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Student e-Admission Solution for a Faculty of Sciences, Sefako Makgatho Health Sciences University, South Africa

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Abstract: This study presents the results of an exploratory quantitative research study undertaken to pilot an electronic admission of students at the Sefako Makgatho Health Sciences University (SMU). SMU's School of Science and Technology (SST) admit students who apply for admission by manually allocating space and rejecting applications. Wasted time was vast. Mistakes were sometimes detected with SMU students. Some students were admitted when they should have been rejected and others were rejected when they should have been admitted. The study presents a software solution for student selection. It then tests with the marks of previous applications to check the consistency in the previous approach with that of the software. The results showed that the manual method was heavily too slow, prone to error and lacked quality proper checks. The software application identified mistakes in admissions and rejections made in the past while in its own application was impressively accurate and quick.

INTRODUCTION

Organizations aim to select best candidates for inclusion in their mass of skilful members in order to be competitive. This occurs in staffing in which best candidates can ensure that the company can match leading corporates. Governments require best candidates and employees to promote development. Academic institutions compete for best students to enhance increasing graduations and represent their institutions in the market. Where weaker students are admitted, modern trends show that blended teaching and Information Technology (IT) tools are used to help support such students. When IT is not utilised, institutions tend to be backwards in competition. In all these, suitably leading candidate are the targets for new allocation.

Selection problems are unlimited and differ in contexts and complexities. A case of the admissions of new science students for SMU refers. At the beginning of every year, the sub-directorate of sciences struggles with the applications for admission into the Bachelor of Science (BSc) courses. Members of the various academic staff categories gather in university halls and students have to queue for both admission and enrolment. These students apply for a place by filling in a suitable application form for the different schools (Health Sciences, Medicine, Oral Health, Pharmacy and SST) on campus. That information is captured on the system and

lists forwarded to the respective schools for consideration. In the SST, printed hard copies are produced for manual evaluations of suitability of the applicants. Then a selection committee consisting of the school dean and heads of respective subject disciplines sits and places each and every applicant into the respective clusters based on applicant's matric results, the requirement s of each cluster and the required quota of each cluster. The current quotas for clusters Mathematical and Computational; Molecular and Life and Physical and Mineral are 40, 120 and 60 first-year students respectively. Furthermore, applicants with second or third choice in other schools often find their applications forwarded to the SST after failing to secure a place from their first or second choice. This leads to the committee having to meet again to consider these applicants at a convenient later date. The successful applicants get advised of their outcomes through written letters from the admission's office and sometimes by telephone. These manual methods are slow and prone to error. Recently, mistakes were discovered in which students in their final year of the BSc degree had not qualified for admission to BSc. For example, a student was found in 2014 already in third year of the BSc course having not completed the prerequisites including having not passed Mathematics I while registered for Mathematics III.

All the sittings are done manually, despite this being the information and technology era. Lack of quality admission occurs, there is a long time to process applications, mistakes occurring and inconsistencies in interpreting the rules of admission, among others. On average, each sitting for admission purpose consumes at least two days. The other drawback of the manual system is that no quality checks are made. When a student is rejected, the process stops. This means that a wrongly rejected student remains rejected because no monitoring is done to correct errors. These problems lead to time wasting in which valuable research time of academic staff is wasted. Many of the students admitted in SST have poor backgrounds. Hence, the time wasted on this manual admission exercise could be used for staff training on teaching methods and for crafting strategies to teach and support students effectively.

The manual method of admissions is outdated in the modern era. It lacks effectiveness and the needed efficiencies in student allocation for SMU. It shows errors in both admissions and in rejections. It is also too slow for the modern times. The mistakes made manually can be an embarrassment to an institution if exposed to the world outside. The quality of methods at entry level is easily associated with the quality of the education offered. Hence, in order to boost its image, the SMU should ensure that it tightens possible loopholes of error right from its admission policy and practice.

This study presents the automated e-method useful in selection and placement problems of students with improved efficiency and effectiveness and particularly to save time for value-added work. It applies Information Technology (IT) on comparison problems in which students are checked for satisfying the minimum requirements and then ranking students in terms of merit. In addition to the problems outlined, the manual process of selection and placement of applicants has several drawbacks which include:

- Securing convenient days for selection committee to make selections
- Erroneous placement of some applicants by the selection committee
- Applicants with insufficient grading eventually offered places
- Delays in informing successful applicants
- Overpopulation or under-population in some subject disciplines with successful applicants
- Low staff morale and
- Inability to keep correct statistics

The study objective was to develop a computer-based system that is capable to enforce accurate, fast and cost-effective admissions of students at tertiary level in a SST.

