Simulation modelling and analysis of a satellite campus's registration model

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ABSTRACT

The registration model is a very important part of any tertiary education institution's value chain, as this is the first contact that many students have with the institution. Therefore it is of extreme importance that this process runs efficiently and is well organised, as a poorly run registration model can damage the image of the institution.

This study is part of a strategic planning initiative by the School of Modelling Sciences. Due to the fact that BSc students are high up on the subsidy scale, recruitment personnel are going to focus on recruiting BSc students, with a goal of having 100 first year BSc students.

Currently the first year BSc students are registered in 5 hours. Given the expected increase, management wants to know how many resources should be added to the various sub-processes in the registration model to keep registering the first year BSc students in 5 hours, with more than 85% of students realizing a turnaround time of less than 120 minutes. This will be accomplished through building a representative simulation model on which the various number of students will be tested to see what their influence will be on the time needed to complete the first year BSc registration. If this time is above 5 hours, resources will be added until the registration is completed in 5 hours and more than 85% of students realize a turnaround time of less than 120 minutes. With cost being a factor in deciding on a solution, estimated costs will be provided for each solution in order to aid decision making.

OPSOMMING

Die registrasie model is 'n baie belangrike deel van enige tersiëre opleidings- instelling se waarde ketting, aangesien dit die heel eerste keer is wat meeste van die studente met die instelling kontak het. Daarom is dit uiters belangrik dat hierdie proses effektief bestuur en behoorlik georganiseer word, aangesien 'n registrasie model wat swak bestuur word die beeld van die instelling kan skade aanrig.

Hierdie studie is deel van 'n strategiese beplannings inisiatief deur die skool vir Modelleringswetenskappe. Omdat BSc studente hoog op die subsidie skaal lê, gaan werwings personeel hulle toespits op die werwing van BSc studente, met die doel op 100 BSc eerstejaar studente.

Tans word die eerstejaar BSc studente in 5 ure geregistreer. Gegewe die verwagte styging, wil bestuur graag weet hoeveel hulpbronne by elkeen van die verskeie sub-prosesse in die registrasie model bygesit moet word sodat eerstejaar BSc studente nog steeds in 5 ure geregistreer kan word, met meer as 85% van die studente wat 'n omkeertyd van onder 120 minute realiseer. Dit sal bereik word deur 'n verteenwoordigende simulasie model te bou waarop die verskeie hoeveelheid studente getoets sal word om te sien wat die invloed sal wees op die tyd wat benodig word om die eerstejaar BSc studente te registreer. Indien hierdie tyd bo 5 ure is, sal hulpbronne bygevoeg word totdat die registrasie in 5 ure voltooi word en meer as 85% van die studente 'n omkeertyd van minder as 120 minute realiseer. Met koste wat 'n faktor is in die kies van 'n oplossing, sal beraamde kostes voorsien word om besluitneming te ondersteun.

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CHAPTER 1

1 CONSEPTUALIAZATION OF THE STUDY

1.1 Introduction

Various researchers have argued for the special role of the University, and for the need for it to operate outside of the economic forces that define activity in the commercial sector (see, e.g., Gilbert, 2001; Pister, 1999; Scott, 1998). There may be strong arguments for public support for the University to allow it, to a limited degree, to sit outside of the competitive marketplace. However, in the neoliberal climate of the day, the emergence of for-profit universities and the need to ensure value in order to gain and retain public support, compels university administrators and faculty to examine the means by which value is created and retained by their institution.

The value chain framework is an approach for breaking down the sequence (chain) of business functions into the strategically relevant activities through which value is added to products and services. Value-chain analysis is undertaken in order to understand the behaviour of costs and the sources of differentiation (Shank & Govindarajan, 1993). *Differentiation* is achieved in education by creating a perception among targeted learners that the course, the program, or the university's offerings as a whole are unique in some important way, usually by being of higher quality. Image and the perception of quality are important for higher education institutions, thus the appeal of differentiation. It is this perception that allows the institution to charge higher tuition fees, and in so doing outperform the competition in revenues without reducing costs significantly.

Survival in today's highly competitive business environment depends on any organization achieving, at least temporarily, a competitive advantage. Listed below are three possible strategies for achieving this advantage.

- ***A low cost/price strategy***. This strategy focuses on providing goods or services at a lower cost than the competition, or superior goods or services at an equal cost.
- ***Differentiation***. The primary focus of this strategy is to create a unique position in the market through provision of goods or services that are valued for their uniqueness or fitted to the needs of a particular group of buyers.

- ***Focus***. A strategy for targeting a very specific segment of the market as defined, for example, by type of learner (e.g., disadvantaged students), specific type of program offered, or specific characteristics of a geographic area.

It is the perception of quality that allows the organization to outperform the competition. Each activity in the value chain of any institution plays a critical role in ensuring the institution's success.

The abovementioned image and perception of quality of a university depends on the services of highly competent academics and tutors, registry staff, student advisers, and counsellors, as this can create a strong and unique bond between the university and its learners. It is this unique bond that becomes a differentiating competitive advantage when the institution subscribes to a vision of quality, support, service, and excellence (Woudstra & Powell, 1989).

An institution can determine which type of competitive advantage to pursue, and how to pursue it, through the use of value chain analysis. Value chain analysis has two components, namely: the industry value chain and the organization's internal value chain. The learning institution must first look for discrete activities that create value in fundamentally different ways before it can identify its internal value chain activities. This includes a set of discrete activities, such as course design, online registration, program and course promotion and counselling. Each of these activities has distinctively different costs, cost drivers, and assets, involves different personnel, and creates value in a fundamentally different way.

1.2 Problem statement

As times change, institutions have to keep reviewing the activities in the value chain, especially if a problem area is identified. Failure to do so will harm the image of the institution as well as the perception of quality that prospective students might have.

For the purpose of this study the registration process of first year BSc students is taken as one of the activities (processes) of the value chain.

The research problem investigated in this study is contained in the following questions.

- Using simulation, will it be possible to make recommendations regarding resource requirements, given that the number of students is expected to rise to 100 and the fact that the registration of first year BSc students is required to be completed in 5 hours?
- What are the cost implications inherent to additional resources?

The dramatic increase in the number of students at the university over the past five years is shown in Figure 1. The increase in the number of students has a dramatic effect on the infrastructure of the university. Management tries to alleviate these problems by providing more class rooms, offices, student residences, libraries and computer laboratories. The increase in the number of students also causes administrative problems during the registration process at the beginning of the academic year, for example. The registration process plays a critical role in the value chain of the university as it is the first time that most of the students have contact with the institution, and therefore the institution cannot afford to project a poor image during the registration time.

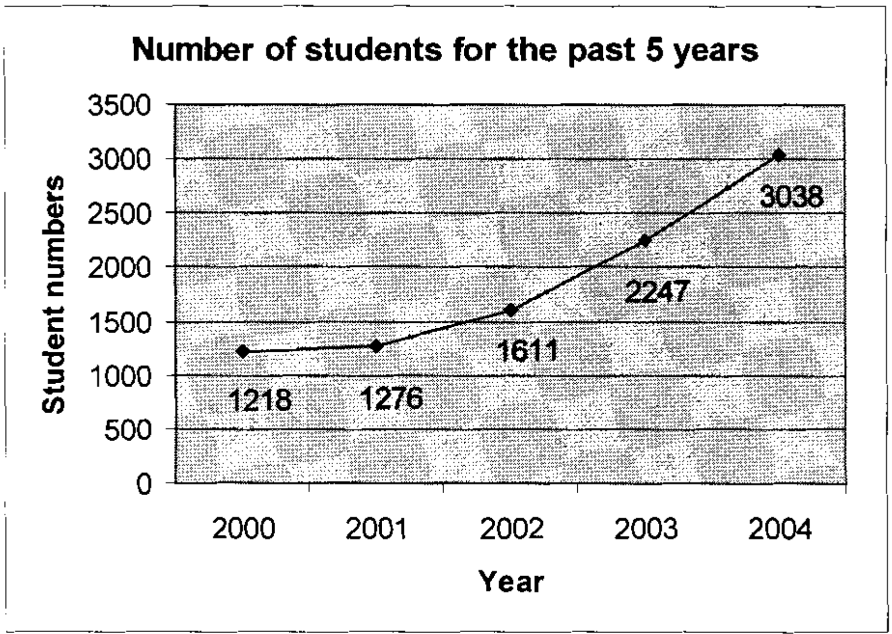


Figure 1 Number of students

1.3 Objectives of the study

To find solutions to the questions in the problem statement the following aims have been set for this study:

- Examine the registration model of first year BSc students.

- Simulate and optimize the registration model of first year BSc students up to an expected number of 100 students, given the constraint to complete the registration in 5 hours.
- Determine the cost implications of the proposed resource increases.

A well-run, streamlined and efficient registration model, as one of the first activities at the beginning of the university's value chain, will immediately project a positive image to the students, and it is this perception of quality that can lure even more prospective students to the institution.

1.4 Research Methodology

To achieve the aims set out in the objectives of this study, interviews will be conducted with key role players in the various administration departments of the university. One of the reasons why interviews are used to collect data is because the university's registration model is not documented at all. Interviews as a method to acquire data are discussed in section 4.5.

Once the interviews are completed and the necessary data is collected, a model will be compiled to simulate the registration process. Many simulation languages are available, for example GPSS, SIMSCRIPT, SLAM, ARENA, and SIMAN. According to Kelton *et al.* (2002:12), most of these languages have traded in flexibility for ease of use, whereas ARENA combines the ease of use found in high-level simulators with the flexibility of simulation languages, and even all the way down to general purpose procedural languages like the Microsoft® Visual Basic programming system or C if you really want (Kelton *et al.* 2002:12). Simulation will be used to evaluate the current system, so that recommendations can be made regarding the number of resources required for the expected growth of the institution. A full discussion on the software selected will follow in chapter 3.

1.5 Demarcation of the study

Various processes precede the day of the actual registration on the campus. Unfortunately many of these processes are student dependent, and the university cannot influence or control them in any way. These uncontrollable processes forced this study to focus on the actual day of registration on the campus. However, if there were a way to improve these student-dependent processes or even just to make them occur more timely, its effects would be far-reaching with regards to the improvement of the entire registration model.

1.6 Layout of the study

Chapter 1 Contextualization of the study

Chapter 1 defines the research problem, research objectives and aims of the study.

Chapter 2 Analysis of higher educational institution value chain

This chapter involves a literature study into the process of value chain analysis. We looked at the application of the value chain framework to academia and we discussed the various steps involved in setting up the value chain.

Chapter 3 Simulation

This chapter includes a literature study of simulation, in which we discuss the steps in the simulation process, why we use simulation instead of other process improvement techniques, the benefits and features inherited through the use of simulation, and finally where ARENA fits into the simulation framework.

Chapter 4 Models

A literature study into the registration models of two universities. Each model was analyzed in terms of current model flow, and positives and negatives of the model as experienced by the students, personnel and administrators.

Chapter 5 Application of the simulation process

In this chapter we apply the steps involved in the simulation process. The steps compiled by Law (2007:66-70) will be used to guide this process.

Chapter 6 Conclusions and recommendations

In the final chapter we present our findings and make recommendations for resource requirements given the expected growth.

Appendix A

The questionnaire used to obtain student opinions and registration model ratings.

1.7 Conclusion

This chapter highlighted the important role a university's image plays in ensuring its survival, and continued support. It is for this very reason that a university cannot afford to have any of its processes running inefficiently or in a disorganized manner. The problem statement and the objectives of this study were formulated. Finally the chapter highlighted the research methodology which will be used in this research and the layout of the study.

CHAPTER 2

2 ANALYSIS OF HIGHER EDUCATIONAL INSTITUTION VALUE CHAIN

2.1 Introduction

The value chain of a modern university can be viewed as a network of activities centred on the functions of teaching, research, and community service, which, in turn, involve educational design, educational delivery, assessment, research and development, and outreach activities (Sison, *et al.* 2000a:1). Each process individually adds value to the total educational package provided to students. These processes are supported by activities such as recruitment, admission, enrolment, academic service, alumni support and student affairs.

The modern university is an organization which is divided into various academic schools. This is done to enable specialization in a specific field of study. To complicate matters, the external environment presents a changing landscape characterized by heightened customer consciousness and demands, rising education costs, increasing competition in the form of new and alternative sources of learning and information (such as internet-based distance learning), and the increasingly palpable presence of information-age technologies, particularly the Internet (Sison, R. 2000b).

The registration of students is one of the activities in the value chain that plays a very important role, since it is the start of the academic year for most students. The purpose of this chapter is to describe the processes in the university, and to highlight the importance of the registration process, in so doing indicating the relevance/purpose of this study.

2.2 A higher education value chain framework

In any modern tertiary education institution a seemingly unlimited amount of tasks have to be performed to ensure the smooth operation of the institution. These activities form the value chain of the institution and can be divided into three major groups, namely, pre-education (for example, career guidance), education and post-education (for example, graduate placement). According to Sison *et al.* (2000b:1) education can be further disaggregated into three major sub-activities, namely, admission (a one-time occurrence), enrolment, and educational delivery. The value chain framework as formulated by Porter (1985) was applied to higher education institutions by Sison *et al. (2000b:1)*, which resulted in the value chain depicted in Figure 2.

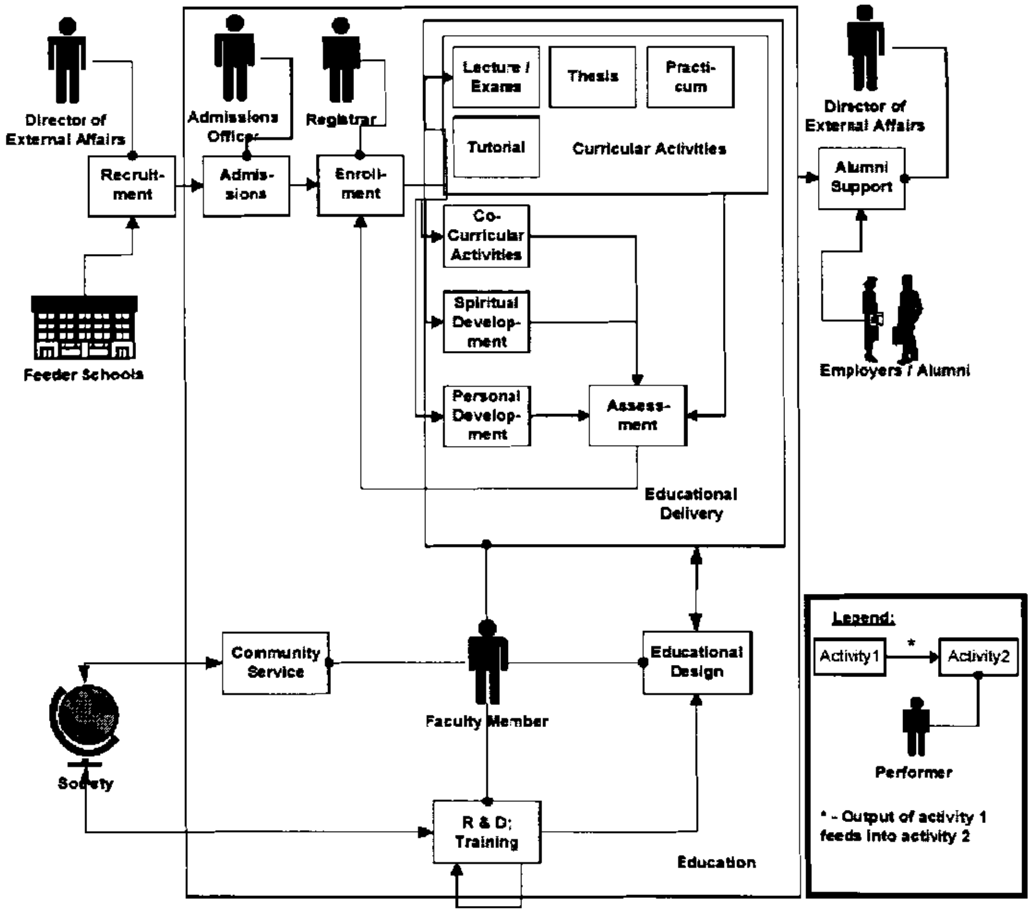


Figure 2 A higher educational institution's value chain (from Sison et al. (2000b:1))

Figure 2 indicates that there can be a variety of curricular activities, including lectures, examinations, tutorials, practicum or on-the-job training sessions, and thesis writing. A student's performance in these activities needs to be measured. If his/her performance is satisfactory, the student will progress to the next step of their tertiary education, whereas if the performance is unsatisfactory, the student is forced to revise the course work.

The activities that involve educational design and delivery are the activities that add the most value to the educational package. Even though this study covers only a small part of the educational value chain, the entire educational "supply chain" is represented in Figure 2, starting with the feeder schools (suppliers) and ending with the employers (buyers). Turner & Stylianou (2003) also applied the value chain framework defined by Porter & Millar (1985) to academia. This resulted in a different interpretation of the educational "supply chain" and is depicted in Figure 3.

