Journal of Theoretical and Applied Information Technology
15th February 2021. Vol.99. No 3
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ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

DEVELOPMENT OF A FINITE STATE MACHINE MODEL FOR MONITORING THE ACADEMIC PROGRESSION OF UNDERGRADUATE STUDENTS

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ABSTRACT

The automated examination result processing system (AERPS) which is currently used by many tertiary institutions in Nigeria and beyond for monitoring students' academic progression (from their first year of study till their possible graduation from school) is deficient to a large extent. This is because the AERPS uses only the CGPA of students as the yardstick for determining such progression out of several other factors like: (i) a student's academic duration in school, (ii) a student's CGPA benchmark, (ii) a student's examination and moral misconducts in school, etc. These factors are very paramount in ascertaining a student's true academic state so that an appropriate action can be taken on the student for proper academic and moral nurturing such as: promoting him/her to the next level of study, or placing him/her on one year probation, or suspending/expelling him/her from school, etc. The aim of this work, therefore, is to develop a finite state machine model that will incorporate all these multi-faceted factors affecting the academic progression of an undergraduate student for effective monitoring. A mixture of quantitative and qualitative research methodology was used in developing the mathematical models required for simulating the input data of students. The generated input data was used by the FSM model to simulate the academic progression of 25 first year students for one academic session. Results showed that, using the 95% confidence interval of the t-distribution, the FSM model is better than the AERPS technique in determining the true academic state of a student. This ensures that every student is properly screened in character and learning before graduating. It also helps course advisers/lecturers in counselling students properly during course registration as well as in writing unbiased referee reports about them when needed.

Keywords: *Finite State Machine, Model, Academic Progression, Automated Examination Result Processing System, Simulation*

1. INTRODUCTION

According to [1], at the end of each academic year, a faculty assesses the academic performances of her students to determine those that are eligible to continue with their courses of study. If a student makes a satisfactory progress, he/she would be assigned the status of "Good Standing" and then permitted to re-enroll for the next level of study. On the other hand, if a student failed to make a satisfactory progress, he/she may be placed on probation, suspended, or excluded from school.

From the foregoing, we can see that there are several possible states a student can find himself/herself in at the completion of an academic session. These are: promotion to the next level of study, graduation from school, probation (or repetition of year of study), withdrawal from school, suspension/expulsion from school, etc. A student is 'promoted' to the next level of study if his CGPA meets the minimum benchmark. A student becomes a 'Graduate' if he successfully completed his academic programme within the required duration, and his CGPA meets the minimum benchmark, and there are no outstanding

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courses for him to write. A student is put on 'Probation' if his CGPA falls below the minimum benchmark. A student is 'withdrawn' from school if after the probation state his CGPA still falls below the minimum benchmark. The 'Suspension' or 'Expulsion' state occurs when a student commits examination or character misconduct, etc. It is therefore very imperative for every institution to keep proper track of the academic state of a student so as to take appropriate action as and when due.

The existing Automated Examination Result Processing Systems (AERPS) developed so far by various authors, such as the ones by [2], [3], [4], and [5] cannot be efficiently used in keeping track of the academic states of a student. This is because they do not provide a comprehensive check of a student's academic progression. For instance, for a student to progress to the next level of study after the completion of an academic year in a given Department, the following important checks must be done: (i) the CGPA of the student must not be below a specific benchmark; (ii) the student must not have exceeded his/her maximum year of academic programme; (iii) the student must not have committed any examination or character misconduct; (iv) the student must not have changed or deferred his/her Degree programme; (v) the student must not have withdrawn from school. All these important checks are not provided by the AERPS, thereby making the system an inefficient tool for monitoring students' academic progression. When a student's academic progression is not properly monitored, a lot of issues arise such as (i) increased moral decadence in school, (ii) many students not being able to graduate within the required academic timeline due to too many accumulated failed courses. (iii) many students ending-up their academic programmes with disappointing results such as, "3rd class", "Pass", or outright "Failure", (iv) many students not being employable in the labour market due to their extremely poor academic records, (v) lecturers not being able to counsel students properly during course registration, or writing unbiased referee reports about students when needed, etc.

This aim of this work, therefore, is to develop an FSM model that will incorporate all the aforementioned factors affecting the academic progression of an undergraduate student for effective monitoring so that the model can be used by various stakeholders such as the school registrar, lecturers/academic advisers, parents/sponsors, and students. The FSM model is "deterministic" in nature, and employed the Mealy technique so as to uniquely determine the next academic state of a student from his/her current state.

The research question for this work therefore focuses on whether the FSM model is better than the AERPS technique in determining the true academic state of a student at any point in time, as given by the following hypothesis:

> **H_0:** there is no significant difference between the FSM model and the AERPS technique in determining the true academic state of a student
>
> Vs
>
> **H_1:** the FSM model is better than the AERPS technique in determining the true academic state of a student

1.1 Objectives Of Study

The specific objectives for actualizing the aim of this work are:-

i. To carry out an empirical study of the existing system
ii. To develop mathematical models for simulating students' input data that will be used by the FSM model
iii. To use the FSM model to simulate the academic progression of 25 students from their first year of study to the next academic state
iv. To compare the performance of the FSM model with the existing AERPS technique

1.2 Limitations Of Study

Using a finite state machine (FSM) diagram to model a system becomes more complex to draw and understand when the number of states involved in a system increases. This work therefore considered the major states required in the academic progression of a student so as to keep the FSM model very compact and easy to understand.

2. LITERATURE REVIEW

Table 1 shows the summary of the views of some authors with respect to the monitoring of academic progression of undergraduate students.

Table 1: Some authors views with respect to the monitoring of academic progression of undergraduate students

Author's name	Model/System used	Technology applied	Strengths of the system	Weaknesses of the system
[2]	Automated examination result processing system (AERPS)	Web-based application	Can be used by academic advisers & students. A student uses the system to register courses & view semester results & GPA. On the other hand, an academic adviser uses the system to upload & view semester results	The system has no provision for other stakeholders like the school registrar & parents/sponsors. The system calculates only student's GPA but not CGPA. The system cannot be used to determine other factors pertaining to students' academic progression such as, cheating in exam, character misconduct, change of degree programme, etc.
[5]	Automated examination result processing system (AERPS)	Cloud-based application	Can be used by school registrar, lecturer, course adviser, exam officer, student, HOD, & external bodies. Results can be uploaded, viewed, & transcript generated with the system. Also data can be encrypted for secure transmission	Non-involvement of parents/sponsors in the system. No provision for CGPA benchmark for ascertaining the promotion of a student to the next level. The system cannot be used to determine whether a student has changed Dept, or withdrawn from school, or committed exam or character misconduct, etc
[4]	A cyclic model for monitoring student's progress	A manually-based progress chart	The system uses four main stages in the cycle for monitoring a student's academic progress. the 4th stage advocates the use of a "Progress record form" for recording students continuing academic progress. Various information that can be generated from the form include the following: (a) the number of students that dropped out of school, (ii) the number of students that are on probation, (iii) the average GPAs (that is, CGPAs) of students, (iv) the number of students proceeding to the next level of study, etc. *This work capitalizes on this stage extensively by automating it with a Finite State Machine*	The model is manually-based, and so cannot be efficiently used for monitoring the academic progression of students
[3]	A Finite State Machine model for determining the	Markovian chain for determining probability values	The model uses a directed graph that consists of nodes and	It is probabilistic in nature, and so does not give accurate figures about students'

	probability of academic progression of students		edges for determining various probability values about the academic progression of students. The idea of using a finite state machine for problem-solving was applied in this work	academic progression

3. THEORETICAL BACKGROUND

3.1 Modeling

A model is a graphical, physical, or mathematical representation of a real system [such as: an idea, an object, or a process] which is used to describe and explain the real system [6] and [7].

A *graphical model* uses pictures or static images to represent a reality. A physical model uses three dimensional image or motion picture to represent a reality. A mathematical model, on the other hand, uses equations to represent a reality. The type of model employed by the researcher in this work is a combination of *graphical* and *Mathematical* model. The *graphical model* is a directed graph that shows the movement of a student from one academic state to another (as shown in figure 4). On the other hand, the *mathematical models* developed in this work are of two kinds: (i) the mathematical models for generating students' input data (as shown in table 2), (ii) the Boolean algebraic expressions that manipulate the students' input data in order to determine the transition of a student from one academic state to another (as shown in table 6).