Idea conception: Addressing selection problems ensures that items meeting the criteria are included while others are excluded. Selection problems differ in complexities, and may also require ranking in terms of merit. They are integrated in sorting to identify leading items[1]. The sort order identifies the sequence of the sorted data, either ascending or descending. IT selection and sorting methods are faster than manual methods.

In practice, the use of IT (e-method) is efficient when we have several selection tasks. It has one initial expensive sort that is followed by many cheap selection operations. Selection problems occur in a multitude of applications where often an optimal solution is sought given a set of competing activities[2, 3]. In this study, students applying for first time entry into the BSc program compete for placement into the three units namely, Mathematical and Computational, Physical and Mineral and Biological and Life sciences. The selection and placement into these units is based on the National Senior Certificate (NSC) level of achievement and the Admission Point System (APS) requirements.

Artificial intelligence: Artificial Intelligence (AI) is the intelligence exhibited by machines or software and the branch of computer science that develops machines and software with intelligence. AI is the study and design of

intelligent system that manipulates its environment and takes actions that maximise its chances of success[4].

The general problem of simulating (or creating) intelligence has been broken down into a number of specific sub-problems. These consist of particular traits or capabilities that researchers would like an intelligent system to display. The traits described below have received the most attention.

AI algorithms are a step-by-step reasoning that humans use when they solve puzzles or make logical deductions[5]. They are useful methods for dealing with uncertain or incomplete information employing probability concepts. AI solves difficult and complex problems requiring huge computational resources (or combinatorial explosion) and use vast computer memory and quick response times[6]. The main ambition of AI research is to pursue efficient problem-solving algorithms. In AI, a hierarchical control system is a management system in which relevant devices and governing software are arranged in a hierarchy to resolve a problem. Once AI goals are set, the future is visualised or planned through forecasting and then relevant tools acquired to perform the tasks needed. These tools are deployed to make choices seeking to maximise the value from the available alternatives. AI covers machine learning (the study of computer algorithms to enhance mechanical methods through experience), social intelligence, creativity, cybernetics and brain simulation, statistical data, logic, probabilistic models, neural networks, classifiers and statistical learning methods and control theory, among others[7].

Methods for selecting students at universities: USA universities do not select first time entry students based on merit alone. They use technology to entice would be first year entering students by offering them (among others) chat rooms with the university administration staff, question and answer forums through use of blogs, so that, the students can understand the institution as well as the programs on offer. In South Africa, universities use open days where prospecting first year students visit these institutions to learn about them and the programs offered. They pre-select students into their programs based entirely on the NSC and the APS systems.

Some universities also give an entry test in conjunction with the NSC and APS. Limited technological evidence exists on how applicants are selected into the respective programs under certain schools[8]. In South African universities, applicants are ranked based on the accumulated high school marks or on the accumulated APS as stipulated by the Department of Higher Education and Training.

Table 1: Admission points

NSC-Level of achievement (%)	Admission Point (AP)
8(90100)	8
7(80-89)	7
6(70-79)	6
5(60-69)	5
4(50-59)	4
3(40-49)	3
2(30-39)	2

Each university then specifies its own criteria or minimum requirements as guide to admit applicants into the different programs offered.

Poor matric results up to year 2012 led some universities as from 2014 to have new minimum requirements into certain programs. In South African universities of Limpopo (UL) and KwaZulu-Natal (UKZN), students are admitted into certain programs based on academic merit which is assessed by converting NSC symbols into APS system. UKZN calculates and ranks the Admission Points (APs) in descending order for respective choices of programs $\cup_{(\cdot)}^{(\cdot)}$ and selects the high ranked applicants until the number of students into the respective program is achieved. At UL, admission into a program is based on the calculation of obtained NSC marks and ranked in descending order. Selection is done from top-down into the respective units until the number of those qualifying reaches a stipulated quota. This process as whined is done manually by academic staff: SST dean, discipline heads and admission officers, among others. Table 1 shows the NSC and APS equivalents.

The next section discusses how fuzzy logic is used in selection of applicants as a solution to the challenges of student over- or under-population and wrongful placement of applicants into certain programs.