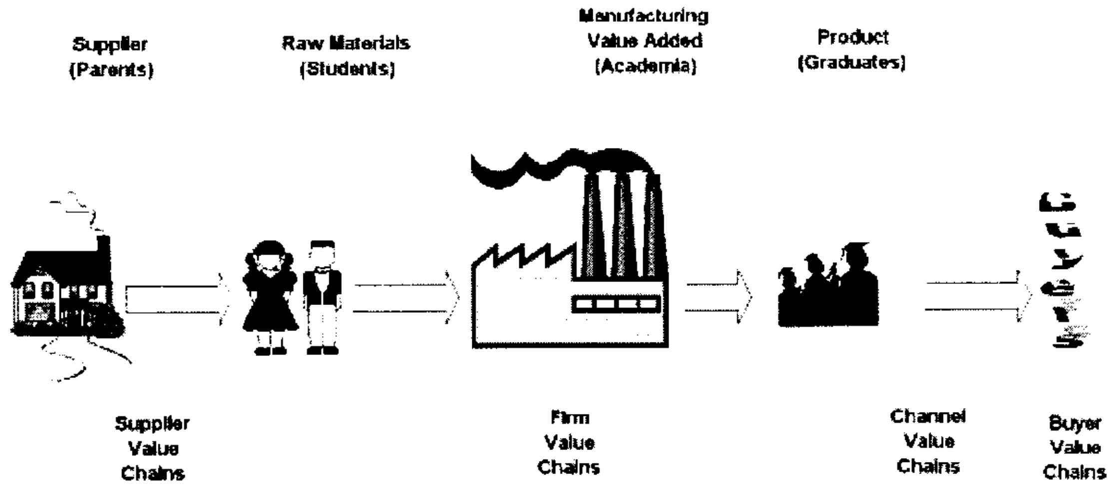


Figure 3 A value system for academia (from Turner & Stylianou (2003))

According to Sison *et al.* (2000b:1), the fact that the faculty is a major actor in the educational process cannot be ignored. A faculty member may either contribute directly to educational design and delivery, or alternatively, make a contribution through conducting research (motivated by various factors, such as gaps in the body of knowledge that is being taught, and societal needs). As Figure 2 illustrates, the output of this activity may benefit society directly (community service) or may feed back into educational (re)design (educational design).

2.3 An advantage assessment model

In analysing the value chain of any institution, certain steps have to be followed (expanded step 3 of Figure 4). If these steps are followed completely, an accurate estimate can be made regarding the level of advantage of the institution (keep in mind that Figure 4 is included in this chapter for the sake of completeness). Figure 4 shows the adaptations made by Turner & Stylianou (2003), to the advantage assessment model initially developed by Porter & Millar (1985). These modifications were necessary if the model was to be applied to academia.

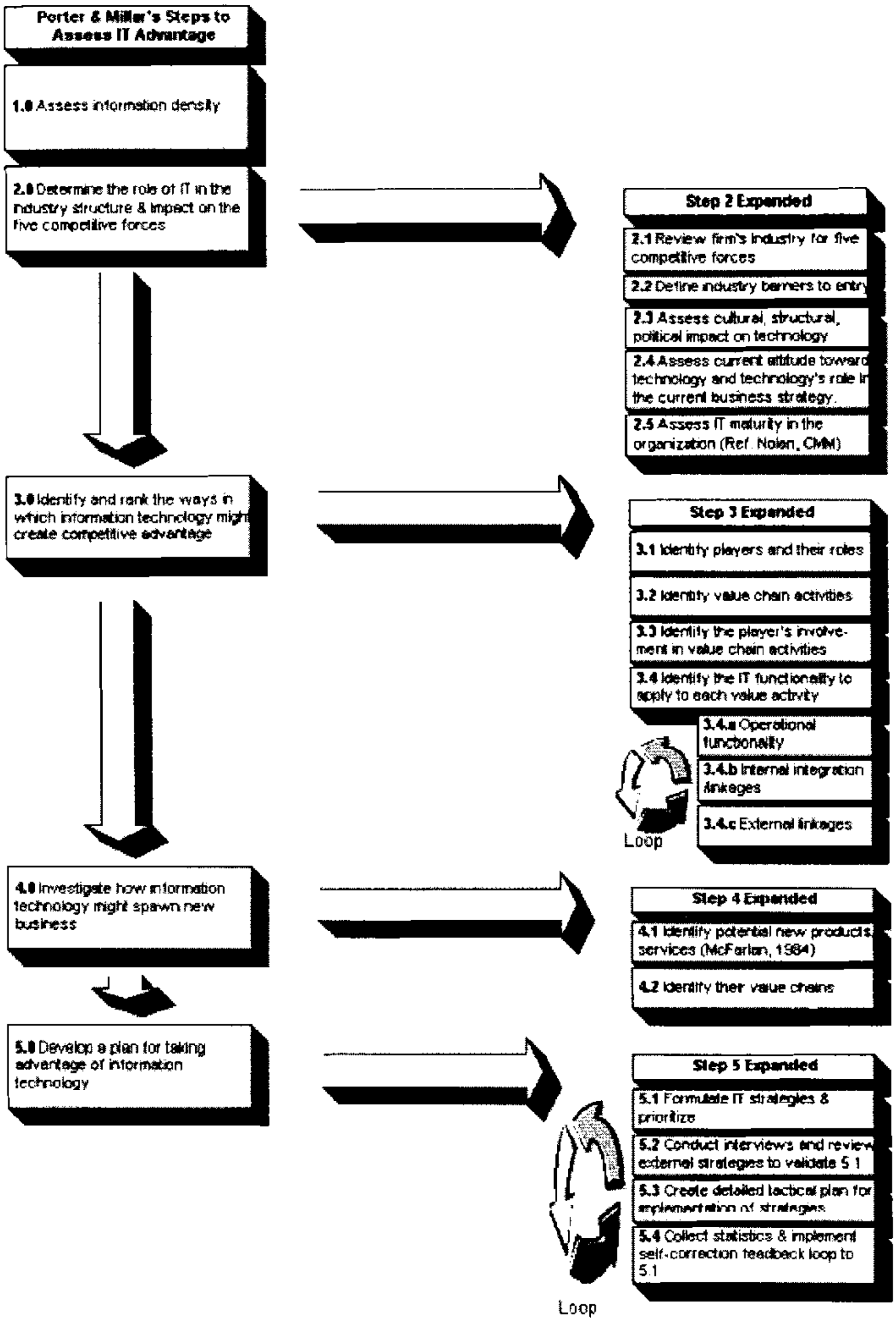


Figure 4 The information technology (IT) advantage assessment model (from Turner & Stylianou (2003))

The following sections provide discussions on the various steps that are involved in developing the value chain. These discussions have been formulated by Turner & Stylianou (2003). When grouped together they form step 3 as listed in Figure 4.

2.3.1 Identify players and their roles

Each industry is unique in the number and types of players involved and their different agendas. To view academia as a business, one must also consider who the players are, since they will suggest current and future value activities. Academia is unique in the number and types of players involved, and their different agendas. Academia also differs from other industries in that its raw materials can refuse to go through the assembly line, or at least not go through with excellence, thus affecting the product's quality.

A distinction is made between adult students and their younger more full-time counterparts because it is believed that their interaction with academia is slightly different. Society and community must also be handled separately, because academia may interact with society as a whole in a slightly different manner than the local community in which it resides. For example, society as a whole may place a high value on the study of history, while the community in which a particular academic institute is located may feel otherwise. Banks are another major role player, since they are the funding source for student loans as well as capital improvements to academia. In this context, banks interact differently with academia than with other businesses.

The various buyers: students, adult students, and parents all pre-pay or at least pay for the degree product before manufacturing (studying) is complete. The buyers (employers) of academia's products get the product after manufacturing is complete, and pay the holder of the degree instead of the manufacturer (university).

2.3.2 Identify the value activities

Porter and Millar (1985:150) define value activities as "the technologically and economically distinct activities [a company] perform to do business." They go on to say that "to gain competitive advantage over its rivals, a company must perform these [value] activities at a lower cost, or perform them in a way that leads to differentiation and a premium price (more value)." A complete list of the most common value activities should be compiled for the organization in this step, and these activities should be compiled at the organizational level.

The following are a few examples of the most common value activities for academia:

- admissions,
- administration,
- student recruitment,
- classroom instruction,
- research, and
- curriculum development.

Classroom instruction is most likely the primary mechanism that adds value to the raw materials (students). However, other activities add value to the process of producing graduates. The perceived value of the classroom would likely decrease in a cold, dark environment. Also, without the reporting of grades and classroom reporting, the student incentives would most likely be lower. Class planning also adds value to the manufacturing process, while accounting helps to keep the needed supplies on hand that are consumed in the manufacturing process, and aids in resource allocation tracking. This assists management in maintaining efficiency and competitiveness.

2.3.3 Identify the players' involvement in value activities

The players' involvement in each of the value activities should be determined in order to fully define value activities, to be better able to spot potential linkages between activities, and to see the potential impacts when formulating strategies for information technology related to value activities.

A given player can be involved in one or many value activities. If a player is not involved in any value activities, this is an indication that either the player is not actually a player or that additional value activities remain to be discovered. This linking of players to activities allows the discovery of "major players", who are involved in many value activities, as well as "minor players", who perform a specific task.

2.3.4 Identify the IT functions to apply to each value activity

Recognizing that each college or university is at a different level in applying information technology (IT), three levels of IT application have been defined so as to better stratify IT usage in preparation for strategy development. Each level is additive and assumes the existence of the IT in the previous level. The levels are defined in the following sub-sections (Turner & Stylianou, 2003).

2.3.4.1 Operational functionality

This is a beginning, a rudimentary level, without a great deal of connectivity or leveraging of connectivity in the organization. It does, however, define those activities needed to be operational (provide service, enhance or make quality improvements) within the IT function. Note, only IT functions that are specific to the value activity and are without linkages (see next section) are defined in this step.

2.3.4.2 Internal linkages

Linkages are defined by Porter and Millar (1985) as those activities connecting value activities and which themselves add value. Internal linkages are those activities capitalizing upon connectivity throughout the organization such as collaboration, common data storage, and common data access. Activities of this type are driven by business opportunity, and justified in terms of business benefits. For example, a linkage such as collaboration in teaching, adds value directly to the product.

2.3.4.3 External linkages

External linkages are those activities that can be categorized most accurately as activities connecting the organization with external organizations as well as customers. This level makes extensive use of the internet along with extranet and intranet technology.

IT strategies at this level for academia are focused on connections to students. However, they could also include linkages to prospective students, parents, alumni, and other players.

2.4 Conclusion

This chapter highlights the importance of an accurate and complete value chain analysis. If the analysis is not done properly, vital information might be overlooked, and the results obtained might be useless. In the first section academia was analyzed from two different points of view, both using the value chain framework developed by Porter (1985). The first point of view formulated the value chain for tertiary education institutions, whereas the second point of view represented academia as a supply chain. The chapter concludes with a section that discusses some of the steps involved in setting up the value chain for academia, as well as a few steps that can be followed to assess the IT advantage within an institution. All of these steps make provision for the role that IT plays in a tertiary education institution.

CHAPTER 3

3 Simulation

3.1 Introduction

Simulation can be an extremely general term since the idea applies across many fields, industries, and applications. "*Simulation refers to a broad collection of methods and applications to mimic the behaviour of real systems, usually on a computer with appropriate software*". (Kelton, *et al.* 2002:3)

Simulation, like most analysis methods, involves systems and models of these systems. This refers to the "*process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behaviour of the system and/or evaluating various strategies for the operation of the system.*" (Robinson, 2004:1)

Computer simulation deals with models of systems. A system is a facility or process either actual or planned. People often study a system to measure its performance, improve its operation, or design it if it doesn't exist. Managers or controllers of a system might also like to have a readily available aid for day-to-day operations, like help in deciding what to do in a factory if an important machine goes down.

3.2 The simulation process

According to Smith (1998:1) the steps in the simulation process are as illustrated in Figure 5. These steps are briefly discussed next.

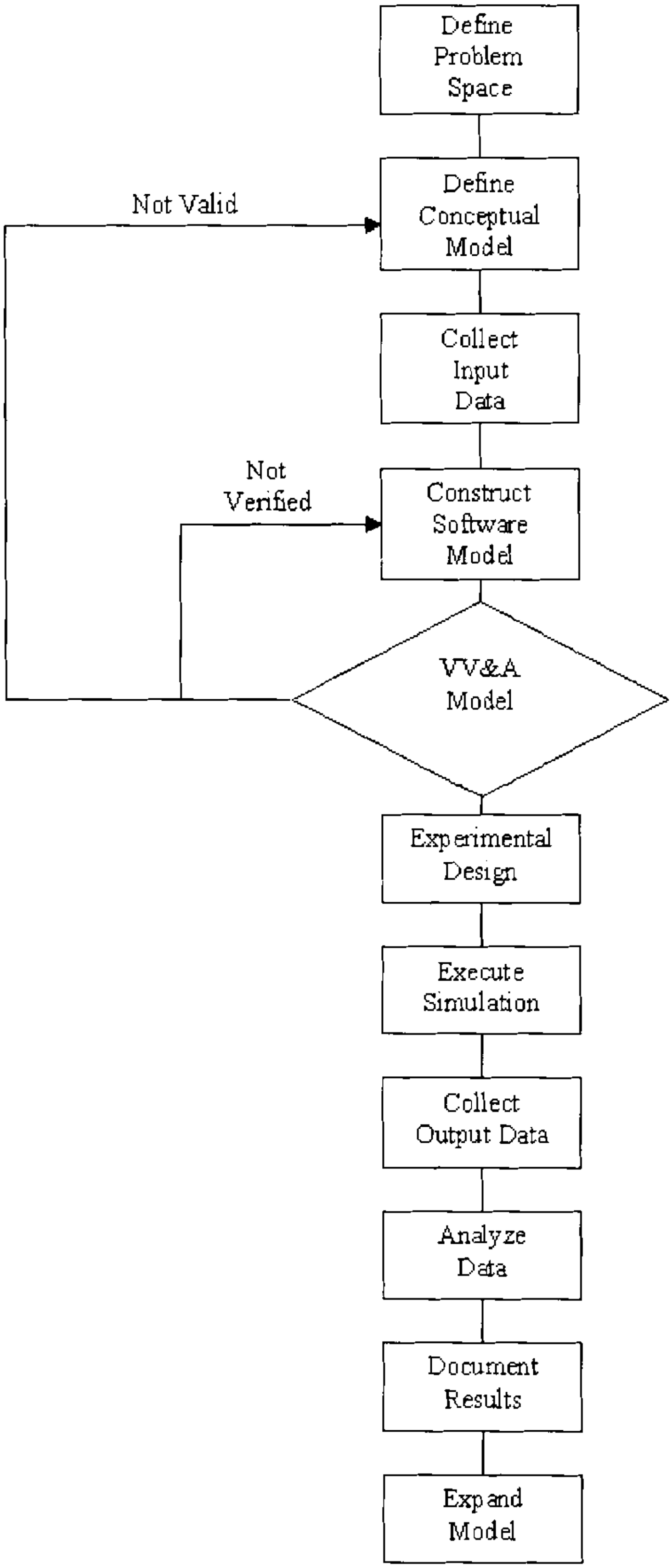


Figure 5 The simulation process

- **Define problem space.** The first step in developing a simulation is to explicitly define the problem that must be addressed by the model. The objectives and requirements of the project must be stated along with the required accuracy of the results. Boundaries must be defined between the problem of interest and the surrounding environment. Interfaces must be defined for crossing these boundaries to achieve inter-operability with external systems. A model cannot be built based on vague definitions of hoped-for results.

- **Define conceptual model.** Once the problem has been defined, one or more appropriate conceptual models can be defined. These include the algorithms to be used to describe the system, input required, and outputs generated. Assumptions made about the system are documented in this phase, along with the potential effects of these assumptions on the results or accuracy of the simulation. Limitations based on the model, data, and assumptions are clearly defined so that appropriate uses of the simulation can be determined.

  The conceptual model includes a description of the amount of time, number of personnel, and equipment assets that will be required to produce and operate the model. All potential models are compared, and trade-offs made, until a single solution is defined that meets the objectives and requirements of the problem, and for which algorithms can be constructed and input data acquired.

- **Collect input data.** Once the solution space has been determined, the data required to operate and define the model must be collected. This includes information that will serve as input parameters, aids in the development of algorithms, and can be used to evaluate the performance of the simulation runs. This data includes known behaviours of working systems, and information on the statistical distributions of the random variants to be used. Collecting accurate input data is one of the most difficult phases in the simulation process, and the most prone to error and misapplication.

- **Construct software model.** The simulation model is constructed based on the distributions defined and the data collected. Mathematical and logical descriptions of the real system are encoded in a form that can be executed by a computer. The creation of a computer simulation, as with any other software product, should be governed by the principles of software engineering.

- **Verify, validate, and accredit the model.** Verification, validation, and accreditation (VV&A) is an essential phase in ensuring that the model algorithms, input data, and design assumptions are correct and solve the problem identified at the beginning of the process. Since a simulation model and its data is the encoding of concepts that can be difficult to completely define, it is easy to create a model that is either inaccurate or which solves a problem other than the one specified. The VV&A process is designed to identify these problems before the model is put into operation.

  For the purposes of VV&A, the simulation development process is divided into the problem space, conceptual model, and software model, with definite transitions and quality evaluations between these stages.