3.2. Simulation

Simulation is experimentation with a model such that the behavior of the model imitates some salient aspects of the behavior of the system under study [8]. In the same limelight, [9] defines simulation as the execution of a model (which can be represented by a computer program) by a computer so as to give information about the system being investigated. Thus, Simulation involves the manipulation of a model of a real system with varied input data (or random data) in order to understand how the real system behaves at various circumstances. Simulation is typically used in order to save time or cost of studying the real system, or when studying the real system would be too dangerous or impossible to undertake [9].

The results of the simulation of the mathematical models in tables 2 and 6 are shown in tables 7, 8, 9, and 10.

3.3 Academic States of a Student

Figure 1 shows all the possible academic states of a student undergoing a four-year degree programme at university of Nigeria. A similar scenario is obtainable in other tertiary institutions round the globe.

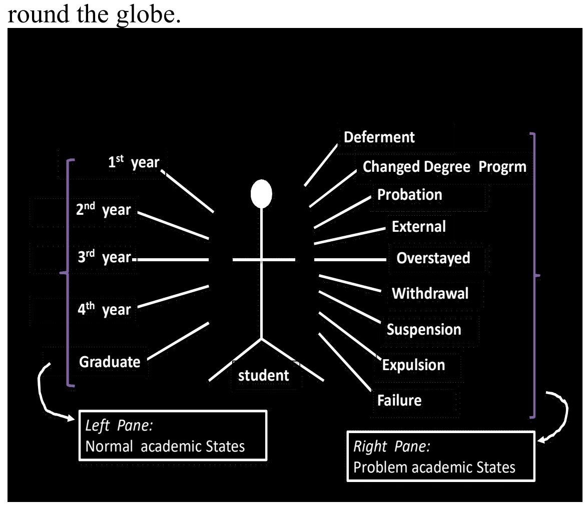

Figure 1: All the possible academic states of a student running a four-year degree programme

The left pane of figure1 shows the various states a student undergoes in **normal** academic circumstances. On the other hand, the right pane shows the **problem** states a student encounters in the course of his/her academic programme. The left pane shows that when a student is admitted to a university for a four-year degree programme, he will automatically be in "1st year" state. On the completion of 1st year, he is promoted to a new state being "2nd year" if he satisfies all the conditions required for being promoted. He keeps being promoted in like manner until he reaches his "4th (and final) year" of study. On the completion of 4th year, he becomes a "Graduate" if his CGPA meets the minimum benchmark, and there are no outstanding courses for him to write.

Coming to the **problem** state at the right pane, the *Deferment* state occurs when a "1st year"

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student postpones his admission till next academic session due to late admission, financial or health problems, etc. The state: *Changed Degree programme* occurs when a student, on completion of 1st year, 2nd year, or 3rd year, and possessing the required CGPA, wants to change to another course of study when, perhaps, he/she is finding the present course too difficult or no longer interesting. The *Probation* state occurs when a student, on completion of 1st year, 2nd year, or 3rd year, does not possess the minimum CGPA to be promoted to the next level of study; the student therefore repeats the current level of study. The *External* state occurs when a student, on completion of his 4th year of study, could not graduate as a result of some failed/outstanding courses to write. The *Overstayed* state occurs when a student reaches his maximum year of studentship without graduating from the university as a result of some failed/outstanding courses to write. The *Withdrawal* state occurs when a student, at any level of study, is compelled to withdraw temporarily or permanently from the university due to financial, academic, health problems, etc. The *Suspension* or *Expulsion* state occurs when a student, at any level of study, commits examination or character misconduct. The *Failure* state occurs when a student successfully completed his Degree programme and passed all the courses required of him, but did not possess the minimum CGPA required of him to graduate.

Figure 2 shows the academic life cycle of a student with respect to the academic states shown in figure1.

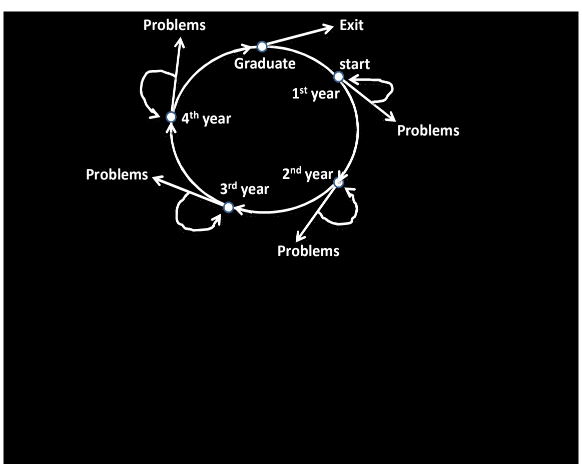

Figure 2: The academic life cycle of an undergraduate student

As figure 2 shows, the proposed course of study runs from 1st year (the 'start year' of study) to 4th year before a student can graduate, and then exit successfully from the system. If a student enters a **problem** state (as shown in the figure), the student repeats the year of study, or leaves the system temporarily or permanently

3.4 Finite State Machine

A Finite State Machine (FSM) is an abstract [or imaginary] machine used for modeling the behaviour [or keeping history] of the lifetime of an object of a system by specifying the sequence of stages or states that an object goes through during its lifetime in response to certain events [10] and [11].

A finite state machine is typically represented as a directed graph which consists of a finite number of states. An object can only be in one of the states at any given time, and can transit (or move) from one state to another at the occurrence of an event. An FSM, according to [12], consists of four main elements. These are:-

i. The various states for keeping stages of information of an object

ii. The transitions of an object from one state to another

iii. The rules or conditions that must be met for a state transition to occur

iv. The input events (which can be externally or internally generated) that trigger the transitions

According to [13], a Finite State Machine, denoted as M, can be defined mathematically as a 5-tuple ($Q, \sum, \delta, q_0, F$), where:-

- **Q** is the finite non-empty set of states of M
- $\sum$ is the finite non-empty set of distinct input symbols of M called the input alphabet
- $\boldsymbol{\delta}$ is a transition function that maps $Q \times \sum \rightarrow Q$; that is, δ is a mapping of the set of states Q, and the set of input symbols, $\sum$ onto a new set of states, Q which is also the set of the original set, Q
- $\mathbf{q_0 \in Q}$ is the initial state of M where the state transition begins
- $\mathbf{F \in Q}$ is the final state(s) of M where the state transition ends

Figure 3, for example, shows a finite state machine for promoting a 1st year student to 2nd year of study (or withdrawing him/her from school)

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based on the student's CGPA. The rounded rectangles denote the various academic states in which a student can assume at any point in time. Each state stores information about a student at that stage. An 'arrowhead' drawn from one state to another denotes a 'state transition' between the two states. It indicates a movement from one state to another. The transitions: T1, T2, and T3 denote the following: T1 = "go on probation" (i.e. 'repeat 1st year'), T2 = "promoted to 2nd year" , T3 = "Withdrawal from school"

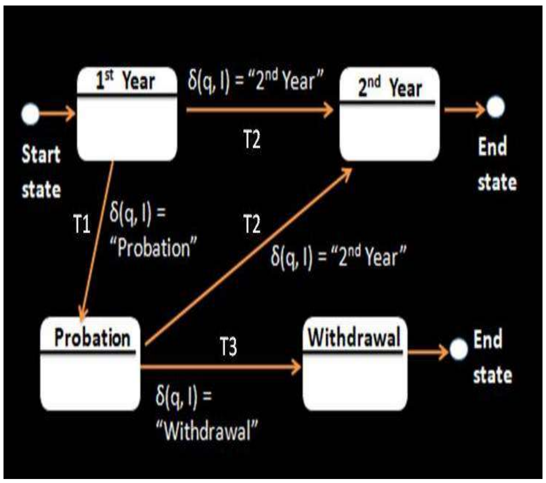

Figure 3: A finite state machine example

Representing the above figure 3 mathematically as a 5-tuple: (Q, ∑ , δ, q_0, F), we have:

Q = the set of all the finite states of the machine, M
= {"1st year", "2nd year", "Probation", "Withdrawal"}

q_0 = the initial or start state of the machine
= "1st Year"

F = the set of final or end states of the machine
= {"2nd Year", "Withdrawal"}

δ = the transition function that determines the new state of a student from a current state. It can generally be represented as, $\delta(q,I) = q_n$; where **q** is the current state of a student; **I** is the set of input symbols (or value) required of a student at state, **q**; while $\mathbf{q_n}$ is the new state a student transitions to.