Fuzzy logic in selection: Fuzzy logic involves reasoning under uncertainty (Fig. 1)[9]. Uncertainty can lead to people making poor decisions or preventing people from making best decisions due to lack of adequate information. Rule-based systems often give rise to uncertainty which may result from errors in formulating individual rules or from conflicts of those rules or from mere incompatibility of those individual rules. These individual rules are of "IF-THEN" format which allows modelling complex systems to use higher level of abstraction. The rules are also determined by the number of input values and the number of linguistic variables based on people's knowledge and experience[10].

The input space involves mapping input values onto the fuzzy set in a particular domain. The black box contains the defined rules to transform inputs through approximate reasoning. The generated output for choice of an optimal solution obtained by defuzzification process

Table 2: Criteria and attributes

Criteria	Attributes	Criteria	Attributes	Criteria	Attributes
MC	Mathematics	PM	Mathematics	BL	Mathematics
	Physical science/Information Technology		Physical science		Physical science
	English		English		English
	Life Orientation		Life Sciences		Life Sciences
	Additional subject 1		Life Orientation		Life Orientation
	Additional subject 2		Additional subject 1		Additional subject 1
	Additional subject 3		Additional subject 2		Additional subject 2
Minimum APS	23		23		23

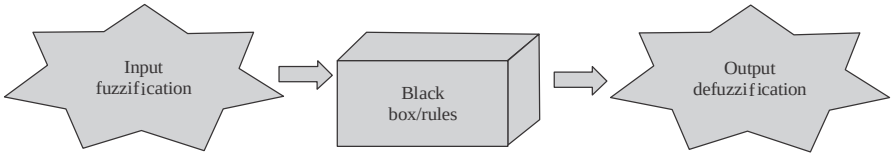

Fig. 1: Fuzzy logic model

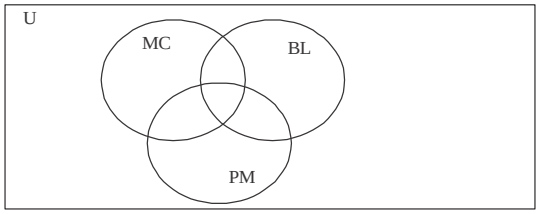

Fig. 2: Universal set

falls within the interval of 0 and 1. Hence, the process tries to eliminate the inconsistencies and inaccuracies that may occur due to human error. However, fuzzy logic starts by defining the membership function:

$$\mu(x):\rightarrow[0, 1] \quad (1)$$

If an object is a member of a set then its characteristic function is 1 and if the object is not in the set, then its characteristic function is 0[10]. Fuzzy logic also helps to select applicants into the different units in this study. Considering that all applicants admitted constitute a universal set U with subsets MC (mathematical and computational, PM (Physical and Mineral) and BL (Biological and Life sciences) represented as: The Universal set can also be expressed as (Fig. 2):

$$U = U_{k=1}^{m}MC+U_{j=1}^{n}PM+U_{i=1}^{0}BL \quad (2)$$

where m, n and o are the stipulated quotas in the respective units and $\bigcup_{(.)}^{(.)}$ denotes the relevant union of sets.

Figure 2 explains the goal of the study as to place applicants with best mathematics scores in subset MC those with best physicals science scores in PM and those with best biology scores in BL. If there is a tie (as in overlapping subsets), other relevant subjects appearing in Table 2 are used in breaking that tie or conflict making use of S-function which according to Giarratano and Riley[9] is defined as (Fig. 3):

$$S(x, \alpha, \beta, \gamma) = \begin{cases} 0 & \text{for } x \le \alpha \\ 2(x-\alpha/\gamma-\alpha)^2 & \text{for } \alpha \le x \le \beta \\ 1-2(x-\gamma/\gamma-\alpha)^2 & \text{for } \beta \le x \le \gamma \\ 1 & \text{for } x \ge \gamma \end{cases}$$

As an example, all elements present in MC have a characteristic function of 1 and those outside the set a characteristic function of 0. Thus, for a criteria MC, attribute maths: all its data are compactly represented by a formula whose parameters (α, β and γ) in S-function can be adjusted to meet the required membership data instead of maintaining a table of data. Adjusting these parameters may possibly result in an exact fit or an approximation giving consistent results. Therefore, each criterion in the fuzzy model will have three dominating attributes which are MC, PM and BL. The additional relevant subjects are selected from designated list which shows all the NSC Grade 12 subjects designated list of schools subjects:

- Accounting
- Agricultural science
- Business studies
- Consumer studies
- Dramatic arts
- Economics
- Engineering graphics and design
- Geography
- History
- Information Technology
- 3 Languages*
- Life Science (Biology/Physiology)
- Mathematics or Mathematical Literacy

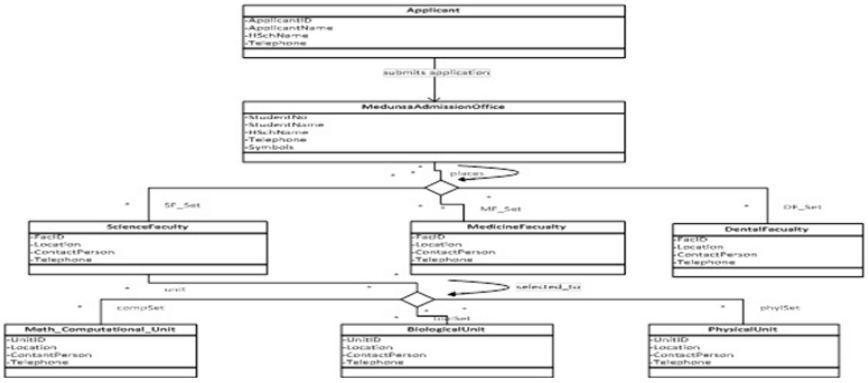

Fig. 3: Selection and placement process

- Music
- Physical Science/Natural Science
- Religion studies
- Visual arts

*One must be the language of teaching and learning at a HEI and two other recognized language subjects).

Operations research is a discipline of applying advanced analytical methods to help in making superior useful decisions[5]. It is concerned with developing and applying models and concepts to help in revealing management issues and solve managerial problems. It deals with real life issues experienced in various areas such as business, industry and universities, among other sectors with the sole purpose of trying to improve efficiency in the work environment. In trying to develop these models to solve a given problem, a number of tools can be used such as linear programming. Koufogiannakis and Young[11] clarify that linear programming is a mathematical modelling tool used in planning of activities to obtain a result that reaches the specified goal best given all possible ways. The modelled activities will then be converted into a system prototype. Prototyping is quick design methodology used in developing software systems. The system is built in small increments which take the form of a working system.

System prototyping is often used to get user requirements and to confirm if the system being designed is what the user really wants[12]. In Software Design Life Cycle (SDLC), the phases which the design must go through are planning, analysis, design and implementation[13]. With system prototyping the analysis, design and implementation phases are carried out at the same time to emerge with a working small system.

Mathematical methods in selection problem: The objective of statistics is to infer or forecast about a parent population using a sample population. Probability theory is a reasoning method under uncertainty, a process often referred to as deduction[14]. Probability theory is extensively used in statistics to come up with a mathematical or theoretical model to acquire and use information in the real world.

Graphing is a method adjoining mathematics and computer science techniques to present and visualize information. A graph is a network diagram, a picturesque illustration and border of an entity appearing as a model. In dynamic situations, the graph changes over time which is done by adding and deleting edges under dynamic graph drawing[15]. Dynamic graphing aims to preserve the user's mental map. In this study, expected changes are increasing selected candidates, changing entry requirements and various competitions among the schools at SMU. Hence, dynamic graphing is needed to match the complexity anticipated.

If applications meet the due dates set by the campus, this study requires quality arrangement in such a way that suitable candidates are included in the programme for which they applied for based on pure merit. Thus, included candidates should have performed better than those not included. Also, rejected candidates could not meet entry requirements. Hence, quality graphing should be able to demonstrate quality in the efforts of the study. Numerous quality measures exist for graph drawings in order to evaluate the aesthetics and usability of drawn graphs impartially[16]. These measures, according to Janos and Sharir include the crossing number, smallest bounding box, symmetry groups, polyline drawings, angular resolution and cubic graphs. Graph theory is suitable in flowcharting in which

logical flow occurs naturally. However, dynamics of reiteration occur where competition has already taken place.