  - **Validation** is the process of determining whether the conceptual model reflects the aspects of the problem space that need to be addressed, and does so in such a way that the requirements of the study can be met. Validation is also used to determine whether the operations of the final software model are consistent with the real world, usually through experimentation and comparison with a known data set.
  - **Verification** is the process of determining that the software model accurately reflects the conceptual model.
  - **Accreditation** is the official acceptance of the software model for a specified purpose. A software model accredited for one purpose may not be acceptable for another, though it is no less valid based on its original design.

- **Design experiments.** This phase identifies the most productive and accurate methods for running the simulation to generate the desired answers. Statistical techniques can be used to design experiments that yield the most accurate and uncompromised data with the lowest number of simulation runs. When simulation runs are expensive and difficult to schedule, experimental design can ensure answers at the lowest cost and on the shortest schedules.

- **Execute simulation.** This is the actual execution of the designed, constructed, and validated model according to the experimental design. The simulation runs generate the output data required to answer the problem initially proposed.

- **Collect output data.** Concurrent with the execution of the model, output data is collected, organized, and stored. This is sometimes viewed as an integral part of the model, but should be distinctly separated, since it is possible to change the data collected without changing the model algorithms or design.

- **Analyse data.** Data collected during the execution of a simulation can be voluminous and distributed through time. Detailed analysis must be performed to extract long-term trends, and to quantify answers to the driving questions that motivated the construction of the simulation. Analysis may produce information in tabular, graphic, map, animation, and textual summary forms. Modern user interfaces have greatly enhanced this phase by displaying data in forms that can be easily understood by diverse audiences.

- **Document results.** The results of the simulation study or training session must be documented and disseminated to interested parties. These parties identify the degree to which the simulation has answered specific questions, and areas for future improvements.

- **Expand model.** Simulation models are expensive and difficult to build. As a result, once a model is built, it will be modified for use on many related projects. New requirements will be levied, new users will adapt it, and the entire development process will be conducted many times over.

3.3 Benefits of simulation

There are several benefits for using simulation above other process improvement techniques (The Simul8 Corporation, 2005:1). These benefits are briefly discussed in this section.

3.3.1 Simulation vs. real life experimentation

- **Cost.** Experimenting in real life is costly. Not only the capital expenditure of hiring new staff or purchasing new equipment, but also the cost of the ramifications of these decisions must be considered. What if you fire 3 staff members and then find you can't cope with the workload, and because of that you loose customers? The only cost with simulation is the software, and the man hours to build the simulation.

- **Repeatability.** In real life it is very difficult to repeat the exact circumstances of a study. You therefore only get one chance to collect the results, and you cannot test different ideas with the exact same circumstances. Justified comparison is not possible to decide on the best idea. With simulation you can test the same system repeatedly with different inputs.
- **Time.** When deciding whether hiring another 3 people to work at a process would decrease customer waiting times or increase throughput, you would have to wait for an entire cycle of the process to see the effect of the changes. With simulation you can run 2, 10 or even 100 years into the future within seconds, giving you the answer now instead of when it's too late to do anything about it.

3.3.2 Simulation vs. other mathematical modelling techniques

- **Interaction of random events.** While some mathematical tools can manage to effectively model a steady state scenario, only simulation lets you build in random occurrences, like a machine breaking down, to see the effects of this further down the line. The more complex the scenario is, the more these tools fail, making simulation a very favourable option.
- **Non-standard distributions.** Many mathematical techniques force the model builder to describe a situation as an approximation. Approximating means factors such as resource utilization time and system idle time are inaccurate. Only simulation gives you the flexibility to describe events and interactions as they occur in real life.
- **Makes you think.** Simulation provides a vehicle for a discussion of all aspects of a model. The rule and data collection steps force you to consider why elements work in a certain way, and if they could work better. It also brings to the surface inconsistencies and inefficiencies (i.e. bottlenecks), especially between different sections of a model which work independently. Sometimes the framework which has been provided for thinking through the issues reveals the solution before the simulation has run to completion.
- **Communication.** Because simulation is visual and animated, you are able to clearly describe your proposal to others. It is more convincing than just displaying the end results, as people can't see where these came from. Simulation is so effective at communicating ideas that many companies now use it as a sales tool to sell their products.

3.4 Advantages and features of simulation

Simulation has a wide range of features and applications. The following two sections briefly mention the most important features as compiled by Simuledge Simulation (2005:5).

3.4.1 Capabilities/Applications

- Reduced operational costs
- Improved throughput
- Capital investment optimisation
- Bottleneck identification and resolution
- Realisation of best practice
- Service level improvement
- Better utilisation of resources (labour, machines and facilities)
- Validation of new processes prior to launch
- Reduced product lead times
- Excellent justification of decision to executives

3.4.2 Value of Simulation

- **Return on investment.** Simulation projects typically deliver a return on investment of over 200% within 6 months of concluding a project (Simuledge Simulation, 2005:5).
- **Excellent justification of decisions.** By simulating a new process, company executives will be a lot more assured that the designed solution will work, making capital justification much easier. In other words, simulation provides proof that the proposed solution will or will not work.
- **Elimination of trial and error.** By simulating a process, up to 12 months of trial and error on the line can be eliminated (Simuledge Simulation, 2005:5). This makes simulation a basic requirement for any major investment project.
- **"What if" analysis.** You can use simulation to simulate a whole series of "What if" scenarios, e.g. machine breakdown, seasonal effects, absenteeism.
- **Quality assurance.** Simulation is an excellent methodology to provide assurance that a proposed solution will work.

- **Modelling of lean manufacturing, just in time, etc.** When implementing modern manufacturing techniques, simulation will identify potential snags that might arise, and identify remedies.
- **Project-based work.** You get to use the service for a fixed cost on a project by project basis. This way you can manage your costs and take care of skills retention.
- **Optimisation of capital spends.** By simulating a new system you can be assured of the exact level of capital required, often saving significantly on initial plans.
- **Optimisation of parameters.** Solutions can be designed to optimise any specific parameter e.g. lead time, stock levels and staff levels.
- **Discrete event and continuous flow simulation.** Simulation models can be used for both discrete events and continuous processes.

3.5 Simulation with ARENA

3.5.1 Simulation languages

Special purpose simulation languages like GPSS, SIMSCRIPT, SLAM and SIMAN provide a good framework for the kinds of simulations many people do (Kelton *et al.* 2002:11). Simulation languages are very popular and are in wide use today.

Nonetheless, you still have to invest some time to learn about their features and how to use them effectively. Depending on the user interface provided, there can be picky, apparently arbitrary, and certainly frustrating syntactical idiosyncrasies that bedevil even old hands.

Thus, several high-level “simulator” products emerged that are indeed very easy to use. They typically operate by intuitive graphical user interfaces, menus, and dialogs. You select from available simulation-modeling constructs, connect them, and run the model along with a dynamic graphical animation of system components as they move around and change.

However, the domains of many simulators are also rather restricted (like manufacturing or communication), and are generally not as flexible as you might like in order to build valid models of your systems. Some people feel that these packages have traded away too much to achieve ease of use.

3.5.2 ARENA's position in the simulation framework

ARENA combines the ease of use found in high-level simulators with the flexibility of simulation languages, and even all the way down to general purpose procedural languages like the Microsoft® Visual Basic programming system or C if you really want (Kelton *et al.* 2002:12). It does this by providing alternative and interchangeable templates of graphical simulation modelling-and-analysis modules that you can combine to build a fairly wide variety of simulation models. For ease of display and organization, modules are typically grouped into panels to compose a template (for example, basic process panel, advanced process panel, advanced transfer panel, etc.). By switching panels, you gain access to a whole different set of simulation modelling constructs and capabilities. In most cases, modules from different panels can be mixed together in the same model.

ARENA maintains its modelling flexibility by being fully hierarchical, as depicted in Figure 6 (Kelton *et al.* 2002:13). At any time, you can drag and drop low-level modules from the Blocks and Elements panel, gaining access to simulation-language flexibility if you need to, and add SIMAN (a special-purpose, process-oriented, simulation language) constructs together with the higher-level modules from another template. For specialized needs, like complex decision algorithms or accessing data from an external application, you can write constructs of your model in a procedural language like Visual Basic or C/C++. All of this takes place in the same consistent graphical user interface, regardless of how high or low you want to go in the hierarchy.

In fact, the modules in ARENA are composed of SIMAN components; you can create your own modules and collect them into your own templates for various classes of systems. In this way, you don't have to compromise between modelling flexibility and ease of use. Further, ARENA includes dynamic animation in the same work environment. It also provides integrated support, including graphics, for some of the statistical design and analysis issues that are part of a good simulation study.

Since ARENA is based on Monte Carlo simulation, it is ideal for systems that involve queuing. This makes ARENA ideal for this study, since waiting time in queues is a performance measure in this study as well as a major decision making factor.

3.5.3 ARENA's basic operation

ARENA stores all information required to build and run simulation models in modules. These modules are placed in the model window and connected to each other to form a flowchart describing the logic of the process you are modeling (Meyer, 2004:11). The flowchart view contains all your model graphics, including the process flowchart, animation and other drawing elements. Some basic flowchart modules (found on the basic process panel and the advanced transfer panel) and their functions are as follows:

- **Create:** The start of the process. The point at which entities (the items that move through the process) enter the simulation.
- **Dispose:** The end of the process. The point at which entities are removed from the simulation.
- **Process:** An activity, usually performed by a resource or a group of resources and requiring some time to complete. A resource can be a machine, a person or any object (in other words, something that can be seized, used and then released after a certain time period). The process time allocated to the resource may be considered to be value added, non-value added, transfer, wait, or other. The associated cost will be added to the relevant category.
- **Decide:** An n-way branch in a process (1 of 2 or more branches may be taken). Branches are taken based on a logical expression or on a chance of something happening (possibility).

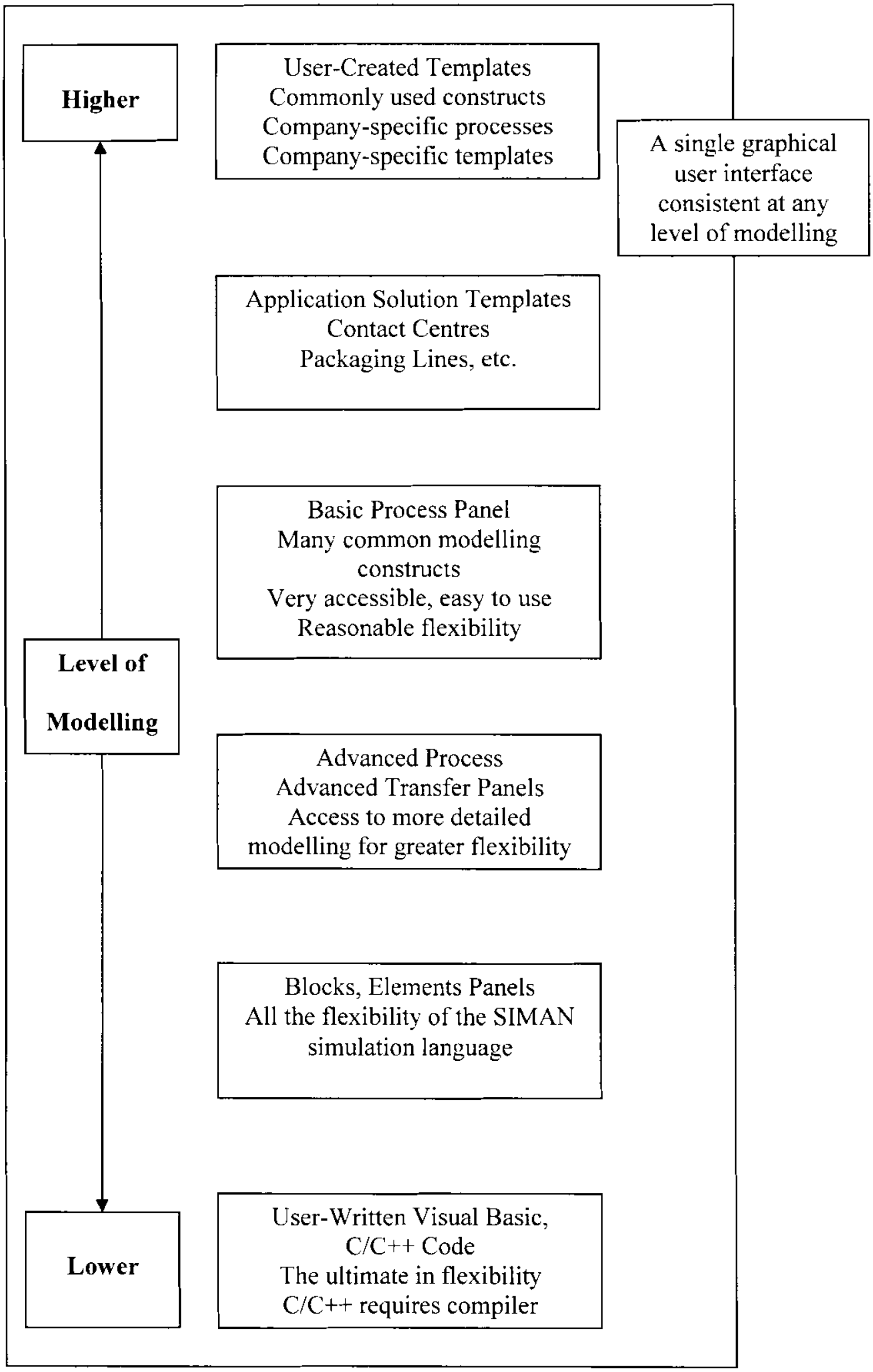


Figure 6 ARENA's hierarchical structure

- **Batch:** Grouping together of a number of entities before they can continue processing.
- **Separate:** Can either duplicate entities for parallel or concurrent processing, or separate a previously established batch of entities.
- **Assign:** Change the value of some parameter during the process, for example, entity type, a model variable, an animation feature or status.
- **Record:** Collect a statistic or set of statistics, for example, entity count or cycle time.
- **Route:** Represents the transport time (the time needed to move between the various sub-processes) in the model. The modeler has to choose a distribution (for example, normal, exponential, weibull, uniform, or random.) on which to base the travel time.
- **Station:** Used to properly connect route modules to process modules.

3.6 Conclusion

This chapter describes simulation as a powerful tool for process improvement. A layout of all the steps involved in the simulation process, and the various advantages of using simulation instead of any other method for process improvement was highlighted. A discussion on the benefits and features of using simulation followed, and the chapter concludes with a discussion on ARENA and its benefits.

CHAPTER 4

4 Models

4.1 Introduction

The word model is a very broad term, which is applicable across many fields, industries and applications. The Houghton Mifflin Company (2004:1) defines a model as "*a schematic description of a system, theory, or phenomenon that accounts for its known or inferred properties and may be used for further study of its characteristics*". For the purpose of this study Thompson's definition of a model "*a simplified description of a system to assist calculations and predictions*" (Thompson, 1996:572) will be used.

4.2 Simulation models

A simulation model is a description of nature (or a process) that can predict things about many similar situations. Simulation models are developed when the creativity and insight of a scientist/analyst are combined with data and observations about many similar scenarios (Annenberg/CPB: 2005:2). Scientists try to identify and generalize patterns in these observations, and use mathematical language to predict the outcome of related situations. The value of a model is that we can trust its predictions about similar situations, even if we don't encounter each situation that may come up in the model, in the actual system.

4.3 Characteristics of a good model

Any model is based on a certain set of observations. A good model must be able to explain as many characteristics of these observations as possible, and these explanations must be as simple as possible (Annenberg/CPB: 2005:2). In addition, a good model must be able to explain phenomena that are seemingly different from the ones we used to develop the model for in the first place. For instance, even though the "spherical earth" model (the model which describes the earth as being round) was used to explain sailing phenomena, educated people were able to link this idea to lunar eclipses. A lunar eclipse happens when the earth passes between the sun and the moon. If we subscribe to the "spherical earth" model, we would expect the shadow of the earth to be round as it passes across the moon — and indeed, it is. This new, seemingly different situation is explained with the same model.

4.4 Limitations of models

All models have limitations, and no model can possibly explain every detail of a scientific phenomenon or process. For example, if we want to predict the distance we would need to travel from one side of the country of Nepal to the other, we could predict it using our "spherical earth" model, but we'll find our estimate is far from accurate. Why? Although the earth is a sphere, there are many topographical features on its surface, including the Himalayan Mountains, which span Nepal. Although we could add all the mountain ranges in the world to our "spherical earth" model, this would make the model quite complex and defeat the utility of having a simple model to make useful predictions.

Interviews are the chosen data acquisition method for this study, since actual data is not available for the registration model, and it is also not documented. The next section will look at the reasons for using interviews, as well as the various advantages and disadvantages associated with the use of interviews.

4.5 Advantages and disadvantages of interviews

Interviews will be conducted with a wide range of people, including students, administrative staff, and management. The interviews will focus on recording the problems people experience with the current model, as well as on the proposed solutions. Interviewees will have the opportunity to make general comments, for example, limitations to keep in mind when designing the new model, certain elements of the current model which they would like unchanged, etc. The design of the new model will incorporate as many of these suggestions and recommendations as possible to meet the requirements and expectations of the people involved in this model.