∑ = the set of all the input values of a student which is required by the transition function, δ, in determining the next academic state of a student from a given state.
= {end of academic year(E) = ('true', 'false'), CGPA = ('poor', 'good')}

The expression: **δ(q,I) = "2nd year"** in figure 3, is evaluated as follows:

q = current state = "1st year"

I = set of input symbols = {E = "true", CGPA = "good"}

Therefore, **δ(q,I) = "2nd year"** implies:-

If((q= "1st year") And (E= "true") And (CGPA= "good")) Then
the transition, T2 occurs
and the new state of the student is "2nd year"

Similarly, the expression: **δ(q,I) = "Withdrawal"** is evaluated thus:

q = current state = "Probation"

I = set of input symbols = {E = 'true', CGPA = 'poor'}

Therefore, **δ(q,I) = "Withdrawal"** implies:-

If((q= "Probation") And (E= "true") And (CGPA= "poor")) Then
the transition, T3 occurs
and the new state of the student is "Withdrawal" from school

According to [14], a Finite State Machine is of two main types: "Deterministic Finite State Machine (DFSM)" and "Nondeterministic Finite State Machine (NDFSM)". A DFSM is a type of Finite State Machine whereby for each pair of state and input string, the next possible state can uniquely be determined. On the other hand, an NDFSM is a type of Finite State Machine whereby for each pair of state and input string, the next possible state cannot be uniquely determined because there are several possible next states. This work makes use of DFSM so as to uniquely determine the next academic state of a student from his/her current state when an input event about the student occurs (such as 'end of an academic session', etc).

4. METHODOLOGY

Table 2 shows the mathematical models developed by the researcher for simulating students' input data. The motive behind this is to quickly generate relevant input data that closely resembles the actual students' data so as to demonstrate how the developed FSM model in this work (shown in figure 4) can apply such data in monitoring the academic progression of students effectively. The student's input data considered in this work for simulation are: (i) exam score, (ii) exam misconduct, (iii) character misconduct, (iv) change of degree programme, (v) deferment of degree programme, (vi) authorized withdrawal from school, (vii) unauthorized withdrawal from school, and (viii) readmission to school

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Table2: Mathematical models for generating students' input data through simulation

s/n	Student input data	Mathematical model formulated	Logic & assumptions used
1	Exam score	***i.*** *below average students:* examscore = 0.85 * ($0 \leq i \leq 49$) + 0.15 * ($50 \leq j \leq 100$) Where: **i** and **j** are random numbers which can be determined with the use of the Java random number function called, *randomNumbers.nextInt(p)*. The function returns integer numbers randomly between **0** and **p** – 1. For instance, *randomNumbers.nextInt(30)* returns integer random numbers in the range: 0 to 29, inclusive. The above examscore for 'average students' can therefore be re-rewritten as, *examscore = 0.85 * (randomNumbers.nextInt(50) + 0.15 * (50 + randomNumbers.nextInt(51)*. The same principle applies to the other models that follow.	**(a)** the following 5-point grading system was used for modeling students' examscores: {70-100=A=5pts; 60-69=B=4pts; 50-59=C=3pts; 45-49=D=2pts; 40-44=E=1pt; 0-39=Fail=0pt.} **(b)** students were categorized into three IQ groups as follows: ***(i)***. *'below average students' = group X*: their assumed number is 15% of the class size, and their likelihood of scoring between 0% - 49% is 85% = 0.85, while their likelihood of scoring between 50% - 100% is (1 – 0.85) = 0.15 = 15%. ***(ii)*** *'average students' = group Y*: their assumed number is 75% of the class, and their likelihood of scoring between 50% - 69% is 75% = 0.75, while their likelihood of scoring between 0% - 49% or 70% - 100% is (1 – 0.75) = 0.25 = 25%. ***(iii)*** *'above average students' = group Z*: their assumed number is 10% of the class size, and their likelihood of scoring between 70% - 100% is 90% = 0.9, while their likelihood of scoring between 0% - 69% is (1 – 0.9) = 0.1 = 10%. **(c)** thus, in a class of size, N, those in group X = 0.15*N; those in group Y = 0.75*N; while those in group Z = 0.1*N
		ii. *average students:* examscore = 0.75 * ($50 \leq i \leq 69$) + 0.25 * ($0 \leq j \leq 49$) **or** examscore = 0.75 * ($50 \leq i \leq 69$) + 0.25 * ($70 \leq k \leq 100$)	
		iii. *above average students:* examscore = 0.9 * ($70 \leq i \leq 100$) + 0.1 * ($0 \leq j \leq 69$)	
		iv. from logic (c), the individual students, Sx in X, are $1 \leq Sx \leq N$	
		v. from logic (c), the individual students, Sy in Y, are $1 \leq Sy \leq N$	
		vi. from logic (c), the individual students, Sz in Z, are $1 \leq Sz \leq N$	
		vii. from iv, v, and vi above, we have that, $\sum Sx+\sum Sy+\sum Sz = N$	
2	Exam misconduct	**i.** total number of students, Tx, in group X involved in exam misconduct = 0.25*0.15*N ii. the individual students, Sx in Tx, involved in the offence = $0 \leq Sx \leq 0.15*N$	**(a)** the researcher observed that, at university of Nigeria, Nsukka, exam misconduct is more committed by students in group X than those in groups Y & Z. **(b)** let the average % of exam misconducts committed by those in groups X,Y, & Z be 25%, 15%, and 10%, respectively **(c)** there are four categories of exam offences at University of Nigeria, [15]: **i.** category 'A': involves expulsion from sch. **ii.** category 'B': involves suspension from school for 1 year **iii.** category 'C': involves a 'Fail' grade in all the courses taken in that semester **iv.** category 'D': involves a 'Fail' grade in
		i. total number of students, Ty, in group Y involved in exam misconduct = 0.15*0.75*N **ii.** the individual students, Sy in Ty, involved in the offence = $0 \leq Sy \leq 0.75*N$	
		i. total number of students, Tz, in group Z involved in exam misconduct = 0.1*0.1*N	

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		ii. the individual students, Sz in Tz, involved in the offence = $0 \leq Sz \leq 0.1*N$ the actual category of exam misconduct committed by any of the offenders in groups X,Y, & Z = $1 \leq$ category ≤ 4	the course affected in that semester
3	Character misconduct	**i.** total number of students, Tc, involved in character misconduct = 0.02*N **ii.** the individual students, Sc in Tc, involved in the offence = $0 \leq Sc \leq N$	**(a)** character misconducts include the following offences: rape, prostitution, cultism, theft, robbery, kidnapping, duping, rioting, killing, drug trafficking, etc. A student that commits any of such offences is usually expelled from school. **(b)** the researcher observed that any student can indulge in any of such offences. However, the rate of committing such offences (at university of Nigeria, Nsukka, for instance) is quite low. Let the assumed average % of committing such offences be 2% of the class size, N
4	Change of degree pgrm	**i.** total number, Tm, of M students that changed their programme = 0.02*M **ii.** the individual students, Sm in Tm, that changed = $0 \leq Sm \leq M$ **i.** total number, Tr, of N – M students that changed their programme = 0.07* (N – M) **ii.** the individual students, Sr in Tr, that changed = $0 \leq Sr \leq N - M$	**(a)** the researcher observed that(at university of Nigeria, Nsukka, for instance) the % of students that change their degree programme at the beginning of an academic year is higher amongst those with low CGPA than those with high CGPA **(b)** let CGPA = 1.5points be the benchmark for ascertaining those with low or high CGPA **(c)** in a class of N students, M of them have high CGPA if the CGPA of each student is $\geq$ 1.5, while N – M of the remaining students have low CGPA if the CGPA of each student is < 1.5 **(d)** the assumed % of M students that change their degree programme = 2%, while that of N – M students that changed = 7%
5	Deferment of degree pgrm	**i.** in a class of N students in 1st year of study, the total number, T1, of students that deferred their programme = 0.03*N **ii.** the individual students, Si in T1, that deferred their programme = $0 \leq Si \leq N$	**(a)** at university of Nigeria, Nsukka, for instance, deferring of degree programme is only allowed in the first year of study of a student. A 1st year student can defer his/her programme for any/some of the following reasons: financial problems, health problems, late admission, etc. **(b)** the researcher observed that the rate of such deferment is usually low. **(c)** the assumed % of 1st year students that defer their admission = 3%
6	Authorized (or legal) withdrawal from sch.	**i.** in a class of N students, the total number, Tg, of students that withdraw legally from school = 0.02*N **ii.** the individual students, Sg in Tg, that withdrew from school = $0 \leq Sg \leq N$	**(a)** a student can voluntarily withdraw from school for personal reasons provided such withdrawal was legally approved by the school registrar. **(b)** the researcher observed that the rate of such withdrawal is usually low. **(c)** the assumed % of such withdrawal = 2%