Graphs for selecting candidates should ensure that acceptable candidates are included and better ones in terms of the set criteria are placed ahead of the weaker ones. This means that there need to be a flow of arguments in the selection process as well as some iteration based on having to compare a new inclusion with previously included cases. Graphs and graph drawings that could assist in these are Hasse diagrams (a type of graph drawing specialized to partial orders), computer network programs (depictions of the nodes and connections in a computer networks)[17, 18], flow charts (drawings in which the nodes represent the steps of an algorithm and the edges represent control flow between steps); data flow diagrams (drawings in which the nodes represent the components of an information system and the edges represent the movement of information from one component to another). Flow charts as well as data flow diagrams will be used in this study as shown by Fig. 3.

MATERIALS AND METHODS

The study uses a mix methodology that combines qualitative and quantitative methods. The qualitative part addresses outdated approach in student selection that SMU follows each year to admit students. The quantitative part consists of use of marks from NSC that are criteria for admission. The minimum marks are checked through an IT system if the applicant meets the criteria, then allocates according to where she/he should be placed according to the choices made. Straight rejections are effected where necessary. When the next applicant is evaluated, the same process is repeated and a comparison is made with the previously pre-admitted applicant for ranking. The process is repeated, unsuitable applicants rejected and suitable ones allocated and ranked accordingly. In this process, software application implementing the throwaway prototyping methodology whose Fig. 4 is shown can be convenient (Fig. 4).

The process has all the System Development Life Cycle (SDLC) phases. The design prototype above represents a system which still needs additional refinements. It contains enough detail to help users to understand the issues being considered. The system implementation uses C++, PHP and MySQL as software development platforms.

During the experimental stage while trying to prove the concept, simulated data were generated from the scores known to be the minimum requirements for admission. After this pilot phase, student marks of previously admitted students were requested from the office of the registrar of SMU and the real exercise was performed. The test data used in the study were past applicants who had applied for a BSc degree at SMU.

Data analysis consisted of experimentation and tests of the model based on NSC marks. The SMU registrar provided NSC marks of previously rejected applications as well but only few of which were provided. Applications for three years (2012-2014) were used which involved current SMU students from first to third years. The manual admission per year took a minimum of 2 days which is therefore, a minimum of six days for the 3 years. The experiment needed to compare with the software usage.

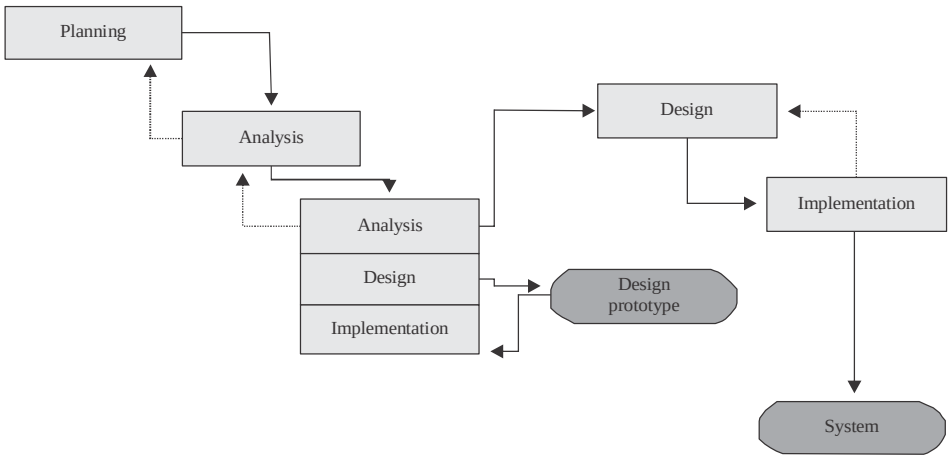

Fig. 4: The throwaway prototype methodology[12]

RESULTS AND DISCUSSION

This study compares the capabilities of manual processing with the e-application involving various scientific algorithms from various mathematical and computer sciences. The main variables of comparison were speed and accuracy of processing. The benefits and limitations of each approach are also used in the comparison.

Speed of processing the applications: For the data of 3 years, the processing of applications manually consumed at least six days in the past three years. The NSC marks were inputs for the decisions to be made. Within <(5) min the three data sets had been addressed in which allocation of students had been made and rejections reported accurately. Therefore, in terms of speed, the manual approach does not come close to matching the e-method. The advantages of speed are confirmed emphatically by Dalim *et al*.[19]. Other findings made are discussed below.