4.5.1 Reasons for using interviews

Interviews are a useful method to (eVALUEd, 2004:1)

- investigate issues in an in-depth way;

- discover how individuals think and feel about a topic and why they hold certain opinions;
- investigate the use, effectiveness and usefulness of particular library collections and services;
- inform decision making, strategic planning and resource allocation;
- raise sensitive topics which people may feel uncomfortable discussing in a focus group;
- add a human dimension to impersonal data;
- deepen understanding and explain statistical data.

4.5.2 Advantages of interviews

The main advantages of interviews are (eVALUEd, 2004:1):

- They are useful to obtain detailed information about personal feelings, perceptions and opinions.
- They allow more detailed questions to be asked.
- They usually achieve a high response rate.
- Respondents' own words are recorded.
- Ambiguities can be clarified and incomplete answers followed up.
- Precise wording can be tailored to the respondent and precise meaning of questions clarified (eg for students with English as a second language).
- Interviewees are not influenced by others in the group.
- Some interviewees may be less self-conscious in a one-to-one situation.

4.5.3 Disadvantages of interviews

The main disadvantages of interviews are (eVALUEd, 2004:1):

- They can be very time-consuming: setting up, interviewing, transcribing, analysing, feedback, reporting.
- They can be costly.
- Different interviewers may understand and transcribe interviews in different ways.

The next section will look at the registration model of a tertiary education institution. The discussion includes a short description of the institution, a discussion of the registration model used by the institution, and finally the information obtained through interviewing the various role players (i.e. administrators, personnel and students).

4.6 The registration model of a satellite campus

In this section the registration model of a satellite campus will be investigated and for the purpose of this discussion we refer to this satellite campus as "the institution". The institution has approximately 3100 registered students. The student percentage per study field is about 40% for B.Ed, 30% for B.Com, 20% for B.A and 10% for B.Sc. The campus is currently celebrating its 43rd anniversary, and has been at its current location for 24 years. The institution is fully bilingual as all courses are presented in both Afrikaans and English. As discussed in chapter 1, this study will focus on the registration of first year BSc students. Whether a specific group of students is considered, or the organization is considered, the registration process stays the same; and that is why the registration model is discussed on an organizational level in the next section.

4.6.1 The registration model

When a prospective student is considering tertiary education, he/she requires certain information. This information can be obtained from current students, or from the department of student affairs on campus, depending on what information the student requires; for example, information regarding boarding fees, social activities, sporting activities or admission requirements. If the information the prospective student receives sounds promising, the next step usually involves career guidance (occupational counselling), especially if he/she does not satisfy the admission requirements for his/her chosen field of study. After the student's application has been approved based on his/her grade 11 results, they apply for admission to the institution. Admission is subject to the following requirements:

- matric exemption,
- relevant P-score[1] and
- specific course requirements for the field of study.

After the students have been admitted to the institution, they need to register during the official registration period. Once they arrive on the campus they acquire their detail and

[1] The p-score is a score that is determined using the prospective student's school-end results. This score is used to determine whether a student qualifies for admission to the faculty of his/her choice.

subject forms. After receiving their forms they need to check their details so that any mistakes can be rectified on the system. If a student has any financial or bursary enquiries, or they wish to open an account with the bookshop, these would be their next points of service. If a student has neither, they proceed directly to the subject advisers. The typical tasks of the subject advisers include: adding or removing subjects, checking for timetable clashes, approving the syllabus to be registered, etc. After their syllabus has been finalized, the students proceed to the cashiers to pay a registration fee (unless arrangements have been made during the previous optional steps). The next step involves registration of the subjects on the system after which they receive their proof of registration. At this stage, all first year and new senior students proceed to the point where they receive their student cards. The final two steps then involve registering as a user of the institution's computer network, and acquisition of their study guides.

Even though this study focuses on the part of the registration model which takes place on the day of registration on campus (listed as step 5 below), keep in mind that the entire registration model actually consists of the many components which have been discussed above. The following is a summary of these various components (in sequence):

1. Prospective students require information.
   a. Provided by senior students. For example, details about social activities and campus life, information about sporting activities, etc.
   b. Provided by administration. For example, admission requirements for their chosen faculty, tuition and boarding fees, etc.
2. Occupational counselling/career guidance.
   This step involves: IQ testing, suggesting an alternative field of study if requirements for chosen field of study are not met, etc.
3. Apply for admission when application is approved.
   Grade 11 results are used to approve/reject the application.
4. Approval requirements for admission:
   a. Matric Exemption.
   b. Relevant P-Score.
   c. Specific course requirements of the chosen study field.
5. Registration model:
   a. Acquire personal detail and subject forms.
   b. Verify details on forms.
   c. Financial and bursary enquiries and academic book shop.

d. Subject advisers. Their tasks typically include: Adding or removing subjects, checking for timetable clashes if subjects were added, approving the syllabus to be registered, etc.
e. Payments.
f. Register subjects and acquire proof of registration.
g. Student cards.
h. Collect study guides.

This registration model has been in use for 10 years. During this time some attempts have been made to streamline the model, but unfortunately most of the changes that were implemented had a negative effect, in fact, they increased the total registration time. For example, instead of coming to the administration building, subject advisers were kept in their offices which are roughly 600 metres away. This might have suited the advisers, but it increased the transport time (the time it takes students to move between the various sub-processes of the registration model) since most students have to walk to the offices and back to administration. This in turn may increase the total time needed to register.

4.6.2 Data acquisition

The data acquisition for this study consists of identifying the various problem areas in the registration model, as well as obtaining suggestions (from the various role players, i.e. administrators, personnel and students) on how to solve these problems. This data was collected by conducting interviews with the administrators and other role players involved in the registration process (refer to section 4.5).

The main concerns regarding the poor performance of the registration model that came to light after interviewing the administrators were:

- The newly implemented administration system (slow and unreliable).
- The long time needed to complete the registration process.
- Lack of proper communication between the relevant role players, such as personnel not sharing ideas for possible improvement of the registration model, or personnel not being informed of some decisions made by the administrators, or changes in the registration model not being communicated to senior students, in other words between:

- lecturers and administration personnel,
- administration personnel and students before and on the day of registration, and
- all the personnel directly involved in the model.

There were quite a few suggestions made to alleviate the second problem. For example, make the relevant closing dates earlier so that more thorough preparation can be done; assign certain personnel to perform only specific tasks, provide adequate training to additional temporary personnel. The communication problem needs to be solved as soon as possible. If proper communication channels exist, they will accelerate the improvement process.

When interviewing the various personnel directly involved with the registration model, the following problems were raised:

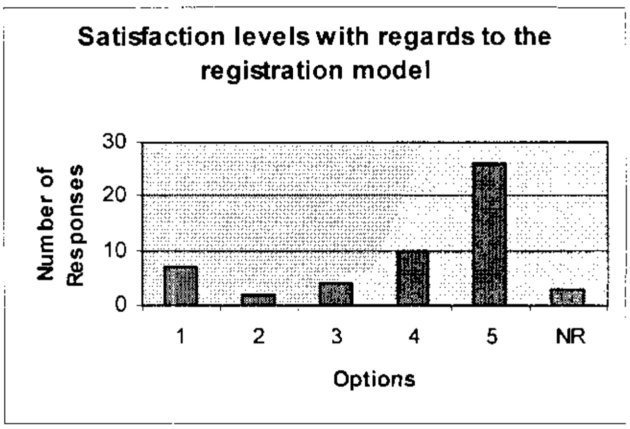
1. Poor preparation (preparation entails ensuring that enough study guides are available, ensuring that all relevant documentation has been printed, students ensuring that they have clarity about the curriculum that they have to follow, etc.), from both the students and administration staff.
2. The venue where registration must take place is too small, so the process has become spread over the entire campus.
3. Lack of co-operation from some of the personnel involved.
4. The new registration/administration system (slow and unreliable).

The suggested solution to problem 2 was to reorganise the model layout so that all its various sub-processes can be joined at one single or two adjacent venues. The solutions to problems 1 & 3 are unfortunately not that simple, as people are the direct cause of these problems, and will have to include a lot of managerial involvement. There is not much that can be done about the problems caused by students, as it will be impossible to contact some of them before the beginning of the academic year. Problem 4 was seen by many people as the biggest problem, as they felt it was the cause of many smaller, related problems. The system was full of glitches, and had a lot of teething problems. The solution will be to provide more training to its users, and to get the system developers to sort out the various problems the users experienced.

4.7 Student opinions of the registration process

Please take note that this section is only included to serve as extra motivation for this study. Nothing from this section is going to be used as data.

Due to the highest number of students in the campus's history, the Student Affairs department decided to do research into how the first year students experienced their first few days at the institution. Questionnaires were handed out to them during their orientation week on the campus. These questionnaires covered the registration model, as well as all the events that took place during the orientation week. Unfortunately the return rate was only 5.2%. (For an example of these questionnaires see Appendix A). The following graph provides a summary of the various responses.



Graph 1 Satisfaction levels

In Graph 1 the number 1 represents utmost dissatisfaction, 5 represents utmost satisfaction, and NR represents no response. Even though it seems from the graph as if the students are satisfied with the current model, the low questionnaire return rate must be kept in mind. The following extra comments as mentioned in the questionnaires, will serve as further motivation for the purposes of this study:

- *"Administration can be more informative, explain the various costs involved, and explain the specific course contents."*
- *"The registration model is very stressful."*
- *"I think that more attention should be given to developing more effective ways of managing the long queues."*

- *"It is disgusting to see how administration is handled on the campus of such a big institution. In simple terms, the institution is disorganised."*
- *"I feel as if some critical information is withheld. The institution does not send any relevant information to their students before the beginning of the academic year, for example, the location and flow of the registration model, the documentation which is needed for the first registration."*
- *"Offices are too far apart, we had to walk long distances with our parents on a sunny day."*
- *"Faculty guidance should explain all the relevant information about the chosen course, for example, how much the books will cost."*

Various senior students were interviewed as well, and this produced completely different results from those obtained from the first years. There was an overwhelming feeling of utmost dissatisfaction, and various problem areas were highlighted. Perhaps due to a lack of background knowledge of the functioning of the various sub-processes, they could not provide any possible solutions.

4.8 Conclusion

It is reasonable to state that the perfect registration process does not yet exist. To redesign and improve the registration model, two possibilities exist. Firstly, design a completely new model, disregarding the current model, and secondly, simply modify the amount of resources at each of the sub-processes until the perfect balance between cost and performance is found.

It is important to remember that there will be certain limitations/restrictions inherent to the institution which have to be kept in mind when designing the improved model. For the proposed solution to be viable, these limitations/restrictions will have to be adhered to completely.

CHAPTER 5

5 Application of the simulation process

5.1 Introduction

Law (2007: 66-70) has formulated a procedure to compile and execute a sound simulation study. In this chapter Law's procedure will be used to guide the application of the simulation process of this study. These steps are not necessarily a simple sequential process, as you might have to go back to previous steps during the application of the process, Law (2007:66).

5.2 Formulation of the problem and plan the study

5.2.1 Problem of interest

From a strategic planning viewpoint the university wants to increase the number of students from the current enrollment of about 3,000 students to about 5,000 by the year 2010. The university receives subsidy from the government according to a subsidy model, and this model benefits the B.Sc. qualification more than other qualifications. Taking this benefit into consideration and in line of the university's strategic aims, the School of Modeling Sciences, one of six schools on campus, wants to double its first year student numbers from the current intake of about 50 students to about 100 by the year 2010. Taking this growth into consideration, the school is proactively interested in the effect that such an increase in first year B.Sc. students will have on their registration model.

5.2.2 Information gathered from meetings

Formal meetings were conducted with management, administrative staff, and students, as discussed in section 4.5.

Currently the first year BSc students are registered in a morning, from 08:00 to 13:00. Management would like to keep it this way to minimize the impact on the registration of the rest of the students. Therefore, it is important to know how many resources must be added to each of the sub-processes to still complete the registration of the first year BSc students in a morning. In other words, to keep registering first year BSc students in a morning is the main objective of this study.

The main performance measures on which decisions will be based with regards to deciding where to add resources will be the waiting time of students, and resource utilization at each of these sub-processes. The industry norm for when a resource is being over-utilized is when the resource utilization reaches 65%. This is motivated by the fact that the physical service times at each of the sub-processes cannot be changed at this point, and finding ways to decrease service times falls outside the scope of this study.

This study is limited to the registration model of the first year BSc students, as this is the qualification on which recruitment agents will be focusing. It will focus on obtaining the amount of resources that will be required to register the first year BSc students in a morning.

The number of students for which different system configurations will be modeled include 50 (current number of first year BSc students), 60, 70, 80, 90, and 100 (goal number of first year BSc students). This makes provision for a 100% growth in current student numbers, with increments of 10.

This study will be conducted within a time frame of 1 5-hour day, since the first year BSc students only register in a morning. The system is only run for 5 hours since it is a terminating system (every student that enters the system, leaves the system).

5.2.3 Select the software for the model

ARENA will be the simulation language used for this study. Refer to Chapter 3 for a full discussion on why ARENA was chosen.

5.3 Collect data and define a model

5.3.1 Collect information on the system structure and operating procedures

Thompson (1996: 712) defines a process as "a course of action or proceeding, especially a series of stages in manufacture". The definition for a sub-process differs from this in that a sub-process does not produce the end product (a registered student in our case), but only makes a contribution to the larger process; the registration of students in the university's case.

A diagram listing the flow of the various steps involved in the registration model is given in Figure 7.

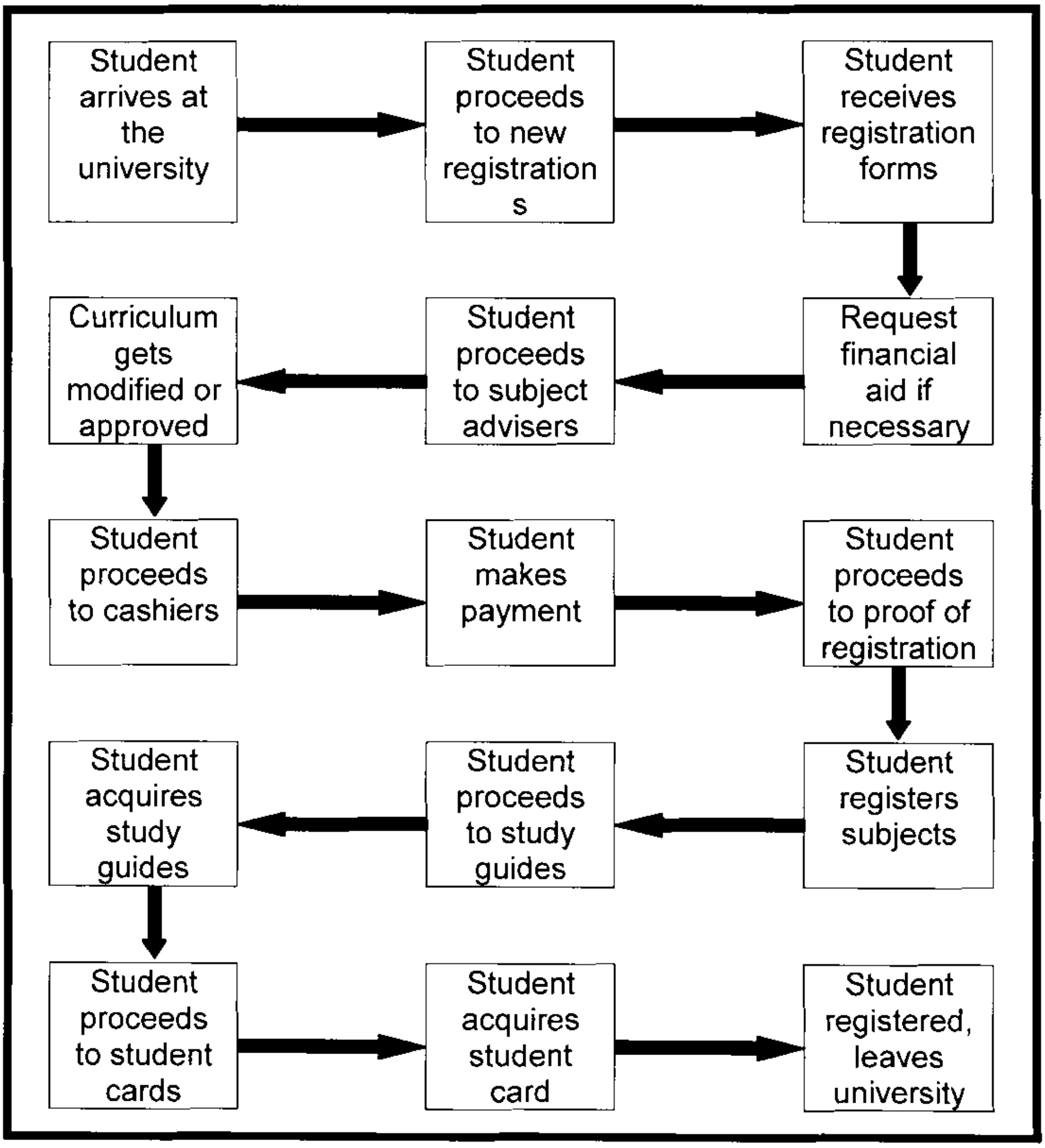


Figure 7 Flow of the registration model

The registration model consists of different sub processes and we will now distinguish between them. Sub-processes experience unique problems that have to be solved or minimized to improve the entire registration model. The current registration model consists of the seven sub-processes and eight links as indicated in Table 1. It is important to realize that the links indicated in Table 1 are only "connectors" or "linkages" between different sub-processes and therefore cannot be changed.