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7	Unauthorized (or illegal) withdrawal from sch.	**i.** in a class of N students, the total number, Tw, of students that withdraw illegally from school = 0.02*N **ii.** the individual students, Sw in Tw, that withdrew from school = $0 \leq Sw \leq N$	**(a)** circumstances such as death, permanent injury, business venture or some kind of personal reasons may cause a student to withdraw illegally from school. **(b)** the researcher observed that the rate of such withdrawal is usually low **(c)** the assumed % of such withdrawal = 2% (d) illegal withdrawal occurs when a student fails to register 1st and 2nd semester courses in an academic session
8	Readmission to school	i. let D denote the total no of students that deferred their admission ii. let W denote the total no of students that withdrew legally from school iii. for each student, Si in D, or Sj in W, the number of years, t, it would take such a student to be readmitted to school = $1 \leq t \leq 3$	**(a)** the academic regulations of [15] stipulates that any student that voluntarily [that is, legally] withdrew from the university, or deferred his/her admission is expected to apply for readmission within a maximum of 3 years, otherwise the student's application for readmission may not be granted. Also, a student that withdrew unlawfully from the university may not be readmitted. **(b)** based on the above information, this work only considers the readmission of the following students:- **(i)** those that deferred their admissions **(ii)** those that withdrew legally from school **(iii)** those suspended from school (this last option is ignored since the year of readmission is usually specified)

The simulated input data will be used by the FSM model shown in figure 4 for monitoring the academic progression of students. The FSM model utilizes the Boolean expressions shown in table 6 for performing such tasks.

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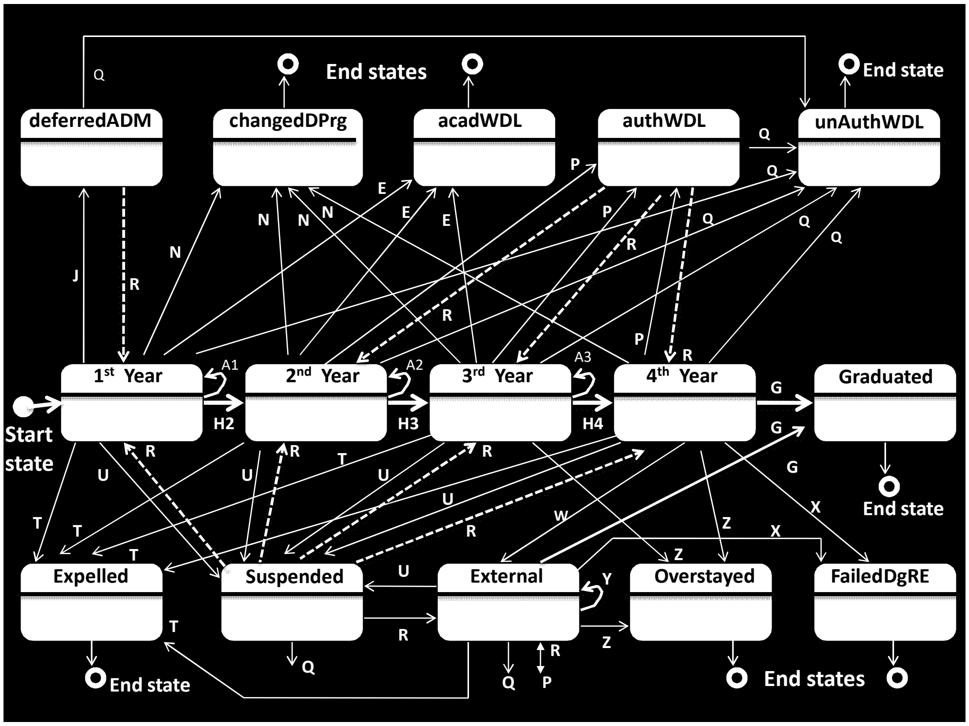

Figure 4: The finite state machine (FSM) model for monitoring the academic progression of undergraduate students

The full meaning of some of the abbreviations in the figure are: "deferredADM" = deferred Admission; "changedDPrg" = changed Degree programme; "acadWDL" = academic withdrawal; "authWDL" = authorized Withdrawal; "unauthWDL" = unauthorized withdrawal; "failedDgRE" = failed Degree programme.

The FSM model can be represented mathematically by the following 5-tuple: (Q, ∑ , δ, q_0, F), where:

Q = the set of all the finite states of the FSM
= the set of all the possible academic states of a student
= {"1st year", "2nd year", "3rd year", "4th year", "Graduated", "FailedDgre", "External", "Overstayed", "Suspended", "Expelled", "DeferredAdm", "ChangedDPrgm, "AcademicWDL", "authWDL", "unauthWDL"}

$\mathbf{q_0}$ = the initial or start state of the machine
= "1st Year". It is from this state that the transition of a student to other states commences.

F = the set of final or End states of the machine
= {"Graduated", "FailedDgre", "Overstayed", "Expelled", "ChangedDPrgm", "AcademicWDL", unauthWDL"}. No further transition can occur from any of these End states because a student either graduates from school or his/her studentship is terminated

δ = the transition function that determines the new state of a student from a current state. It can generally be represented as, δ(q,I) = q_n ; where **q** is the current state of a student; **I** is the set of input symbols (or value) required of a student at state, **q**; while $\mathbf{q_n}$ is the new state a student transitions to.

∑ = the set of all the input symbols of a student which is required by the transition function, δ, in determining the next academic state of a student from a given state. Table 3 contains a full list of the input symbols.

Table 3: Definition Of Input Symbols/Variables Used By The Transition Function, Δ, Of The FSM In Determining The Transition Of A Student From One State To Another

Input symbols/variables	Its complement
a = end of academic session	a′ = not end of academic session
b = CGPA ≥ 1(acceptable)	b′ = CGPA < 1(not acceptable)
c = committed character misconduct	c′ = no character misconduct committed
d = max. academic duration < 6yrs (acceptable)	d′ = max. academic duration ≥ 6yrs (unacceptable)
e = end of 1st semester	e′ = not end of 1st semester
f = end of 2nd semester	f′ = not end of 2nd semester
g = passed all undergraduate courses	g′ = has not passed all undergraduate courses
h = committed type-A exam malpractice	h′ = no type-A exam malpractice committed
i = committed type-B exam malpractice	i′ = no type-B exam malpractice committed
j = committed type-C exam malpractice	j′ = no type-C exam malpractice committed
k = committed type-D exam malpractice	k′ = no type-D exam malpractice committed
L = probation count ≤ 1	L′ = probation count > 1
m = registered 1st semester courses for the session	m′ = didn't register 1st semester courses for the session
n = registered 2nd semester courses for the session	n′ = didn't register 2nd semester courses for the session
p = suspension period is over	p′ = suspension period is not yet over
q = current state	q′ = previous state
r = permitted for readmission to school	r′= not permitted for readmission
t = permitted to defer admission	t′= not permitted to defer admission
v = permitted to change degree programme	v′ = not permitted to change degree programme
w = permitted to withdraw from school	w′ = not permitted to withdraw from school
y = withdrawal /deferment period ≤ 3yrs (acceptable)	y′ = withdrawal /deferment period > 3yrs (unacceptable)

The full meaning of the transition variables earlier shown in figure 4 is explained in the following table 4.

