (best budget distribution) that increases the model quality. The genetic algorithms implemented here works by generating a random population of solutions to a problem, evaluating those solutions and then using cloning, recombination and mutation to create new solutions to the problem.
The design vector represents the spending on each design factor that in turns affect the education quality. The relationship between each design variable and the corresponding design factor is based on an estimated formula that was derived from either statistical or economical evaluation for the true values of the utilities.
The design vector which is composed of the nine variables that contribute to improve the nine design factors, as explained earlier in table 1, has been constrained to have a total greater or equal to zero and less than or equal to the total budget. Although the limits of the constraints are not necessarily realistic, they give the program the ability to cover all the possible solutions.
It was also chosen to run the model for three years as the basis for optimization. This time period was chosen to minimize the time required for the model evaluation while allowing for enough time for possible effects to take action, such as the impact of increased spending on the different design factors.

4.3. Optimization
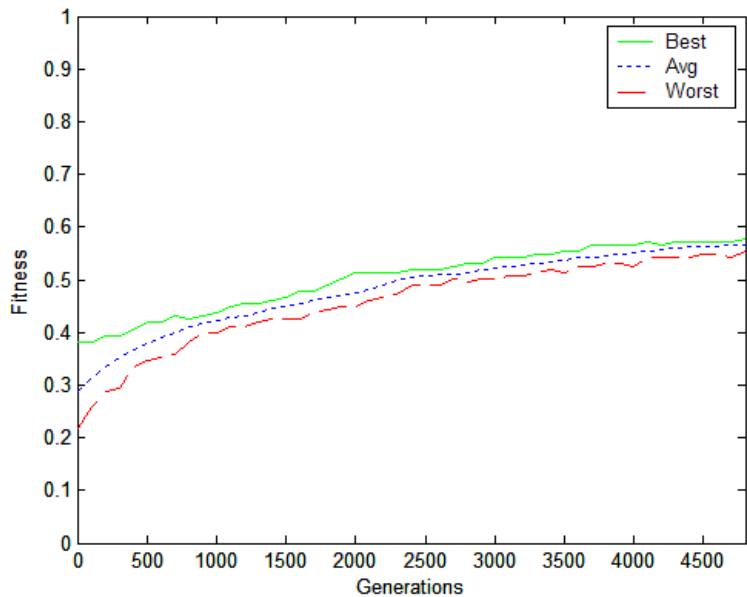
(a)
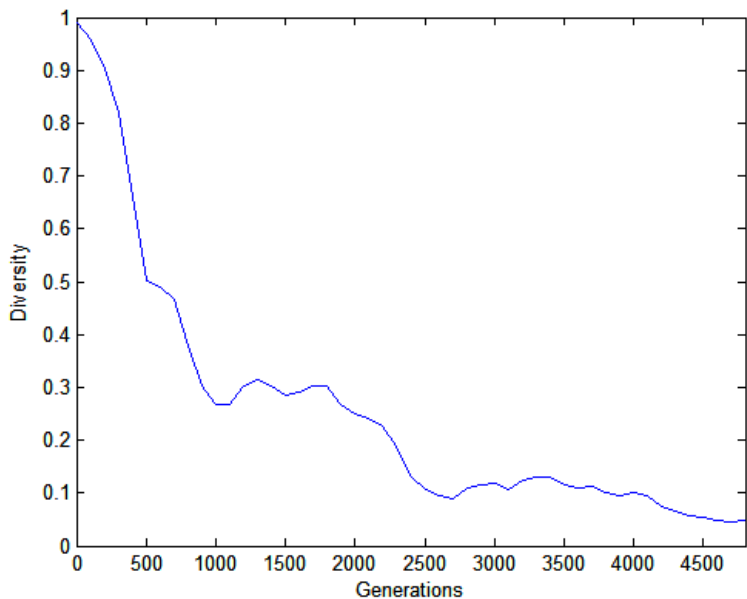
(b)

Fig. 8. Fitness (a) and diversity (b) curves for the optimization process

Initially many individual solutions are randomly generated to form an initial population. The population size is of 300 possible solutions. During each successive generation, a proportion of the existing population is selected to breed a new generation. Individual solutions are selected through a fitness-based process, where fitter solutions are typically more likely to be selected. The used selection method, roulette wheel selection, rates the fitness of each solution, which is based on the average quality over the three years, and preferentially selects the best solution.

The next step is to generate a second generation from population of solutions selected through crossover, and mutation. For each new solution to be produced, a pair of "parent" solutions is selected for breeding from the pool selected previously. By producing a "child" solution using the above methods of crossover and mutation, a new solution is created which typically shares many of the characteristics of its "parents". New parents are selected for each child, and the process continues until a new population of solutions of appropriate size is generated. These processes ultimately result in the next generation population of chromosomes that is different from the initial generation. This generational process is repeated until a termination condition has been reached; the highest ranking solution's fitness has reached a plateau such that successive iterations no longer produce better results fig. 8.a.

Diversity was measured using the Hamming distance between the bit strings representing each structure (ie the number of bits which do not match). So that a large uniqueness value does not preclude search in a small subspace at the end of the search, the uniqueness value of k bits is slowly decreased to one bit as the search proceeds. Thus at the start of the search the space is sampled over a relatively coarse ``grid,'' and as the search progresses, the grid size is gradually reduced until adjacent points are considered as shown in fig. 8.b.

Table 3 shows how the technique could improve the quality of the institution compared to the estimated quality found from the model over the selected years of simulation.

	Estimated quality	Optimized quality
Year 1	0.42	0.51
Year 2	0.46	0.59
Year 3	0.52	0.63

Table 3. Optimized qualities against estimated qualities from the model

Design factors	First year budget distribution	Second year budget distribution	Third year budget distribution
Building and facilities	25%	26%	28%
Courses	5%	4%	4%
Marketing	8%	6%	4%
Counselling	3%	4%	3%
Libraries and information centres	15%	16%	17%
Students' services	10%	11%	12%
Research and environmental services	27%	28%	26%
Legalism and morals	2%	1%	1%
Scientific evaluation	5%	4%	5%

Table 4. Optimized resources distribution proposed for the three years duration

The best solution is therefore, the best budget distribution over the three years period and aims to give the organization managers an indication for the priority of spending in order to better utilise their resources and provide the best affordable quality of education.

Table 4 summarises the best possible budget distribution which depends on the initial resources of the institution and their financial budgets over the years.

5. Conclusion

In this research, system dynamics has been chosen to capture the complex relations that affect the behaviour of the education quality model. The environment selected for this simulation provides an easy way for integrating different tools and allows for different techniques to be utilized. The modular design also allows for additional modules to capture additional factors that can influence the system.

The modelling of the system itself before it is to be used in optimizing the budget distribution needed a great involvement in the design of the model from different parties to achieve advanced levels of prediction. That involvement proves more useful for the policy makers and helps to integrate them with system formulation and interrelated causalities.

This research provided as well a comparison between the normal quality management for budget distribution and the optimized budget distribution and their effect on the quality. For comparison reasons, it was important to use realistic values which were obtained from the normal management methods and compare the results with the estimated values for the quality. That comparison although it is an estimated one but it can give an idea to the quality management planers of what the outcome can be if they relied on modelling the EQC system and optimizing the solution to achieve maximum education quality.

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