	Flow of the registration model	**Sub-process or Link**
1.	Student arrives at the university	Link
2.	Student proceeds to new registrations if not applied	Link
3.	Student receives registration forms	Sub-process
4.	Request financial aid if necessary	Sub-process
5.	Student proceeds to subject advisers	Link
6.	Curriculum gets modified or approved	Sub-process
7.	Student proceeds to cashiers	Link
8.	Student makes payment	Sub-process
9.	Student proceeds to proof of registration	Link
10.	Student registers subjects	Sub-process
11.	Student proceeds to study guides if necessary	Link
12.	Student acquires study guides	Sub-process
13.	Student proceeds to student card if necessary	Link
14.	Student acquires student card	Sub-process
15.	Student registered, leaves university	Link

Table 1 Flow of the registration process

The links mentioned in Table 1 have travel times associated with them. These travel times have to be included in the model to increase its accuracy. The travel times are given in Table 2, and are all based on the triangular distribution. According to Kelton *et al.* (2002:596), the use of the triangular distribution is appropriate if the exact form of the distribution is not known, but estimates (guesses) of the minimum, maximum, and most likely values are available.

The analysis of each sub-process involved identifying the purpose of the sub-process, possible problems experienced by the sub-process, suggested solutions, and the estimated service times. Special care was taken to explain to the interviewees that service times are required. In other words only the time they spend helping a student, and not the total time a student spends at their sub-process, both waiting and receiving service.

Traveling from	Traveling to	Minimum time (min)	Most likely time (min)	Maximum time (min)
Parking area	Building 25	2	3	5
Parking area	New registrations	2	3	5
Building 25	Administration	2	3	5
New registrations	Administration	3	4	7
Administration	Subject advisers	1	2	3
Subject advisers	Cashiers	1	2	3
Cashiers	Proof of registration	0.5	1	2
Proof of registration	Parking area	2	3	5
Proof of registration	Study guides	2	4	7
Study guides	Student cards	7	10	15
Student cards	Parking area	1	2	3

Table 2 Travel times

5.3.1.1 Subject advisers

The B.Sc. advisers assist students with curriculum planning. This involves verifying the modules (subjects) that the students enroll for in the current academic year. This planning is influenced by certain prerequisites being met (or not met), as well as the timetable for the academic year. Depending on the student's record this can be a very time consuming process, as some students do not pass all their modules in the prescribed year, and this causes clashes on the time table and numerous other problems. If subject advisers lack knowledge of the various curricula and academic rules, it also slows down the process considerably. Sufficient knowledge of the different programs, modules and prerequisites will improve the curriculum planning process. Selecting senior staff to give subject advice will also improve the situation. After consulting with the subject-matter experts (SME's), the service times for this sub-process were declared as follows: 2 minutes minimum service time, 5 minutes most likely service time, and 10 minutes maximum service time, based on the triangular distribution.

5.3.1.2 Financial enquiries

This sub-process administrates the students' financial matters. This includes bursary administration, extension of payment deadlines, and loan applications. Problems arise when students do not have all the required documentation with them. Better communication between the students and the university's administration department prior the registration day of what documentation and information is needed, can solve many of the problems experienced at this sub-process. After consulting with the SME's, the service times for this sub-process were declared as follows: 4 minutes minimum service time, 5 minutes most likely service time, and 6 minutes maximum service time, based on the triangular distribution.

5.3.1.3 New registrations

Although the university requires students to apply for admission months before the registration date, some students delay until registration day. The new registration sub-process caters for these students. The main problem experienced at the new registrations sub-process is similar to that at the financial enquiries sub-process, namely missing relevant documentation. This causes long-term problems, as students are either given provisional entry which will only become official on representation of the outstanding documents, or they are refused entry until the required documentation has been submitted. After consulting with the SME's, the service times for this sub-process were declared as follows: 6 minutes minimum service time, 8 minutes most likely service time, and 10 minutes maximum service time, based on the triangular distribution.

5.3.1.4 Payment

At this point of the registration model, the payment sub-process, the university receives and processes the prescribed minimum fees payable with registration from the students. The main problem experienced by this sub-process is the possible slow reaction time of the computers in use (the system is connected with the computers at the main campus in Potchefstroom). When the line speed slows down to such an extent that the computers' reaction time is unacceptable, receipts have to be issued by hand. This information has to be entered into the computer system at a later stage when the data transfer rate has returned to normal or the system has become on-line again. After consulting with the SME's, the service times for this sub-process were declared as follows: 2 minutes minimum service time, 3 minutes most likely service time, and 4 minutes maximum service time, based on the triangular distribution.

5.3.1.5 Receive forms

Students need their academic records, curriculum planning and personal detail forms for use during the registration process. The purpose of this sub-process is to provide these documents to the students. There are two main causes of problems in this stage of the registration model. Firstly, the biggest problem is caused when not all of the required forms are available (not printed). The students spend time in the queue only to find out that his/her forms are not available, and that he/she has to proceed to the next sub-process in the registration model, namely print forms (see the "print forms" section). The impact of this problem can be decreased significantly with better preparation and better control over the form printing process. Secondly, all the forms are not in alphabetical order. The implications of this is that if a form is not found where it is supposed to be, hundreds of other forms have to be searched to try to locate the required form. As in the case of the first problem, this problem can be overcome with better preparation. After consulting with the SME's, the service times for this sub-process were declared as follows: 3 minutes minimum service time, 4 minutes most likely service time, and 5 minutes maximum service time, based on the triangular distribution.

5.3.1.6 Print forms

This sub-process prints the forms required by students for registration if the forms were not pre-printed and found in the receive forms step of the registration model. Problems that can influence this part of the registration process occur when the computer system is off-line or the printers are not functioning properly (out of toner). After consulting with the SME's, the service times for this sub-process were declared as follows: 3 minutes minimum service time, 4 minutes most likely service time, and 5 minutes maximum service time, based on the triangular distribution.

5.3.1.7 Register subjects

At this point in the registration process the student's information, as approved by the subject advisers, is entered into the computer system. A slow computer system and mistakes by subject advisers can influence this sub-process considerably. More experienced subject advisers may minimize mistakes. After consulting with the SME's, the service times for this sub-process were declared as follows: 5 minutes minimum service time, 7 minutes most likely service time, and 10 minutes maximum service time, based on the triangular distribution.

5.3.1.8 Student cards

At this sub-process students receive their student cards. After consulting with the SME's, the service times for this sub-process were declared as follows: 3 minutes minimum service time, 4 minutes most likely service time, and 5 minutes maximum service time, based on the triangular distribution.

5.3.1.9 Study guides

The purpose of this sub-process is to provide all undergraduate students with the relevant study guides required to master their specific subjects. Problems occur when there are not enough study guides available. This problem is unfortunately not easy to rectify as administration has to predict the number of study guides to order. However, the impact of this problem can be reduced by proper research into past trends of new registrations during the registration period. After consulting with the SME's, the service times for this sub-process were declared as follows: 3 minutes minimum service time, 4 minutes most likely service time, and 6 minutes maximum service time, based on the triangular distribution.

5.3.2 Collect data to specify model parameters and input probability distributions

Various scenarios will be tested and the inter-arrival times of the students for the different scenarios will vary between 1.5 and 3.5 minutes, based on the random exponential distribution. According to Kelton *et al.* (2002:590), the use of the random exponential distribution to simulate arrival times is appropriate.

We assume that all the students will arrive within the first 3 hours on the morning of registration, since they will be notified that they can only register during that specific morning. As the number of students increase the inter-arrival time of the model will have to decrease to keep to the 3 hour arrival time.

5.3.3 Delineate above information and data in a written assumptions document

The flow of the registration model is depicted in Table 3. Table 3 identifies both the sub-processes involved in the model and the links between them.

	Flow of the registration model	**Sub-process or Link**
1.	Student arrives at the university	Link
2.	Student proceeds to new registrations if not applied	Link
3.	Student receives registration forms	Sub-process
4.	Request financial aid if necessary	Sub-process
5.	Student proceeds to subject advisers	Link
6.	Curriculum gets modified or approved	Sub-process
7.	Student proceeds to cashiers	Link
8.	Student makes payment	Sub-process
9.	Student proceeds to proof of registration	Link
10.	Student registers subjects	Sub-process
11.	Student proceeds to study guides if necessary	Link
12.	Student acquires study guides	Sub-process
13.	Student proceeds to student card if necessary	Link
14.	Student acquires student card	Sub-process
15.	Student registered, leaves university	Link

Table 3 Flow of the registration process

After consulting with the various SME's, the service times (see Table 4) were identified for the sub-processes involved in the registration of first year B.Sc. students, as mentioned above. All the service times are based on the triangular distribution, and measured in minutes.

Sub-processes were investigated with regards to the maximum amount of resources that each can accommodate. These limitations are depicted in Table 5, followed by a description on how these limits were obtained. It is important to remember that these restrictions are on the current system, and therefore not necessarily long term constraints, as we are planning ahead, i.e. by the time a hundred students are reached, the reasons for some or all of these restrictions may have disappeared completely, for example, more personnel may have been appointed, larger venues might have been built, etc.

	Minimum service time	Most likely service time	Maximum service time
BSc advisers	2	5	10
Financial enquiries	4	5	6
New registrations	6	8	10
Payments	2	3	4
Print forms	3	4	5
Receive forms	3	4	5
Register subject	5	7	10
Student cards	3	4	5
Study guides	3	4	6

Table 4 Service times per sub-process

	Variable	**Lower Limit**	**Upper Limit**
A	B.Sc. advisers	1	2
B	Financial enquiries	1	2
C	New registrations	1	3
D	Payments	1	2
E	Print forms	1	1
F	Receive forms	1	2
G	Register subject	1	3
H	Student cards	1	1
I	Study guides	1	1

Table 5 Sub-process resource limits

The upper limits were calculated as follows:

- B.Sc. advisers: The school of modeling sciences is the smallest school on the campus (in terms of number of students registered). Therefore they can only spare two members of staff for the duration of the registration period.
- Financial enquiries: The staff working at this sub-process needs advanced knowledge of the university's financial rules and regulations. This is why only senior members of staff can answer queries with regards to finances, and why the institution can only spare two members of staff during the registration period.
- New registrations: The staff working at this sub-process needs advanced knowledge of the entry requirements and prerequisites for each field of study offered on the campus. They must also be able to make a suggestion for an alternative field of study when entry is not gained into the student's chosen field. Therefore only experienced and specifically trained personnel can work at this sub-

process of the registration model. Currently only three qualified members of staff are available, but this number can be increased by providing training to specific candidates.

- Payments: Due to the construction of the counters at the current location, there is only room for two cashiers. This capacity can only be increased with quite a large capital expenditure.
- Print forms: This sub-process usually takes place before the start of registration. It does however happen that the documentation of some students does not get printed, and that this has to be done during the registration period. Fortunately this happens very rarely, so one member of staff at this sub-process of the registration model is sufficient.
- Receive forms: The one member of staff currently serving this sub-process, is coping with the workload. It would however be beneficial to the registration model if funds were available to appoint a second member of staff. Unlike many of the other sub-processes, the physical space is available to have two members of staff serving this sub-process.
- Register subject: Due to similar limitations as payments, there is only room for three members of staff.
- Student cards: The university only has one computer, one camera, and one printer available for the issuing of student cards. Before a second member of staff would be of any help, the university would need to purchase more equipment, and this in turn would require another large capital expenditure.
- Study guides: Due to the increase in the amount of subjects offered on the campus, and the tremendous increase in student numbers, the venue that is available for the storing and issuing of study guides is literally overflowing. Due to this lack of space, it is only feasible to have one member of staff assisting students at this sub-process of the registration model. To increase the amount of personnel at this sub-process, the university would have to increase the size of the study guide venue, once again requiring a large capital expenditure. This might be considered justified if the increase in the number of students is substantial.

Based on the information obtained from the meetings (see section 5.2.2), it was decided that 50 students will form the base case for this study, since 50 is the number of students that are currently registered in 5 hours.

The inter-arrival times of the students will vary between 1.5 and 3.5 minutes, based on the random exponential distribution. It is done in this way since we assume that all the students will arrive within the first 3 hours on the morning of registration, since they are aware of the fact that they can only register during that specific morning. So as the number of students increase, their inter-arrival time will have to decrease to keep to the 3 hour arrival time.

5.3.4 Level of model detail

The physical layout of the sub-processes involved in the registration model, will be modeled with as much detail as possible. This will be done so that transport/movement times can be incorporated in the model to improve accuracy.

5.4 Assumptions document

The assumptions document compiled in section 5.3.3 was represented to management and the SME's of the various sub-processes. It was verified and validated by all parties involved, and the go-ahead was given to construct the software model.

5.5 Construct and verify a computer program

5.5.1 Program the model in a programming language

Figure 8 is the flowchart of the registration model, as it was programmed in ARENA. The system starts at the Arrive module in the upper left-hand corner, and ends at the Depart module in the lower right-hand corner.

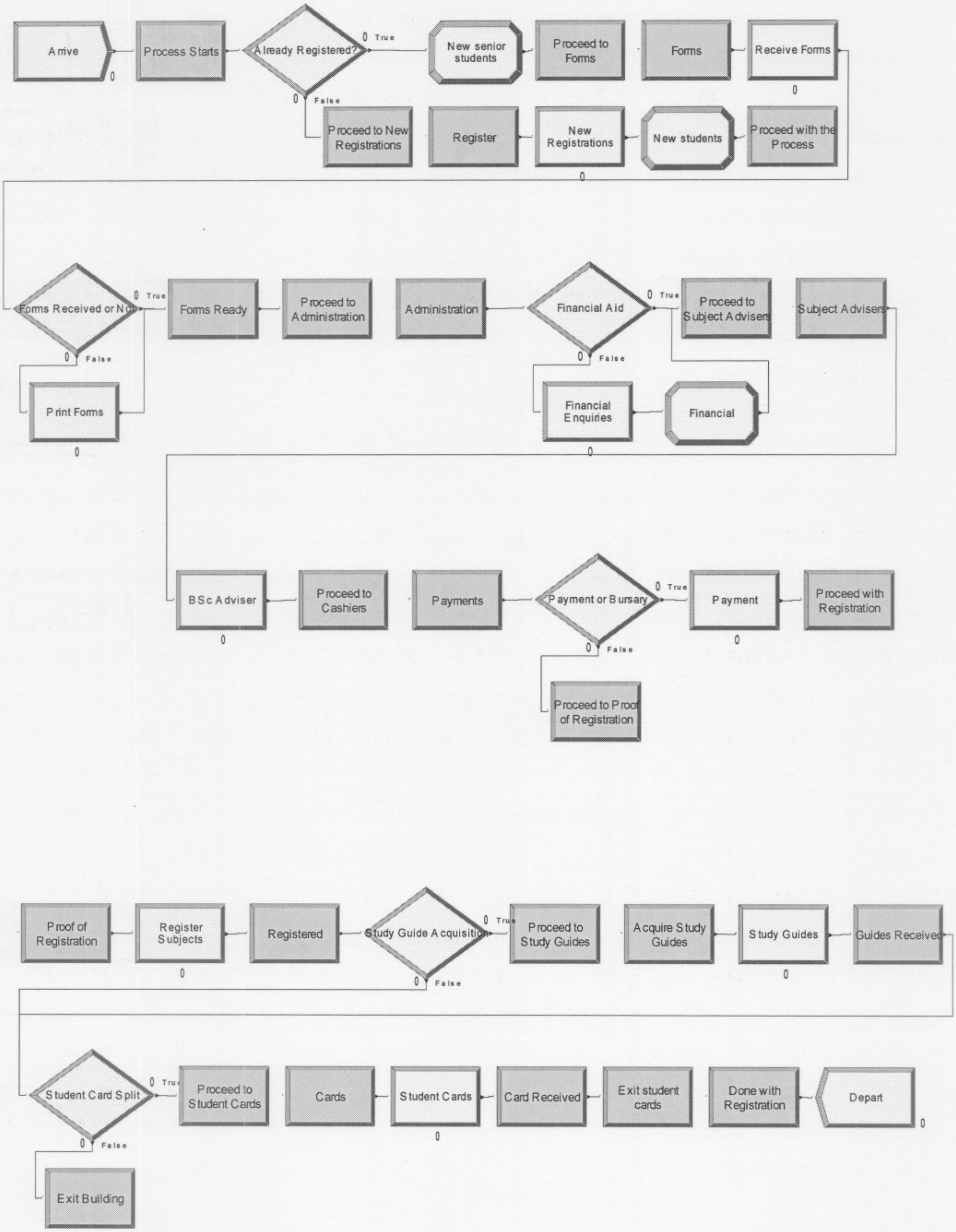


Figure 8 Software flowchart of the registration model

5.5.2 Verify the computer simulation program

The computer simulation program was verified by checking the outputs that were obtained against the inputs that were specified (error checking). For example, checking the service times that were used for the various sub-processes in the simulation, against the service times that were obtained from the SME's.