Table 4: The transition variables used by the FSM model

Transition variable names	Meaning of transition variables
A1	1st year probation
A2	2nd year probation
A3	3rd year probation
E	Forced academic withdrawal
H2	Promoted to 2nd year
H3	Promoted to 3rd year
H4	Promoted to 4th year
G	Graduates
J	Defers admission
N	Changes degree programme
P	authorized withdrawal from school
Q	unauthorized withdrawal from school
R	Readmitted to school
T	Expulsion from school
U	Suspension from school
W	External year
Y	External year (probation)
X	Failed degree programme
Z	Overstayed academic programme

The FSM model earlier shown in figure 4 can also be represented in a tabular form. Such tabular representation is shown in Table 5, and is called a "State Transition table". The State Transition table provides us with the following three main advantages:-

1) to know all the possible next state transitions from a given state
2) to know all the terminal (or End) states

3) to simplify the programmability of the state transitions

Table 5. The State Transition table of the FSM model shown in figure 4

		Next State														
s/n	**Present State**	1st year	2nd year	3rd year	4th year	Graduated	deferdADM	changdDPrg	acadWDL	authWDL	unauthWDL	Expelled	Suspended	External	Overstayed	failedDGR
1	1st year	X	X				X	X	X		X	X	X			
2	2nd year		X	X				X	X	X	X	X	X			
3	3rd year			X	X			X	X	X	X	X	X		X	
4	4th year					X		X		X	X	X	X	X	X	X
5	External					X				X	X	X	X	X	X	X
7	deferdADM	X									X					
8	suspended	X	X	X	X						X			X		
9	authWDL	X	X	X	X						X			X		
10	Graduated **(End State)**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	changedDPg **(End State)**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	acadWDL **(End State)**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	unauthWD **(End State)**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	Expelled **(End State)**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	Overstayed **(End State)**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	failedDGR **(End State)**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

The first entry in table 5, for instance, shows that a student that is presently in "1st year" can proceed to any of the following next states: {1st year probation, 2nd year, deferAdm, changdDprg, acadWdl, unauthWDL, Expelled, or Suspended} depending on the input symbols about the student at the present state (being 1st year). Similar interpretation holds for the other "present states" in the table.

The transition of a student from one state to another is dependent on the transition function $\delta(q,I) = q_n$, where **q** is the current state of a student; **I** is the set of input symbols required of a student at state, **q**; and $\mathbf{q_n}$ is the new state a student transitions to. The transition function, δ manipulates a Boolean expression based on the two input parameters, (q,I), in order to determine the next state, q_n of a student. Table 6 contains a comprehensive list of all the input symbols and Boolean expressions required for determining the transition of a student from one academic state to another.

Table 6: Boolean expressions for determining the transition of a student from one academic state to another

Current State (q)	Input symbols (I)	Transition function δ(q, I)	Boolean expression performed by the Transition function on the input symbols	Transition variable	Next state (q_n)
1st year	q,c,e,m,t	δ(q,I)	$q.e.m'.c'.t$	J	deferAdm
	q,a,c,h,i,m,n,t	δ(q,I)	$q.a.m'.n'.(t'+v'+c'+h'+i')$	Q	unauthWdL
	q,e,f,i	δ(q,I)	$q.(e+f).i$	U	Suspended
	q,c,e,f,h	δ(q,I)	$q.(e+f).(h+c)$	T	Expelled
	q,a,b,c,h,i,L,m,n,t,v	δ(q,I)	$q.a.L.(t'+v'+c'+h'+i').(m+n).b'$	A1	1st year (probation)
	q,a,b,c,h,i,L,m,n,t,v	δ(q,I)	$q.a.L'.(t'+v'+c'+h'+i').(m+n).b'$	E	acadWDL

	q,a,b,c,h,i,L,m,n,t,v	δ(q,I)	q.a.L.(t′+c′+h′+i′).(m+n).b.v	N	changDpg
	q,a,b,c,h,i,L,m,n,t,v	δ(q,I)	q.a.L.(t′+v′+c′+h′+i′).(m+n).b	H2	2nd year (promotion)
2nd year	q,c,e,f,h,i,v,w	δ(q,I)	q.(e+f).(v′+w′+c′+h′+i′).w	P	authWdL
	q,a,c,h,i,m,n,v,w	δ(q,I)	q.a.m′.n′.(v′+w′+c′+h′+i′)	Q	unauthWdL
	q,e,f,i	δ(q,I)	q.(e+f).i	U	Suspended
	q,c,e,f,h	δ(q,I)	q.(e+f).(h+c)	T	Expelled
	q,a,b,c,h,i,L,m,n,v,w	δ(q,I)	q.a.L.(v′+w′+c′+h′+i′).(m+n).b′	A2	2nd year (Probation)
	q,a,b,c,h,i,L,m,n,v,w	δ(q,I)	q.a.L′.(v′+w′+c′+h′+i′).(m+n).b′	E	acadWDL
	q,a,b,c,h,i,L,m,n,v,w	δ(q,I)	q.a.L.(v′+w′+c′+h′+i′).(m+n).b.v	N	changDpg
	q,a,b,c,h,i,L,m,n,v,w	δ(q,I)	q.a.L.(v′+w′+c′+h′+i′).(m+n).b	H3	3rd year (promotion)
3rd year	q,d	δ(q,I)	q.a.(v′+w′+c′+h′+i′).(m+n).d′	Z	Overstayed
	q,c,e,f,h,i,v,w	δ(q,I)	q.(e+f).(v′+w′+c′+h′+i′).w	P	authWdL
	q,a,c,h,i,m,n,v,w	δ(q,I)	q.a.m′.n′.(v′+w′+c′+h′+i′)	Q	unauthWdL
	q,e,f,i	δ(q,I)	q.(e+f).i	U	Suspended
	q,c,e,f,h	δ(q,I)	q.(e+f).(h+c)	T	Expelled
	q,a,b,c,h,i,L,m,n,v,w	δ(q,I)	q.a.L.(v′+w′+c′+h′+i′).(m+n).b′	A3	3rd year (Probation)
	q,a,b,c,h,i,L,m,n,v,w	δ(q,I)	q.a.L′.(v′+w′+c′+h′+i′).(m+n).b′	E	acadWDL
	q,a,b,c,h,i,L,m,n,v,w	δ(q,I)	q.a.L.(v′+w′+c′+h′+i′).(m+n).b.v	N	changDpg
	q,a,b,c,h,i,L,m,n,v,w	δ(q,I)	q.a.L.(v′+w′+c′+h′+i′).(m+n).b	H4	4th year (promotion)
4th year	q,d	δ(q,I)	q.a.(v′+w′+c′+h′+i′).(m+n).d′	Z	Overstayed
	q,c,e,f,h,i,v,w	δ(q,I)	q.(e+f).(v′+w′+c′+h′+i′).w	P	authWdL
	q,a,c,h,i,m,n,v,w	δ(q,I)	q.a.m′.n′.(v′+w′+c′+h′+i′)	Q	unauthWdL
	q,e,f,i	δ(q,I)	q.(e+f).i	U	Suspended
	q,c,e,f,h	δ(q,I)	q.(e+f).(h+c)	T	Expelled
	q,a,c,d,g,h,i,v,w	δ(q,I)	q.a.(v′+w′+c′+h′+i′).d.g′	W	External
	q,c,e,m,v,w	δ(q,I)	q.e.m′.d.(v′+w′+c′).v	N	changDpg
	q,a,b,c,d,g,h,i,v,w	δ(q,I)	q.a.L.(v′+w′+c′+h′+i′).d.g.b	G	Graduated
	q,a,c,h,i,j,k,g,b	δ(q,I)	q.a.L.(v′+w′+c′+h′+i′).d.g.b′	X	failedDGR
External	q,d	δ(q,I)	q.a.(w′+c′+h′+i′).(m+n).d′	Z	Overstayed
	q,c,e,f,h,i,w	δ(q,I)	q.(e+f).(w′+c′+h′+i′).w	P	authWdL
	q,a,c,h,i,m,n,w	δ(q,I)	q.a.m′.n′.(w′+c′+h′+i′)	Q	unauthWdL
	q,e,f,i	δ(q,I)	q.(e+f).i	U	Suspended
	q,c,e,f,h	δ(q,I)	q.(e+f).(h+c)	T	Expelled
	q,a,c,d,g,h,i,w	δ(q,I)	q.a.(w′+c′+h′+i′).d.g′	Y	External (probation)
	q,a,b,c,d,g,h,i,w	δ(q,I)	q.a.(w′+c′+h′+i′).d.g.b	G	Graduated
	q,a,b,c,d,g,h,i,w	δ(q,I)	q.a.(w′+c′+h′+i′).d.g.b′	X	failedDGR
deferAdm	q,y,r	δ(q,I)	q.y.r	R	1st year
	q,y	δ(q,I)	q.y′	Q	unauthWdL
Suspension	q,p,r.q′(=1st year)	δ(q,I)	q′(=1st year).r.p	R	1st year
	q,p,r.q′(=2nd year)	δ(q,I)	q′(=2nd year).r.p	R	2nd year
	q,p,r.q′(=3rd year)	δ(q,I)	q′(=3rd year).r.p	R	3rd year
	q,p,r.q′(=4th year)	δ(q,I)	q′(=4th year).r.p	R	4th year
	q,p,r.q′(=External)	δ(q,I)	q′(=External).r.p	R	External
	q,p,r	δ(q,I)	p.r′	Q	unauthWdL
	q,y,r.q′(=1st year)	δ(q,I)	q′(=1st year).r.y	R	1st year
	q,y,r.q′(=2nd year)	δ(q,I)	q′(=2nd year).r.y	R	2nd year

	q,y,r.q′(=3rd year)	δ(q,I)	q′(=3rd year).r.y	R	3rd year
	q,y,r.q′(=4th year)	δ(q,I)	q′(=4th year).r.y	R	4th year
	q,y,r.q′(=External)	δ(q,I)	q′(=External).r.y	R	External
authWDL	q,y	δ(q,I)	y′	Q	unauthWdL
changDpg	(none)	(none)	(none)	(none)	End state
acadWdL	(none)	(none)	(none)	(none)	End state
unauthWdl	(none)	(none)	(none)	(none)	End state
Graduated	(none)	(none)	(none)	(none)	End state
failDGR	(none)	(none)	(none)	(none)	End state
Overstayed	(none)	(none)	(none)	(none)	End state
Expulsion	(none)	(none)	(none)	(none)	End state