Detecting errors: There were SMU students who were enrolled but did not meet the requirements for admission to BSc. These included dropouts who could not pass a single first module in 2 years. The sentiments are shared by Clemes *et al*.[20]. These also included a student who was enrolled for Mathematics III in 2014 but had not passed or qualified to write an examination in the past 2 years.

Another finding was that among the previously rejected applications, there were students who had been rejected who could have been admitted if the software was used. Thus, mistakes were made by the manual approach and this was not detected as those students did not appear in the SMU register for any course. Muljo[21] point out that early detection of errors has potential to prevent rejections.

Accuracy: The rejections that the software identified were tested manually to determine if they were done correctly. Those applications were found to have been correctly denied. The other test was those who had been accepted by previous manual methods being denied by the softwaremethod this time. These were manually done again and this time, the manual process correctly found that they were mistakenly admitted. Dalim *et al*.[19] also emphasise the use of computers especially for their high level of accuracy.

Number of people involved: Computer usage in processing applications requires inputting of data/marks in the electronic system. The data capturers should make no errors and then only one person is enough to start running the programme. On the manual approach, the various people needed showed that it is labour intensive since many academic staff members from all the departments as well as the dean of school were involved.

The study established that the capabilities of manual processing are inferior to the e-application. involving various scientific algorithms from various mathematical and computer sciences. The main variables of comparison were speed and accuracy of processing. The benefits and limitations of each approach are also used in the comparison. The speed of processing the applications increase by a large magnitude. Work that took over a week can be started and concluded within 5 min. This swift exploit of application processing takes place with the highest level of accuracy. The accurate admissions increase pass rates as only the deserving students are admitted and the non-ready ones excluded. The approach was also able to detect mistakes of the past in which incorrectly rejected applicants and mistakenly admitted students were identified. The number of students to handle this task are also reduced as only one person can do the task. Induced benefits are apple time that academics can use towards research and student advisory services.

CONCLUSION

The software was amazingly fast. A task that took at least six working days to be completed in <5 min is astonishingly very fast. This method saves valuable time.In the software use, mistakes were shown to have not occurred. Hence, there was no evidence that the software could err. However, since, this study is the initial stage, it has to be monitored closely to ensure that it is not open to error. The validity of the system comes through its consistent judgement on cases that occur.

Regarding the manual method, some students were admitted by the manual system when they did not qualify while others were rejected when they qualified. These problems appeared in the three sets for the 3 years of the experiment. Wrong admissions and wrong rejections appeared in all the years of the experiment. However, they showed to differ widely. Also, since, the data sets were few to make a scientific argument, measurements of errors for wrong admission and for wrong rejection could not be prepared from them.

The e-processing of applications could also spot errors in decisions made which was not possible with manual processing. In checking the accuracy of manual processing, the same two-day duration was needed for each year. This was not done as it was assumed that no errors had been committed and everyone involved were exhausted. When manual processing is used to check the e-processing, no error was detected while e-processing could find faults in both rejections and admissions. The

manual processing needed many people to be involved and required more time for the work to be completed. The e-processing needed one person to run the program. Time is thus saved.

A software approach incorporates various technologies and scientific methods to reduce the possible errors and increases speed of accurate judgment to ensure that the applicants can be allocated space properly and those not admitted can know early to find alternatives as well as increasing staff morale. Technology usage is the only indication that a university is on par with the universal expectations of degrees and diplomas offering. It would be in SMU's best interest to adopt this innovative method of student selection processing since it offers a lot of benefits.

RECOMMENDATIONS

Based on the discussions, some recommendations to the SMU's SST are given below. Ineffective labour-intensive time wasting methods of processing student applications should be terminated. Authorities (that is the director, registrar and admission officers) should emphasis speed and accuracy during the processing of student applications for admission into the SST. Customised software applications should be developed for SST for student admissions.

A paradigm shift should occur in the SST dean's office in matching the 21st century trend of technological advancement in processing student applications for admission into SST. Academic staff in the sciences should insist on cost-effective processing technological methods in student admissions. Instead of traditional labour intensive technology, the author prescribes capital intensive technology for University student admission.

LIMITATIONS

The problem that this study faces is the attitude and an initiative of the leaders in as far as implementation of the solution is concerned. They were informed about the software solution and the results with some illustrations of the solution's capabilities sent to them. So, far they have not engaged with the developer or with the study supervisor. They are suspected to be knowing little about computers, and they seem to have inferiority complex to ask for help from junior staff who have been trained in computer science and IT.

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