5.6 Make pilot runs

Once the verification was obtained, a pilot run of the simulation model was executed. The pilot run/results were then used to obtain validation.

5.7 Programmed model valid

5.7.1 Compare model/system performance measures for the existing system

After the verification, the model was taken to the director of administration. He validated the model by inspecting the animation (see figure 9), and by comparing the assumptions document to the results obtained from the pilot run.

Figure 9 Animation of the computer simulation program

5.7.2 SME's review model results for correctness

The results obtained from the pilot run were also taken to the various SME's for approval/validation, and they also validated the model. SME's were used for validation purposes since no actual data existed against which the results could be checked for correctness.

5.8 Design experiments

As mentioned in section 5.2, the various system configurations to be modeled are based on the number of students.

For the 50 student system configuration:

- Each replication will be based on a 5 hour day (from 08:00 – 13:00).
- No warm-up period will be used, since the system starts empty every day.
- The system configuration will be run with 50 replications.
- The average inter-arrival time of the students will be 3.5 minutes.

For the 60 student system configuration:

- Each replication will be based on a 5 hour day (from 08:00 – 13:00).
- No warm-up period will be used, since the system starts empty every day.
- The system configuration will be run with 50 replications.
- The average inter-arrival time of the students will be 3 minutes.

For the 70 student system configuration:

- Each replication will be based on a 5 hour day (from 08:00 – 13:00).
- No warm-up period will be used, since the system starts empty every day.
- The system configuration will be run with 50 replications.
- The average inter-arrival time of the students will be 2.5 minutes.

For the 80 student system configuration:

- Each replication will be based on a 5 hour day (from 08:00 – 13:00).
- No warm-up period will be used, since the system starts empty every day.
- The system configuration will be run with 50 replications.
- The average inter-arrival time of the students will be 2 minutes.

For the 90 student system configuration:

- Each replication will be based on a 5 hour day (from 08:00 – 13:00).
- No warm-up period will be used, since the system starts empty every day.
- The system configuration will be run with 50 replications.
- The average inter-arrival time of the students will be 2 minutes.

For the 100 student system configuration:

- Each replication will be based on a 5 hour day (from 08:00 – 13:00).
- No warm-up period will be used, since the system starts empty every day.
- The system configuration will be run with 50 replications.
- The average inter-arrival time of the students will be 1.5 minutes.

5.9 Make production runs

Based on the information provided in section 5.8, the production runs were executed. According to Kelton *et al.* (2002:118), the number of replications is sufficient when no half width values appear as "insufficient" or "correlated". Kelton *et al.* (2002:118) also defines the half width as being: "the plus-or-minus amount of a 95% confidence interval". The pilot run satisfied this criteria with 50 replications, and therefore the production runs will all be run with 50 replications as well.

5.10 Analyze output data

This section analyses the output data obtained from the production runs. The following information is presented for each production run:

- Number of resources.
- Average number of students in.
- Average number of students out.
- Average waiting time in queue (measured in minutes).
- Average total time spent at each sub-process (measured in minutes).
- Resource utilization (measured in %).
- Average total time spent in system (measured in minutes).
- Minimum average total time spent in system (measured in system).
- Maximum average total time spent in system (measured in minutes).
- Minimum total time spent in system (measured in minutes).
- Maximum total time spent in system (measured in minutes).

	Number of resources	Average number of students in	Average number of students out	Average waiting time in queue (min)	Average total time spent at each sub-process (min)	Resource utilization (in %)
New Registrations	1	10	10	3	11	27
Receive Forms	1	40	40	14	18	53
Print Forms	1	4	4	1	4	5
Financial Enquiries	2	43	43	1	6	36
BSc Adviser	2	50	50	2	8	47
Payment	1	7	7	1	4	7
Register Subjects	2	50	50	6	13	61
Study Guides	1	33	33	4	8	48
Student Cards	1	29	29	1	5	39

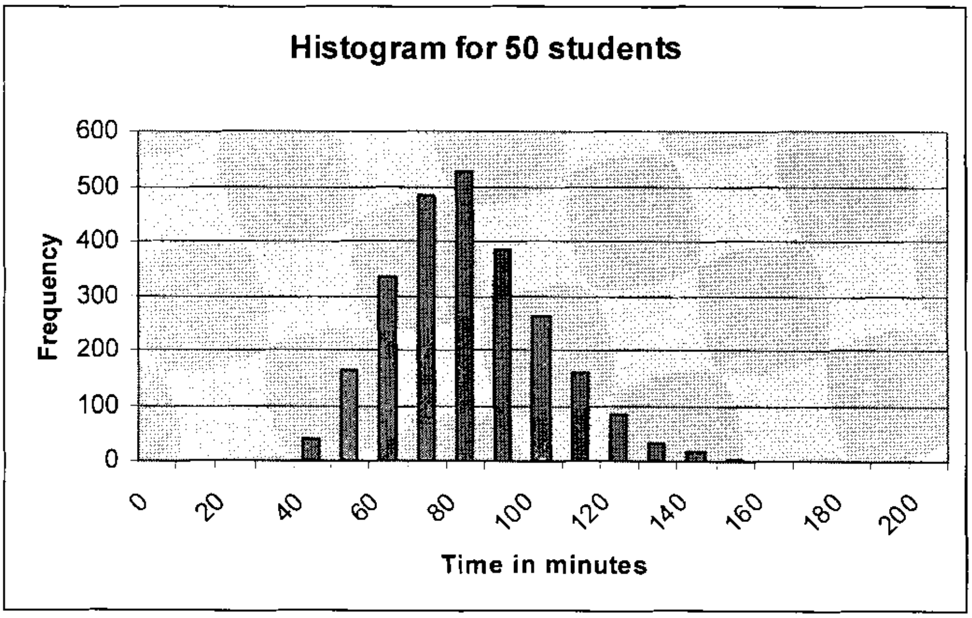
Table 6 Throughput and waiting time results for 50 students

The above results were obtained by running 50 replications (as discussed in section 5.9) of a 5 hour day, with 50 students coming into the system and 50 students leaving the system. The inter-arrival time used was 3.5 minutes, based on the random exponential distribution. Table 7 contains the turnaround times achieved by the 50 students.

Average Total Time	76
Minimum average	60
Maximum average	102
Minimum value	34
Maximum value	153

Table 7 Student turnaround times for 50 students

Graph 2 represents the average total time in the system for the 2500 students (50 students * 50 replications). Only 62 of the 2500 students (2.48%) spent more than 120 minutes in the system, and 97.52% spent less than 120 minutes in the system.



Graph 2 Histogram for 50 students

When the number of students was increased to 60, the inter-arrival time was changed to 3 minutes, and resources had to be added to receive forms, register subjects, and study guides, since their waiting times and resource utilizations were the highest. This was done to keep to the requirement of registering everybody within 5 hours. The results are depicted in Table 8.

	Number of resources	Average number of students in	Average number of students out	Average waiting time in queue (min)	Average total time spent at each sub-process (min)	Resource utilization (in %)
New Registrations	1	11	11	3	11	30
Receive Forms	2	49	49	2	6	33
Print Forms	1	5	5	1	4	7
Financial Enquiries	2	51	51	3	8	42
BSc Adviser	2	60	60	10	15	57
Payment	1	9	9	1	3	9
Register Subjects	3	60	60	1	8	49
Study Guides	2	39	39	1	5	28
Student Cards	1	37	37	3	7	49

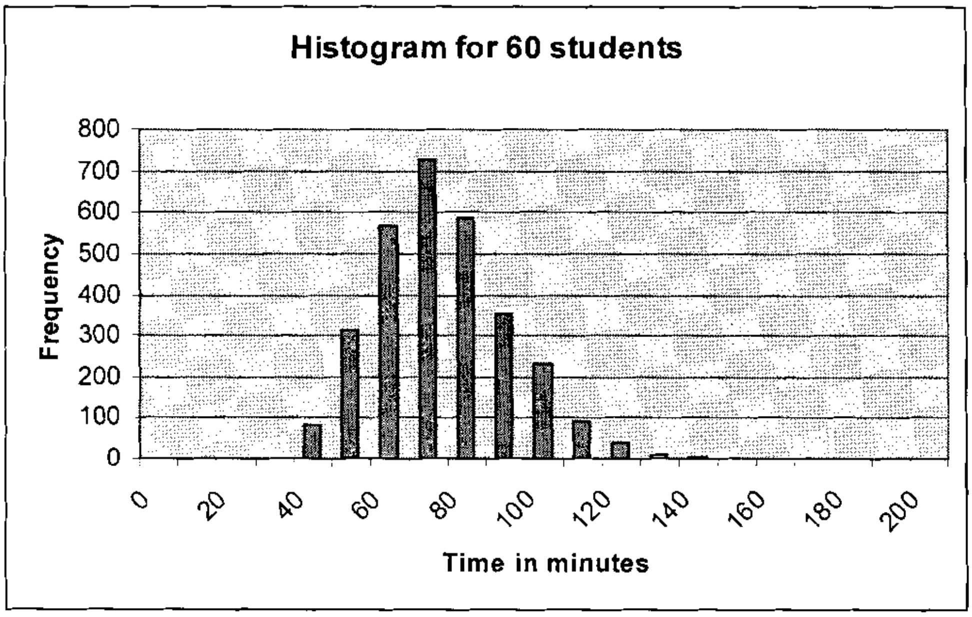
Table 8 Throughput and waiting time results for 60 students

Table 8 was obtained by running 50 replications of a 5 hour day with 60 students coming into the system and 60 students leaving the system. The inter-arrival time was 3 minutes, based on the random exponential distribution. Table 9 contains the turnaround times achieved by the 60 students.

Average Total Time	69
Minimum average	59
Maximum average	86
Minimum value	32
Maximum value	132

Table 9 Student turnaround times for 60 students

Graph 3 represents the average total time in the system for the 3000 students (60 students * 50 replications). Only 13 of the 3000 students (0.43%) spent more than 120 minutes in the system, and 99.57% spent less than 120 minutes in the system.



Graph 3 Histogram for 60 students

When the number of students was increased to 70, the inter-arrival time was changed to 2.5 minutes, and a resource had to be added to BSc adviser since its waiting time and resource utilization was the highest. This was done to keep to the requirement of registering everybody within 5 hours. The results are depicted in Table 10.

	Number of resources	Average number of students in	Average number of students out	Average waiting time in queue (min)	Average total time spent at each sub-process (min)	Resource utilization (in %)
New Registrations	1	14	14	5	13	38
Receive Forms	2	56	56	3	7	38
Print Forms	1	5	5	0	4	7
Financial Enquiries	2	60	60	5	10	50
BSc Adviser	3	70	70	1	6	44
Payment	1	10	10	1	4	10
Register Subjects	3	70	70	4	12	57
Study Guides	2	46	46	1	5	34
Student Cards	1	42	42	4	8	56

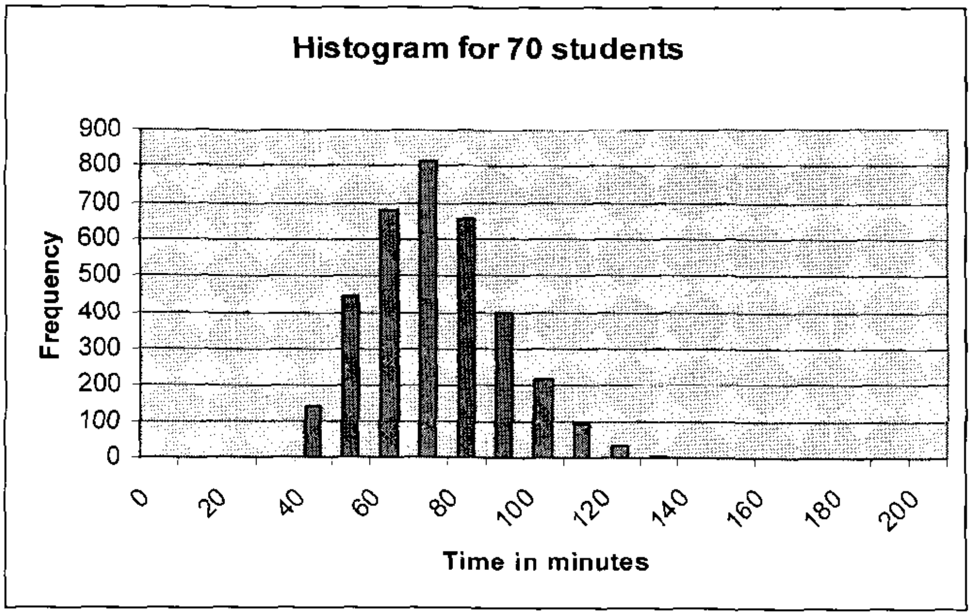
Table 10 Throughput and waiting time results for 70 students

Table 10 was obtained by running 50 replications of a 5 hour day with 70 students coming into the system and 70 students leaving the system. The inter-arrival time was 2.5 minutes, based on the random exponential distribution. Table 11 contains the turnaround times achieved by the 70 students.

Average Total Time	67
Minimum average	58
Maximum average	81
Minimum value	31
Maximum value	133

Table 11 Student turnaround times for 70 students

Graph 4 represents the average total time in the system for the 3500 students (70 students * 50 replications). Only 11 of the 3500 students (0.31%) spent more than 120 minutes in the system, and 99.69% spent less than 120 minutes in the system.



Graph 4 Histogram for 70 students

When the number of students was increased to 80, the inter-arrival time was changed to 2 minutes, and no resources had to be added to keep to the requirement of registering everybody within 5 hours. The results are depicted in Table 12.

	Number of resources	Average number of students in	Average number of students out	Average waiting time in queue (min)	Average total time spent at each sub-process (min)	Resource utilization (in %)
New Registrations	1	16	16	9	17	43
Receive Forms	2	64	64	6	10	43
Print Forms	1	5	5	1	4	7
Financial Enquiries	2	68	68	14	19	57
BSc Adviser	3	80	80	1	7	50
Payment	1	12	12	1	4	12
Register Subjects	3	80	80	10	18	65
Study Guides	2	52	52	1	5	38
Student Cards	1	49	49	5	10	65

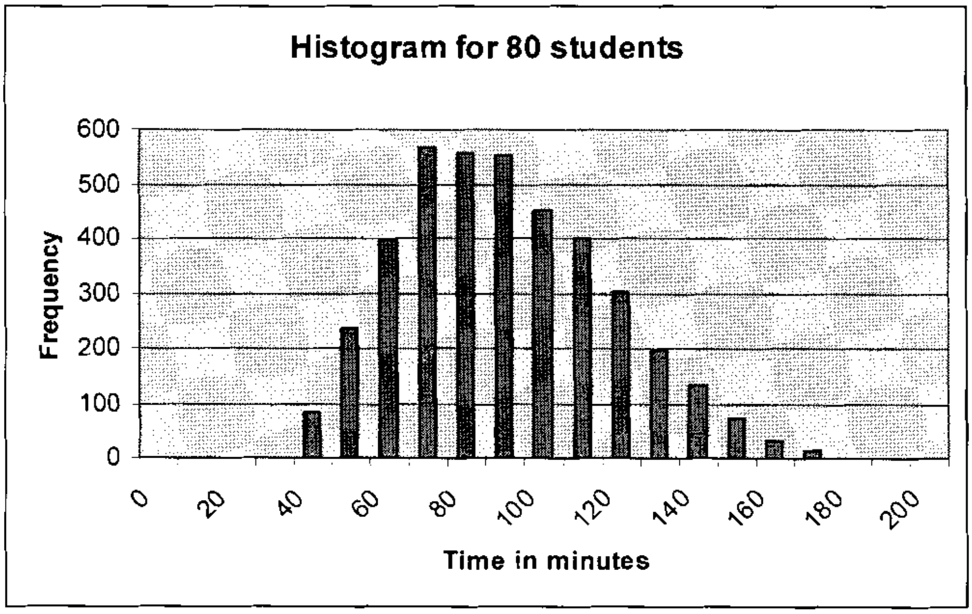
Table 12 Throughput and waiting time results for 80 students

Table 12 was obtained by running 50 replications of a 5 hour day with 80 students coming into the system and 80 students leaving the system. The inter-arrival time was 2 minutes, based on the random exponential distribution. Table 13 contains the turnaround times achieved by the 80 students.

Average Total Time	86
Minimum average	64
Maximum average	109
Minimum value	30
Maximum value	169

Table 13 Student turnaround times for 80 students

Graph 5 represents the average total time in the system for the 4000 students (80 students * 50 replications). Only 471 of the 4000 students (11.78%) spent more than 120 minutes in the system, and 88.22% spent less than 120 minutes in the system.



Graph 5 Histogram for 80 students

When the number of students was increased to 90, the inter-arrival time was kept at 2 minutes, and resources had to be added to financial enquiries, register subjects, and student cards, since their waiting times and resource utilizations were the highest. This was done to keep to the requirement of registering everybody within 5 hours. The results are depicted in Table 14.