4.1 Data Analysis

Table 7 shows the simulated input data for a sample of 25 students for their 1st semester of 1st year of study for 2019/2020 academic year. The data was derived from the application of the mathematical models earlier given in table 2 for the three IQ categories of students. For instance,

- the *IQ categories* (BAV, AVG, and ABV) for the 25 students were derived from row1, column 3 of table 1, as follows:
  a) below average (BAV) = 15% of 25 = 4 students
  b) average (AVG) = 75% of 25 = 19 students
  c) above average (ABV) = 25 – (19 + 4) = 2 students

  the individual students that belong to any of the three IQ categories were determined by applying the random function: 1 + randomNumber.nextInt(25)
- the *exam scores* for each student in any of the three IQ categories were derived by applying the mathematical models in row 1, column 2 of table 2, as follows:
  a) examscore (for BAV) = 0.85 * $(0 \le i \le 49)$ + 0.15 * $(50 \le j \le 100)$, where i and j are random numbers that lie within the specified ranges
  b) examscore (for AVG) = 0.75 * $(50 \le i \le 69)$ + 0.25 * $(0 \le j \le 49)$, or
     examscore (for AVG) = 0.75 * $(50 \le i \le 69)$ + 0.25 * $(70 \le k \le 100)$, where i, j, and k are random numbers that lie within the specified ranges
  c) examscore (for ABV) = 0.95 * $(70 \le i \le 100)$ + 0.1 * $(0 \le j \le 69)$
- similarly, the *character* and *examination misconducts* of students, *deferment of degree programme*, *change of degree programme*, etc (as indicated by the symbols, c,h,i,j,k,t,v, etc under the heading 'Boolean input variables' in table 7) were all simulated from table 2.

Table 7: The simulated input data for a sample of 25 students for their 1st semester of 1st year of study for 2019/2020 academic year

	1st semester 2019/2020 Exam scores											Boolean input variables														
Student No:	IQ	cos103 (2unit	cos105 (2unit	mth111 (3unit	mth121 (2unit	phy115 (2unit	sta131 (2unit	Gsp101 (2unit	Gsp111 (2unit	CGPA	b = CGPA >= 1	e = EOF1st	f = EOF2nd	a = EOAsessn	g = cState = 1	c = XMC	h = TypeA	i = typeB	j = typeC	k = typeD	m = reg1stCrs	n = reg2ndCrs	t = deferAdm	d = unthWdl	v = changDprg	L = prob <= 1
1	AVG	B	B	E	C	B	C	B	D	3.00	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
2	AVG	B	C	C	B	A	B	D	C	3.50	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
3	BAV	E	F	F	F	E	F	F	E	0.33	N	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
4	AVG	B	E	B	C	C	B	B	C	3.27	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
5	ABV	A	B	A	A	A	A	B	B	4.66	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
6	AVG	F	F	F	F	F	F	F	F	0.00	N	Y	N	N	Y	N	N	N	Y	N	Y	N	N	N	N	Y
7	AVG	A	D	B	C	B	D	C	B	3.38	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
8	AVG	B	D	B	A	E	A	C	A	3.72	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
9	AVG	C	D	C	B	A	B	A	A	3.83	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y

10	AVG	C	B	A	D	E	B	B	B	3.38	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
11	BAV	F	F	F	F	F	F	F	F	0.00	N	Y	N	N	Y	N	N	N	Y	N	Y	N	N	N	N	Y
12	AVG	D	B	C	B	A	C	C	D	3.27	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
13	BAV	-	-	-	-	-	-	-	-	-	-	Y	N	N	Y	N	N	N	N	N	N	N	Y	N	N	Y
14	BAV	E	F	F	D	E	F	F	F	0.55	N	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
15	AVG	C	C	D	C	B	D	B	B	3.05	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
16	AVG	D	B	C	C	E	C	B	B	3.00	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
17	ABV	A	A	A	A	A	A	B	A	4.88	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
18	AVG	F	C	E	B	D	B	B	B	2.72	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
19	AVG	B	C	B	C	C	D	C	A	3.38	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
20	AVG	E	B	A	B	C	A	B	C	3.72	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
21	AVG	C	E	B	C	C	B	B	C	3.16	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
22	AVG	B	D	A	C	B	B	A	B	3.88	Y	Y	N	N	Y	N	N	Y	N	N	Y	N	N	N	N	Y
23	AVG	D	B	A	F	A	C	C	B	3.16	Y	Y	N	N	Y	N	Y	N	N	N	Y	N	N	N	N	Y
24	AVG	C	B	C	B	C	C	B	B	3.50	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
25	AVG	A	E	C	C	C	C	C	C	3.00	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y

Key: **BAV** = Below Average, **AVG** = Average, **ABV** = Above Average, **EOF1st** = End of 1st semester, **EOAsessn** = End of acad. Session, **cState** = current state, **XMC** = character misconduct, **TypeA** = typeA exam misconduct, **TypeB** = typeB exam misconduct, **TypeC** = typeC exam misconduct, **TypeD** = typed exam misconduct, **reg1stCrs** = registered 1st semester courses, **reg2ndCrs** = registered 2nd semester courses, **deferAdm** (or **def**) = deferred admission, **1** = 1st yr, **2** = 2nd yr, **unthWdl** = unauthorized withdrawal, **TransitionV** = transition variable, , **sus** = suspended, **Ex** = expelled, **N** = No, **Y** = Yes

The transition of a student to a new academic state (after the completion of 1st semester) was then determined by applying the Boolean expressions shown in the first row of table 6 (for 1st year students), and which is replicated graphically in figure 5.

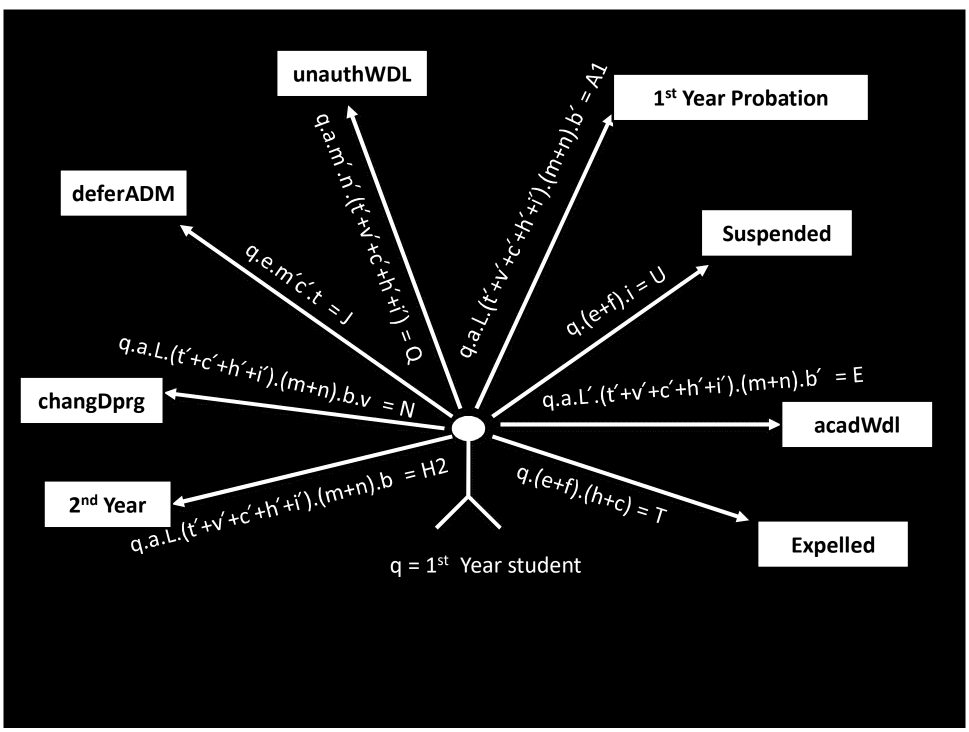

Figure 5: The Boolean expressions for transiting from 1st year to a new academic state

The figure shows that a student will transit from the current state (i.e. 1st year) to any of the eight new academic states (i.e. '2nd year', 'changDprg', 'deferAdm', 'unauthWdl', 1st year probation', 'suspended', 'acadWdl', or 'expelled') whose Boolean expression produces a 'true' value. If a

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ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

'false' value is produced by all the eight Boolean expressions, it means that '*there is no change in state yet (for the student) from the current state*'; the student therefore remains at his/her present state until a change in state occurs.