	Number of resources	Average number of students in	Average number of students out	Average waiting time in queue (min)	Average total time spent at each sub-process (min)	Resource utilization (in %)
New Registrations	1	17	17	8	16	46
Receive Forms	2	73	73	6	10	49
Print Forms	1	7	7	0	4	9
Financial Enquiries	3	76	76	1	6	42
BSc Adviser	3	90	90	4	10	56
Payment	1	14	14	1	4	14
Register Subjects	4	90	90	1	8	55
Study Guides	2	59	59	2	6	43
Student Cards	2	53	53	0	4	36

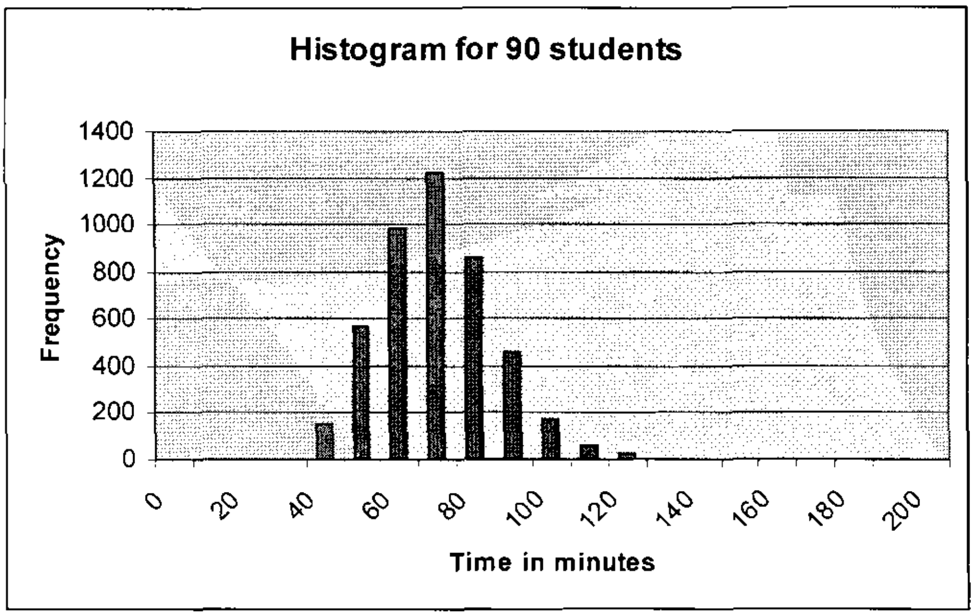
Table 14 Throughput and waiting time results for 90 students

Table 14 was obtained by running 50 replications of a 5 hour day with 90 students coming into the system and 90 students leaving the system. The inter-arrival time was 2 minutes, based on the random exponential distribution. Table 15 contains the turnaround times achieved by the 90 students.

Average Total Time	66
Minimum average	57
Maximum average	79
Minimum value	29
Maximum value	122

Table 15 Student turnaround times for 90 students

Graph 6 represents the average total time in the system for the 4500 students (90 students * 50 replications). Only 3 of the 4500 students (0.07%) spent more than 120 minutes in the system, and 99.93% spent less than 120 minutes in the system.



Graph 6 Histogram for 90 students

When the number of students was increased to 100, the inter-arrival time was changed to 1.5 minutes, and no resources had to be added to keep to the requirement of registering everybody within 5 hours. The results are depicted in Table 16.

	Number of resources	Average number of students in	Average number of students out	Average waiting time in queue (min)	Average total time spent at each sub-process (min)	Resource utilization (in %)
New Registrations	1	20	20	18	26	54
Receive Forms	2	80	80	17	21	54
Print Forms	1	8	8	0	4	10
Financial Enquiries	3	85	85	1	6	47
BSc Adviser	3	100	100	11	16	63
Payment	1	15	15	1	4	15
Register Subjects	4	100	100	2	9	61
Study Guides	2	65	65	2	7	47
Student Cards	2	60	60	1	5	40

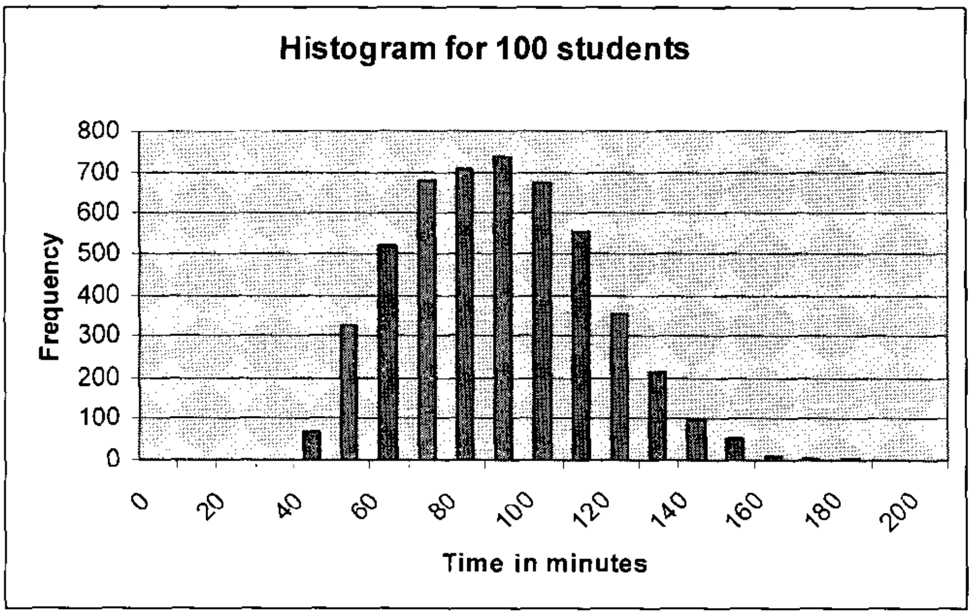
Table 16 Throughput and waiting time results for 100 students

Table 16 was obtained by running 50 replications of a 5 hour day with 100 students coming into the system and 100 students leaving the system. The inter-arrival time was 1.5 minutes, based on the random exponential distribution. Table 17 contains the turnaround times achieved by the 100 students.

Average Total Time	84
Minimum average	69
Maximum average	96
Minimum value	32
Maximum value	180

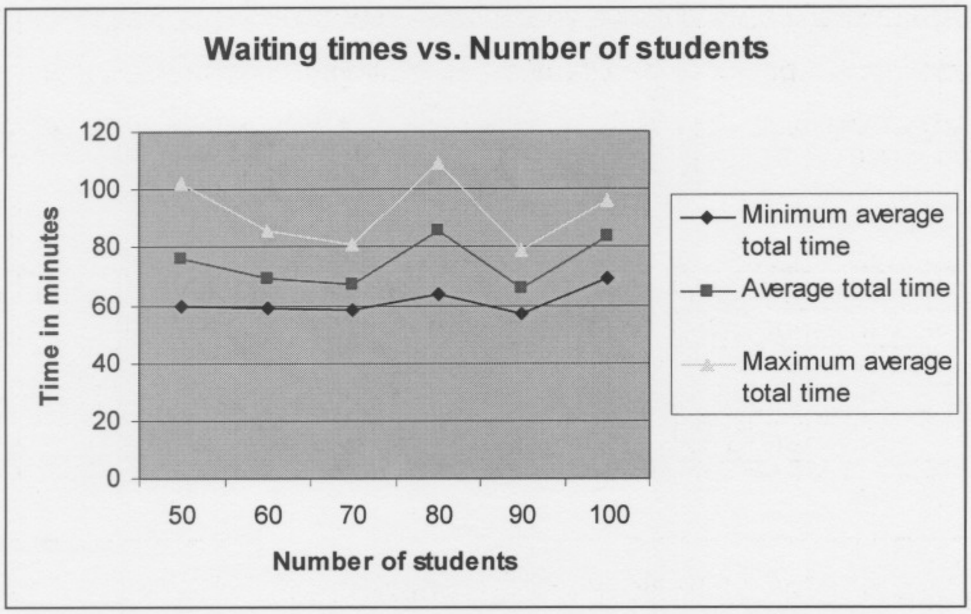
Table 17 Student turnaround times for 100 students

Graph 7 represents the average total time in the system for the 5000 students (100 students * 50 replications). Only 411 of the 5000 students (8.22%) spent more than 120 minutes in the system, and 91.78% spent less than 120 minutes in the system.



Graph 7 Histogram for 100 students

The following graph represents a summary of the minimum average total time, average total time, and maximum average total time obtained in each of the production runs.



Graph 8 Summary of waiting times per number of students

For the purpose of this study the cost factors are included for the sake of completeness, and to give decision makers a better idea of possible financial implications of increasing the resources at the sub-processes. The idea was not to perform a complete cost analysis. For example, to increase the number of resources at student cards is not merely a case of getting more personnel; you will also need another camera, printer, and probably another computer, for this person to be effective. Since that amount of detail with regards to cost was not required for this study, the estimates given in Table 18 will be used.

	Cost per resource
New Registrations	R 3600.00
Receive Forms	R 3000.00
Print Forms	R 3000.00
Financial Enquiries	R 4200.00
BSc Adviser	R 6000.00
Payment	R 3600.00
Register Subjects	R 3600.00
Study Guides	R 3000.00
Student Cards	R 3000.00

Table 18 Cost per resource

Using the above mentioned costs, the cost per sub-process and total cost for when 50 students are expected, is given in Table 19.

	Number of resources	Cost per sub-process
New Registrations	1	R 3600.00
Receive Forms	1	R 3000.00
Print Forms	1	R 3000.00
Financial Enquiries	2	R 8400.00
BSc Adviser	2	R 12000.00
Payment	1	R 3600.00
Register Subjects	2	R 7200.00
Study Guides	1	R 3000.00
Student Cards	1	R 3000.00
Total		R 46800.00

Table 19 Total cost for 50 students

When the number of students increased from 50 to 60, the amount of resources had to be modified to keep to the 5 hour maximum time constraint. The cost implications of that increase are reflected in Table 20.

	Number of resources	Cost per sub-process
New Registrations	1	R 3600.00
Receive Forms	2	R 6000.00
Print Forms	1	R 3000.00
Financial Enquiries	2	R 8400.00
BSc Adviser	2	R 12000.00
Payment	1	R 36000.00
Register Subjects	3	R 10800.00
Study Guides	2	R 6000.00
Student Cards	1	R 3000.00
Total		R 56400.00

Table 20 Total cost for 60 students

When the number of students increased from 60 to 70, the amount of resources had to be modified to keep to the 5 hour maximum time constraint. The cost implications of that increase are reflected in Table 21.

	Number of resources	Cost per sub-process
New Registrations	1	R 3600.00
Receive Forms	2	R 6000.00
Print Forms	1	R 3000.00
Financial Enquiries	2	R 8400.00
BSc Adviser	3	R 18000.00
Payment	1	R 3600.00
Register Subjects	3	R 10800.00
Study Guides	2	R 6000.00
Student Cards	1	R 3000.00
Total		R 62400.00

Table 21 Total cost for 70 students

When the number of students increased from 70 to 80, the amount of resources had to be modified to keep to the 5 hour maximum time constraint. The cost implications of that increase are reflected in Table 22.

	Number of resources	Cost per sub-process
New Registrations	1	R 3600.00
Receive Forms	2	R 6000.00
Print Forms	1	R 3000.00
Financial Enquiries	2	R 8400.00
BSc Adviser	3	R 18000.00
Payment	1	R 3600.00
Register Subjects	3	R 10800.00
Study Guides	2	R 6000.00
Student Cards	1	R 3000.00
Total		R 62400.00

Table 22 Total cost for 80 students

When the number of students increased from 80 to 90, the amount of resources had to be modified to keep to the 5 hour maximum time constraint. The cost implications of that increase are reflected in Table 23.

	Number of resources	Cost per sub-process
New Registrations	1	R 3600.00
Receive Forms	2	R 6000.00
Print Forms	1	R 3000.00
Financial Enquiries	3	R 12600.00
BSc Adviser	3	R 18000.00
Payment	1	R 3600.00
Register Subjects	4	R 14400.00
Study Guides	2	R 6000.00
Student Cards	2	R 6000.00
Total		R 73200.00

Table 23 Total cost for 90 students

When the number of students increased from 90 to 100, the amount of resources had to be modified to keep to the 5 hour maximum time constraint. The cost implications of that increase are reflected in Table 24.

	Number of resources	Cost per sub-process
New Registrations	1	R 3600.00
Receive Forms	2	R 6000.00
Print Forms	1	R 3000.00
Financial Enquiries	3	R 12600.00
BSc Adviser	3	R 18000.00
Payment	1	R 3600.00
Register Subjects	4	R 14400.00
Study Guides	2	R 6000.00
Student Cards	2	R 6000.00
Total		R 73200.00

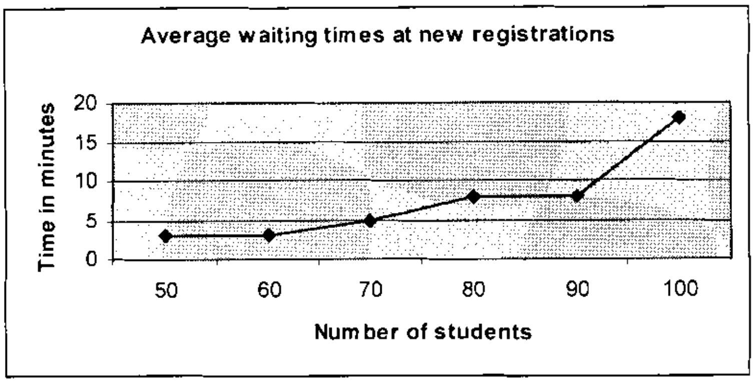
Table 24 Total cost for 100 students

5.11 Document, present, and use results

5.11.1 Document study's results

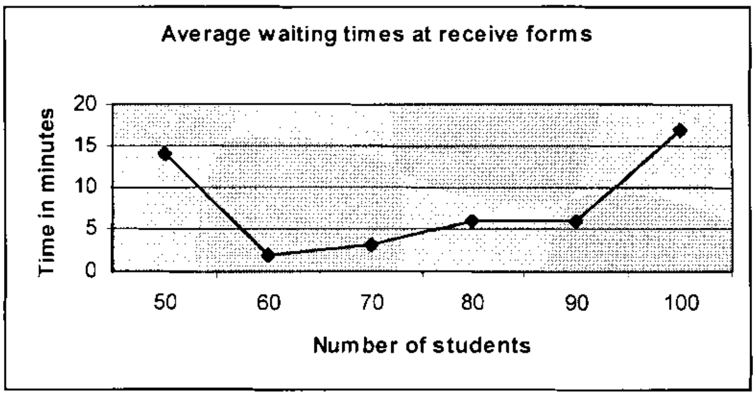
The following graph represents the waiting time of the students at the new registrations sub-process. It contains the waiting times from the base case, right up to 100 students. As can be seen from the graph, one resource is sufficient as long as the number of students stay below

100. If the number of students were to rise above 100, another resource would have to be added.



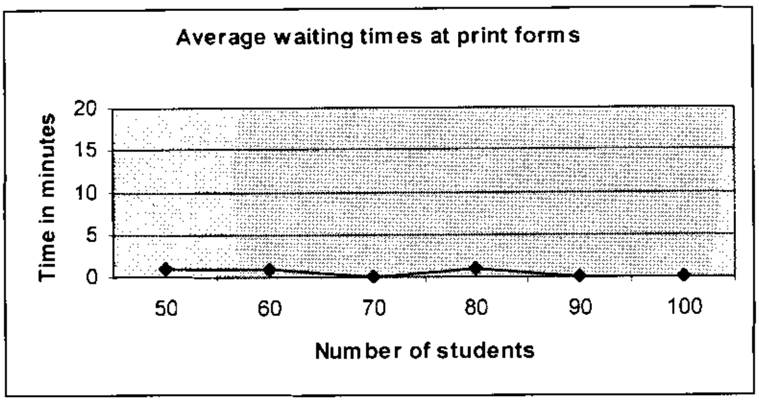
Graph 9 Average waiting times at new registrations

The following graph represents the waiting time of the students at the receive forms sub-process. It contains all the waiting times from the base case, right up to 100 students. As can be seen from the graph, one resource is only sufficient as long as the number of students stay below 50. If the number of students were to rise above 50, another resource would have to be added to keep waiting times low enough to satisfy the 5 hour maximum time constraint. This would have to happen again if the number of students were to rise above 100.



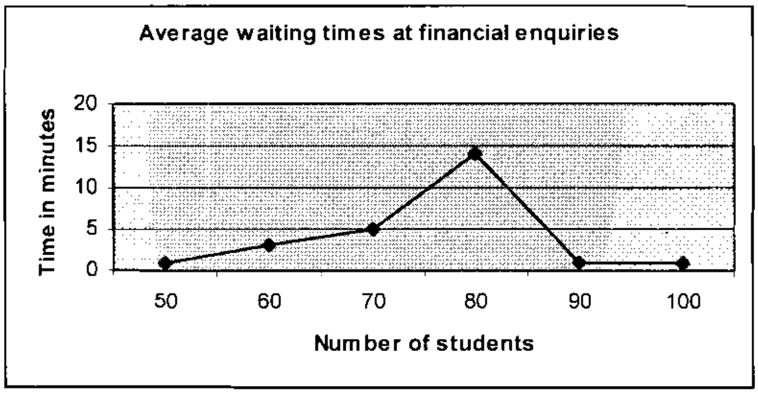
Graph 10 Average waiting times at receive forms

The following graph represents the waiting time of the students at the print forms sub-process. It contains all the waiting times from the base case, right up to 100 students. As can be seen from the graph, one resource is sufficient for this sub-process, even as the number of students reaches 100.