Table 8 shows some examples of how the next academic state of the students in table 7 can be determined with the Boolean expressions in figure 5.

Table 8: Examples of next academic state determination of students using Boolean expressions

	1st sem 2019/2020	Boolean input variables																	Boolean Expressions							
Student No:	IQ	CGPA	b = CGPA >= 1	e = EOF1st	f = EOF2nd	a = EOAsessn	q = cState = 1	c = XMC	h = TypeA	i = typeB	j = typeC	k = typeD	m = reg1stCrs	n = reg2ndCrs	t = deferAdm	d = unthWdl	v = changDprg	L = prob <= 1	q.e.m′.c′.t = J	q.a.m′.n′.(t′+v′+c′+h′+i′) = Q	q.(e+f).i = U	q.(e+f).(h+c) = T	q.a.L.(t′+v′+c′+h′+i′).(m+n).b′ = A1	q.a.L′.(t′+v′+c′+h′+i′).(m+n).b′ = E	q.a.L.(t′+c′+h′+i′).(m+n).b.v = N	q.a.L.(t′+v′+c′+h′+i′).(m+n).b = H2
1	AVG	3.00	Y	Y	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N
13	BAV	3.50	Y	Y	N	N	Y	N	N	N	N	N	N	N	Y	N	N	Y	Y	N	N	N	N	N	N	N
22	AVG	3.88	Y	Y	N	N	Y	N	N	Y	N	N	Y	N	N	N	N	Y	N	N	Y	N	N	N	N	N
23	AVG	3.16	Y	Y	N	N	Y	N	Y	N	N	N	Y	N	N	N	N	Y	N	N	N	Y	N	N	N	N

- for student-1, there is 'no change in state yet'. This is because the Boolean expressions for all the possible eight states produced a *false value* (i.e. 'N'). The student therefore remains in 1st year pending the completion of his/her 2nd semester. The determination of the Boolean values for student-1 are illustrated below

1) q.e.m′.c′.t = J => Y.Y.Y′.N′.N = Y.Y.N.Y.N = N; therefore state J (deferment of admission) did not occur
2) q.a.m′.n′.(t′+v′+c′+h′+i′) = Q => Y.N.Y′.N′.(N′+N′+N′+N′+N′) = Y.N.N.Y.(Y+Y+Y+Y+Y) = N.Y = N; therefore state Q (unauthWdl) did not occur
3) q.(e+f).i = U => Y.(Y+N).N = Y.Y.N = N; therefore state U (suspension) did not occur
4) q.(e+f).(h+c) = T => Y.(Y+N).(N+N) = Y.Y.N = N; therefore state T (expulsion) did not occur
5) q.a.L.(t′+v′+c′+h′+i′).(m+n).b′ = A1 => Y.N.Y.(N′+N′+N′+N′+N′).(Y+N).Y′ = Y.N.Y.(Y+Y+Y+Y+Y).Y.N = Y.N.Y.Y.Y.N = N; therefore state A1 (1st year probation) did not occur
6) q.a.L′.(t′+v′+c′+h′+i′).(m+n).b′ = E => Y.N.Y′.(N′+N′+N′+N′+N′).(Y+N).Y′ = Y.N.N.(Y+Y+Y+Y+Y).Y.N = Y.N.N.Y.Y.N = N; therefore state E (acadWdl) did not occur
7) q.a.L.(t′+c′+h′+i′).(m+n).b.v = N => Y.N.Y.(N′+N′+N′+N′).(Y+N).Y.N = Y.N.Y.(Y+Y+Y+Y).Y.Y.N = Y.N.Y.Y.Y.Y.N = N; therefore state N (changDprg) did not occur
8) q.a.L.(t′+v′+c′+h′+i′).(m+n).b = H2 => Y.N.Y.(N′+N′+N′+N′+N′).(Y+N).Y = Y.N.Y.(Y+Y+Y+Y+Y).Y.Y = Y.N.Y.Y.Y.Y = N; therefore state H2 (promotion to 2nd year) did not occur

Similarly, 'no change in state' occurred for student-2,3,4,5,6,7,8,9,10,11,12.

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- for student-13, a change in state occurred for state J (i.e. '*deferment of admission*') which produced a *true value* (i.e. 'Y'), as computed by the Boolean expression: q.e.m′.c′.t = J => Y.Y.N′.N′.Y = Y.Y.Y.Y.Y = Y. Every other state produced a *false value*. Student-13 will therefore transit from 1st year to a new state (i.e. 'deferAdm'). He/she will not be enrolled for the 2nd semester of the academic year pending the completion of his 'deferAdm' state when he/she will start 1st year all over again for a new academic year.

  'no change in state' occurred for student-14,15,16,17,18,19,20,21,22.
- For student-22, a change in state occurred for state U (i.e. 'suspension from school') which produced a *true value* (i.e. 'Y'), as computed by the Boolean expression: q.(e+f).i = U => Y.(Y+N).Y = Y.Y.Y = Y. Every other state produced a *false value*. Student-22 will therefore transit from 1st year to a new state (i.e. 'suspension'). He/she will not be enrolled for the 2nd semester of the academic year pending the completion of his 'suspension' state when he/she will start 1st year all over again for a new academic year.
- For student-23, a change in state occurred for state T (i.e. 'expulsion from school') which produced a *true value* (i.e. 'Y'), as computed by the Boolean expression: q.(e+f).(h+c) = T => Y.(Y+N).(Y+N) = Y.Y.Y = Y. Every other state produced a *false value*. Student-23 will therefore transit from 1st year to a new state (i.e. 'expulsion'), and the student is summarily dismissed from school.

  'no change in state' occurred for student-24 and 25.

Table 9 shows the rest of the students that successfully proceeded to 2nd semester for the completion of their 1st year of study. The table also contains their simulated input data, as previously done in the 1st semester.

Table 9: The simulated input data for the remaining 22 students for their 2nd semester of 1st year of study for 2019/2020 academic year

	2nd semester 2019/2020 Exam scores											Boolean input variables															
Student No:	IQ	cos102 (3unit	cos104 (2unit	mth122 (3unit	phy116 (2unit	phy118 (2unit	sta132 (2unit	sta172 (2unit	Gsp102 (2unit	Cgpa (1st sem	CGPA (final	b = CGPA >= 1	e = EOF1st	f = EOF 2nd	a = EOAsessn	q = cState = 1	c = XMC	h = TypeA	i = typeB	j = typeC	k = typeD	m = reg1stCrs	n = reg2ndCrs	d = unthWdl	t = deferAdm	v = changDprg	L = prob <= 1
1	AVG	C	F	C	C	B	C	B	C	2.88	2.94	Y	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	N	N	N	Y
2	AVG	B	B	C	D	B	E	C	B	3.16	3.33	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
3	BAV	F	F	C	F	E	E	E	C	1.16	0.75	N	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
4	AVG	B	D	C	C	B	C	C	D	3.05	3.16	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
5	ABV	A	A	A	B	A	A	A	A	4.88	4.77	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
6	AVG	A	B	B	C	D	A	B	B	3.94	1.97	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	Y	Y
7	AVG	B	D	C	B	D	A	C	C	3.27	3.33	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
8	AVG	A	B	B	E	B	B	B	C	3.72	3.72	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
9	AVG	F	F	F	F	F	F	F	F	0.00	1.91	Y	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	N	N	N	Y
10	AVG	B	D	C	B	B	D	B	D	3.16	3.27	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
11	BAV	C	F	F	F	F	F	D	D	0.94	0.47	N	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
12	AVG	B	B	A	D	C	C	B	A	3.83	3.55	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
14	BAV	D	F	F	E	F	D	F	C	1.00	0.77	N	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
15	AVG	B	A	A	A	C	C	B	D	3.94	3.50	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
16	AVG	D	B	D	B	C	D	C	E	2.55	2.77	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
17	ABV	A	B	B	A	A	A	A	A	4.72	4.80	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
18	AVG	E	C	B	C	B	A	C	B	3.27	3.00	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
19	AVG	D	C	E	E	E	C	B	C	2.16	2.77	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
20	AVG	C	C	C	A	B	D	B	D	3.22	3.47	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
21	AVG	B	C	B	A	C	B	E	B	3.55	3.36	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
24	AVG	E	A	C	B	C	B	C	E	2.88	3.19	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y
25	AVG	B	B	B	C	E	C	B	B	3.44	3.22	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y

Table 10 shows the computed next academic states of the students at the completion of 1st and 2nd semesters for 2019/2020 academic year (as previously illustrated with the 1st semester).