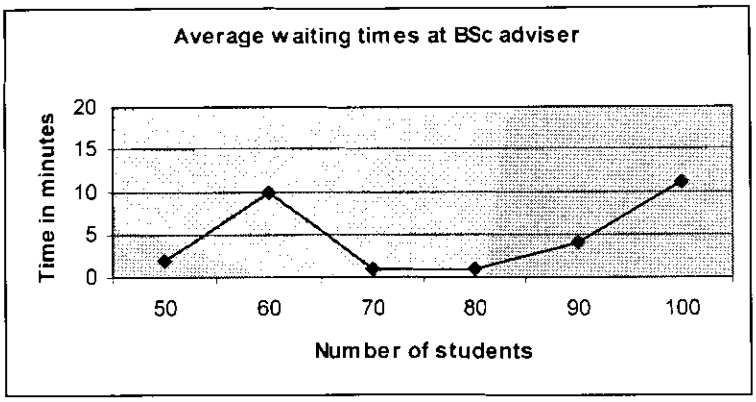
Graph 11 Average waiting times at print forms

The following graph represents the waiting time of the students at the financial enquiries sub-process. It contains all the waiting times from the base case, right up to 100 students. As can be seen from the graph, two resources are only sufficient as long as the number of students stay below 80. If the number of students were to rise above 80, another resource would have to be added to keep waiting times low enough to satisfy the 5 hour maximum time constraint.



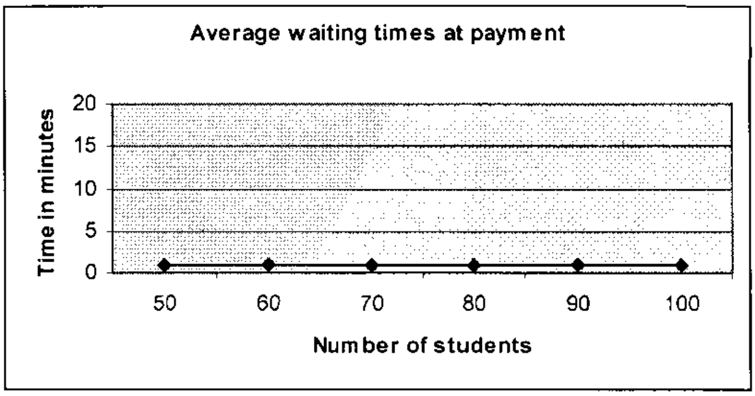
Graph 12 Average waiting times at financial enquiries

The following graph represents the waiting time of the students at the BSc adviser sub-process. It contains all the waiting times from the base case, right up to 100 students. As can be seen from the graph, two resources are only sufficient as long as the number of students stay below 60. If the number of students were to rise above 60, another resource would have to be added to keep waiting times low enough to satisfy the 5 hour maximum time constraint. This would have to happen again if the number of students were to rise above 100.



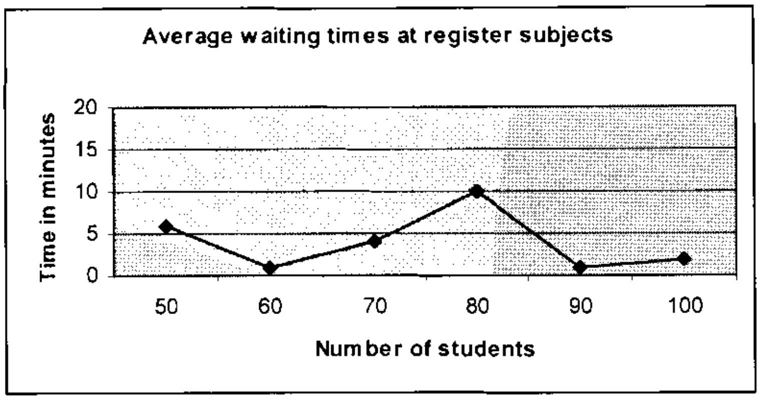
Graph 13 Average waiting times at B.Sc. adviser

The following graph represents the waiting time of the students at the payment sub-process. It contains all the waiting times from the base case, right up to 100 students. As can be seen from the graph, one resource is sufficient for this sub-process, even as the number of students reaches 100.



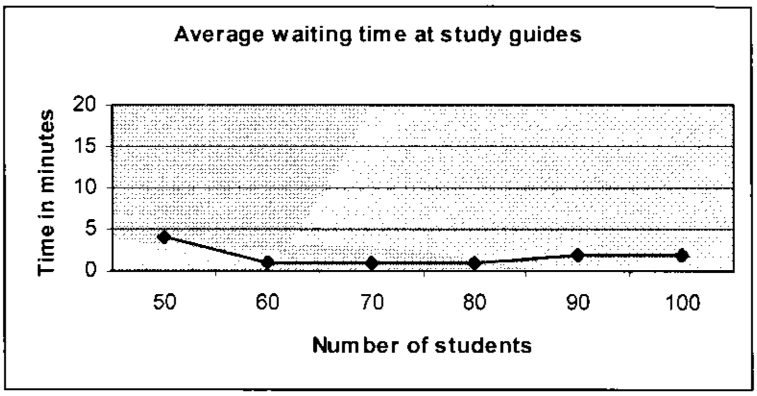
Graph 14 Average waiting times at payment

The following graph represents the waiting time of the students at the register subjects sub-process. It contains all the waiting times from the base case, right up to 100 students. As can be seen from the graph, one resource is only sufficient as long as the number of students stay below 50. If the number of students were to rise to between 50 and 80, another resource would have to be added to keep waiting times low enough to satisfy the 5 hour maximum time constraint. This would have to happen again if the number of students were to rise above 80.



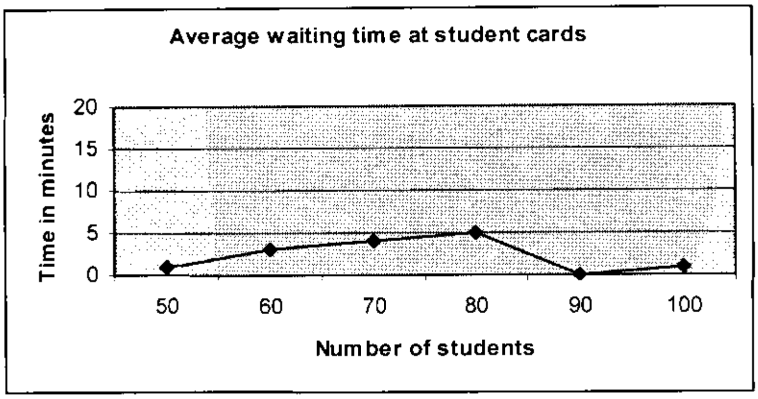
Graph 15 Average waiting times at register subjects

The following graph represents the waiting time of the students at the study guides sub-process. It contains all the waiting times from the base case, right up to 100 students. As can be seen from the graph, one resource is only sufficient as long as the number of students stay below 50. If the number of students were to rise to above 50, another resource would have to be added to keep waiting times low enough to satisfy the 5 hour maximum time constraint.



Graph 16 Average waiting times at study guides

The following graph represents the waiting time of the students at the student cards sub-process. It contains all the waiting times from the base case, right up to 100 students. As can be seen from the graph, one resource is only sufficient as long as the number of students stay below 80. If the number of students were to rise to above 80, another resource would have to be added to keep waiting times low enough to satisfy the 5 hour maximum time constraint.



Graph 17 Average waiting times at student cards

5.11.2 Present study's results

The following table is provided as a summary of the amount of resources required, if the amount of students expected is known. The table makes provision from 50 students, right up to 100 students, as discussed in section 5.2.2.

	Resources for 50 students	Resources for 60 students	Resources for 70 students	Resources for 80 students	Resources for 90 students	Resources for 100 students
New Registrations	1	1	1	1	1	1
Receive Forms	1	2	2	2	2	2
Print Forms	1	1	1	1	1	1
Financial Enquiries	2	2	2	2	3	3
B.Sc. Adviser	2	2	3	3	3	3
Payment	1	1	1	1	1	1
Register Subjects	2	3	3	3	4	4
Study Guides	1	2	2	2	2	2
Student Cards	1	1	1	1	2	2
Total Resources	**12**	**15**	**16**	**16**	**19**	**19**
Total Cost	**R46800**	**R56400**	**R62400**	**R62400**	**R73200**	**R73200**

Table 25 Summary of resources required per number of students

As can be seen in the table, an additional 7 resources will be required if student numbers were to double, bringing the total amount of resources required up to 19. Even if student numbers only increased by 20% (10 students), 3 additional resources would be required, bringing the total amount of resources required up to 15. The estimated costs associated with each scenario are also presented to assist decision making.

5.12 Conclusion

In this chapter the simulation process was applied. It was done using the steps compiled by Law (2007:66-70). According to Law (2007:66), following these steps will compose a typical, sound simulation study. It also became clear that a modeler has to be very careful of "bottleneck shifting", especially when resource adjustment is taking place. For example, by adding a resource to a sub-process early in the model, the bottleneck can merely be shifted to a sub-process later on in the model.

CHAPTER 6

6 Findings and Recommendations

6.1 Introduction

Thompson (1996: 869) defines a solution as "solving or means of solving a problem". The registration model that the university has been using for the past few years has reached its capacity, as many complaints and unhappy customers can prove. The major disadvantage of the registration model is the amount of time that customers spend in queues at different sub-processes in the current model. For the purpose of this research the following criteria were set.

- Registration of first year BSc students is completed within 5 hours.
- 85% of all students can realize a turnaround time of less than 2 hours.

Different scenarios (experiments) were explored, and a cost model was used to estimate the costs involved in increasing the number of resources at the various sub-processes.

6.2 Findings

6.2.1 Aim 1

Examine the registration model of first year BSc students.

The registration model of the satellite campus was analyzed, including the parts that precede the day of registration on campus. These parts were included in order to gain a better understanding of the inner workings of the registration model. The data that was necessary for these analyses was obtained by choosing interviewing as the data acquisition method. Interviews were conducted with the administrators, the administration personnel (SME's), and students. Interviews were conducted with all the role players to ensure that all points of view were covered.

6.2.2 Aim 2

Simulate and optimise the registration model of first year BSc students up to an expected number of 100 students, given the constraint to complete the registration in 5 hours.

After examining and analyzing the registration model of the satellite campus, it was translated into a simulation model. ARENA was the simulation language used to accomplish this. In order to build a simulation model that was as accurate and representative as possible, the various sub-process SME's were asked for service time estimates as well as estimates with regard to the travel times between the various sub-processes. Once all this information was known, the flowchart of the registration model was constructed. The registration model was optimized for 50, 60, 70, 80, 90 and 100 students (as discussed in section 5.2.2).

6.2.3 Aim 3

Determine the cost implications of the proposed resource increases.

Even though a thorough cost analysis was not required for this study, it is important to keep in mind that costs do play a major role in decision making. Therefore estimated costs were used in this study to attempt to quantify the costs involved in increasing the resources at the various sub-processes. A summary of the costs involved in the various solutions is provided in the next section.

6.3 Recommendations

Given in Table 26 is a summary of the results obtained from this study. As can be seen in the second last row, the first criterion of completing registration of first year BSc students in 5 hours is met by all the recommended solutions. The last row also indicates that the second criterion has been met, since all the recommended solutions ensure that at least 85% of students have a turnaround time of less than 120 minutes. The table makes provision for 50 students right up to 100 students, in increments of 10. Once decision makers therefore know how many students are expected to register, they can simply refer to the relevant column in the table.

	Resources for 50 students	Resources for 60 students	Resources for 70 students	Resources for 80 students	Resources for 90 students	Resources for 100 students
New Registrations	1	1	1	1	1	1
Receive Forms	1	2	2	2	2	2
Print Forms	1	1	1	1	1	1
Financial Enquiries	2	2	2	2	3	3
B.Sc. Adviser	2	2	3	3	3	3
Payment	1	1	1	1	1	1
Register Subjects	2	3	3	3	4	4
Study Guides	1	2	2	2	2	2
Student Cards	1	1	1	1	2	2
Total Resources	**12**	**15**	**16**	**16**	**19**	**19**
Total Cost	**R46800**	**R56400**	**R62400**	**R62400**	**R73200**	**R73200**
Time Required	**5**	**5**	**5**	**5**	**5**	**5**
Percentage below 120 minutes	**97.52 %**	**99.57 %**	**99.69 %**	**88.22 %**	**99.93 %**	**91.78 %**

Table 26 Summary of results

6.4 Future research

Even though the registration model has been greatly improved as a result of this study, it is far from the optimum model which will see students registering in just a few minutes. This study focused on the physical part of the registration model, the part that takes place at the campus on the day of registration. This means that there are two main areas that can still be improved on:

1) **Software.** Design new software or modify the current software used in the registration model to streamline the process, and to computerize as much of the work as possible. This will minimize the number of errors made both before and during registration, as less human input is required.
2) **Number of sub-processes.** Time should be invested into finding ways to reduce the number of sub-processes involved in the registration model. This can be done by either combining some of the sub-processes, or by completing them before the registration period. For example, by sending the forms that the students need to register with their end of year results or acceptance letters, the entire sub-process of receiving forms

(which can be found in the current registration model) is eliminated. Even though this will not necessarily reduce the time students spend receiving service, it will definitely reduce the amount of time they wait, as well as the amount of time spent traveling between the various sub-processes (transport time).

6.5 Conclusion

In this chapter a summary of the completed research process was given. Throughout this study it has become clear that a lot can actually be achieved with an absolute minimal amount of capital spent. Even implementing the optimal solution will cost a lot less than might have been expected. The optimal solution reduces the time students need to register to 76 minutes. This is a dramatic improvement, seeing that the time students need to register in the current registration model is 180 minutes.

This chapter started with a section on the findings with regards to the aims set out in section 1.3. This was followed by a section on the recommendations of this paper. The chapter ended with a discussion on the fields in which further research can be conducted.

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APPENDIX A: WELCOMING PROGRAMME EVALUATION QUESTIONNAIRE

Student Affairs

Welcoming Programme Evaluation Questionnaire

Please evaluate the following activities of the week on the basis of the accompanying scale. As the evaluation is done anonymously, please feel free to be as honest as possible. Your ***honest*** *contributions will help the University to improve the programme for coming years. A* ***one (1)*** *on the scale indicates utmost* ***dissatisfaction*** *while a* ***five (5)*** *would indicate utmost* ***satisfaction****. The remaining numbers of the scale would indicate varying degrees of these extremes.*

General
The name of your residence:___________________________________

Duration of programme	1...2...3...4...5
General arrangements	1...2...3...4...5
Meals	1...2...3...4...5

Members of staff (Student Affairs)

Behavior and attitude of members of staff	1...2...3...4...5
Availability of and support from members of staff	1...2...3...4...5
Level of preparedness and competency of members of staff	1...2...3...4...5

Student leaders

SRC

Behavior and attitude of members of the student council	1...2...3...4...5
Level to which SRC members deserve respect	1...2...3...4...5
Level to which SRC members demonstrate leadership	1...2...3...4...5

Your House Committee members

Behavior and attitude of house committee members	1...2...3...4...5
Level to which house committee members demonstrate leadership	1...2...3...4...5

Level to which house committee members deserve respect 1...2...3...4...5

Specific remarks and suggestions regarding the above-mentioned topics:

____
____
____
____

Wednesday 26-01-2005

Official opening 1...2...3...4...5

Finances and Administration 1...2...3...4...5

Faculty Guidance 1...2...3...4...5

The day in general 1...2...3...4...5

Specific remarks and suggestions regarding the above-mentioned topics:

____
____
____
____

Thursday 27-01-2005

Registration 1...2...3...4...5

Friday 28-01-2005

Exposure to the campus 1...2...3...4...5

The day in general 1...2...3...4...5

Monday 31-01-2005

Activities and games 1...2...3...4...5

The day in general 1...2...3...4...5

Specific remarks and suggestions regarding the above-mentioned topics:

____
____
____

Tuesday 1-02-2005

Information Session: Academic Support Services 1...2...3...4...5

Specific remarks and suggestions regarding the above-mentioned topics:

Wednesday 2-02-2005

Sport 1...2...3...4...5

Grand Prix 1...2...3...4...5

Specific remarks and suggestions regarding the above-mentioned topics:

Thursday 3-02-2005

Transformation 1...2...3...4...5

Specific remarks and suggestions regarding the above-mentioned topics:

Friday 4-02-2005

Affiliated bodies 1...2...3...4...5

HIV Aids 1...2...3...4...5

Specific remarks and suggestions regarding the above-mentioned topics:

Please indicate the activity you enjoyed most:

____
____
____
____

Any other comments or suggestions

____
____
____
____

Thank you for your participation