Table 10: The computed next academic states of students at the completion of 1st and 2nd semesters

	1st & 2nd semesters 2019/2020	Boolean input variables																Boolean Expressions							
Student No:	IQ	CGPA (final	b = CGPA >= 1	e = EOF1st	f = EOF 2nd	a = EOAsessn	q = cState = 1	c = XMC	h = TypeA	i = typeB	j = typeC	k = typeD	m = reg1stCrs	n = reg2ndCrs	d = unthWdl	t = deferAdm	v = changDprg	L = prob <= 1	q.e.m′.c′.t = J	q.a.m′.n′.(t′+v′+c′+h′+i′) = Q	q.(e+f).i = U	q.(e+f).(h+c) = T	q.a.L.(t′+v′+c′+h′+i′).(m+n).b′ = A1	q.a.L′.(t′+v′+c′+h′+i′).(m+n).b′ = E	q.a.L.(t′+c′+h′+i′).(m+n).b.v = N	q.a.L.(t′+v′+c′+h′+i′).(m+n).b = H2
1	AVG	2.94	Y	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y
2	AVG	3.33	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	Y	N	N	N	N	N	N	Y
3	BAV	0.75	N	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	Y	N	Y	N	N	N
4	AVG	3.16	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y
5	ABV	4.77	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y
6	AVG	1.97	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	Y	Y	N	N	N	N	N	N	Y	N
7	AVG	3.33	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y
8	AVG	3.72	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y
9	AVG	1.91	Y	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y
10	AVG	3.27	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y
11	BAV	0.47	N	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	Y	N	N	N
12	AVG	3.55	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y
14	BAV	0.77	N	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	Y	N	N	N
15	AVG	3.50	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y
16	AVG	2.77	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y
17	ABV	4.80	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y
18	AVG	3.00	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y
19	AVG	2.77	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y
20	AVG	3.47	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y
21	AVG	3.36	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y
24	AVG	3.19	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y
25	AVG	3.22	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	Y

Figure 6 shows the algorithm for the implementation of the FSM Boolean expressions for determining the next academic state of a 1st year student. The algorithm can be implemented in Java (as a function) as shown in appendix A.

```
If(q == "1stYr")
{
  If((q && e && !m && !c && t) == true )
  {
    // Transition J (i.e. 'deferment of admission') occurs}
  else if(q && a && !m && !n &&(!t || !v || !c || !h || !i ) == true)
  {
    // Transition Q (i.e. 'unauthWdl') occurs}
  else if(q && (e || f) && i == true)
  {
    // Transition U (i.e. 'suspension') occurs}
  else if(q && (e || f) && (h || c) == true)
  {
    // Transition T (i.e. 'expulsion') occurs}
```

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```
    else if(q && a && L && (!t || !v || !c || !h || !i) && (m || n) && !b) == true)
    {
      // Transition A1 (i.e. '1st year probation') occurs}
    else if(q && a && !L && (!t || !v || !c || !h || !i) && (m || n) && !b == true)
    {
      // Transition E (i.e. 'acadWdl') occurs}
    else if(q && a && L && (!t || !c || !h || !i) && (m || n) && b && v) == true)
    {
      // Transition N (i.e. 'changDprg') occurs}
    else if(q && a && L && (!t || !v || !c || !h || !i) && (m || n) && b == true)
    {
      // Transition H2 (i.e. 'promoted to 2nd year') occurs
    }
}
```

figure 6. An algorithm for determining the next academic state of a 1st year student

5. RESULTS AND DISCUSSION

Table 11 shows the comprehensive list of the new academic states of all the 25 first year students at the end of the 2019/2020 academic year. The table was derived from table 10.

Table 11: The new academic states of students after being monitored for one academic year with the FSM model

Student No.	IQ	Present state	Beginning Session	CGPA	Next state	Reason	New Session
1	AVG	1st year	2019/2020	2.94	2nd Year	promoted	2020/2021
2	AVG	1st year	2019/2020	3.33	2nd Year	Promoted	2020/2021
3	BAV	1st year	2019/2020	0.75	Probation-1	Low CGPA (to repeat 1st year)	2020/2021
4	AVG	1st year	2019/2020	3.16	2nd Year	Promoted	2020/2021
5	ABV	1st year	2019/2020	4.77	2nd Year	Promoted	2020/2021
6	AVG	1st year	2019/2020	1.97	changDprg	changed Degree programme	2020/2021
7	AVG	1st year	2019/2020	3.33	2nd Year	Promoted	2020/2021
8	AVG	1st year	2019/2020	3.72	2nd Year	Promoted	2020/2021
9	AVG	1st year	2019/2020	1.91	2nd Year	Promoted	2020/2021
10	AVG	1st year	2019/2020	3.27	2nd Year	Promoted	2020/2021
11	BAV	1st year	2019/2020	0.47	Probation-1	Low CGPA (to repeat 1st year)	2020/2021
12	AVG	1st year	2019/2020	3.55	2nd Year	Promoted	2020/2021
13	BAV	1st year	2019/2020	-	deferADM	Deferred admission	2020/2021
14	BAV	1st year	2019/2020	0.77	Probation-1	Low CGPA (to repeat 1st year)	2020/2021
15	AVG	1st year	2019/2020	3.50	2nd Year	Promoted	2020/2021
16	AVG	1st year	2019/2020	2.77	2nd Year	Promoted	2020/2021
17	ABV	1st year	2019/2020	4.80	2nd Year	Promoted	2020/2021
18	AVG	1st year	2019/2020	3.00	2nd Year	Promoted	2020/2021
19	AVG	1st year	2019/2020	2.77	2nd Year	Promoted	2020/2021
20	AVG	1st year	2019/2020	3.47	2nd Year	Promoted	2020/2021
21	AVG	1st year	2019/2020	3.36	2nd Year	Promoted	2020/2021
22	AVG	1st year	2019/2020	-	Suspended	Committed typeB exam misconduct	2020/2021
23	AVG	1st year	2019/2020	-	Expelled	Committed typeA exam misconduct	-
24	AVG	1st year	2019/2020	3.19	2nd Year	Promoted	2020/2021
25	AVG	1st year	2019/2020	3.22	2nd Year	Promoted	2020/2021

The above table showed that a total of **18** students were promoted to **2nd year**; *three* students (student-3, student-11, and student-14) went on **Probation**; *one* student (student-6) **changed** his/her degree programme; *one* student (student-13) **deferred** his/her admission; *one* student (student-22) was **suspended**; and *one* student (student-23) was **expelled** from school (thus terminating his/her studentship).

We can now compare the effectiveness of the FSM model with the AERPS technique in determining the true academic state of a student. The following hypothesis will be used for making such comparison.

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H_0: there is no significant difference between the FSM model and the AERPS technique in determining the true academic state of a student

Vs

H_1: the FSM model is better than the AERPS technique in determining the true academic state of a student

Table 12 (which is derived from table 11) was used for providing the required data for determining the true or false hypothesis.

.

Table 12. A comparison of the FSM model and AERPS technique for effective determination of the true academic state of a student

			A	B
Student No.	**Present state**	**Next state**	**Exact determination of 'next state' using the FSM model that makes use of multi determinants**	**Exact determination of 'next state' using the AERPS technique that makes use of only the CGPA determinant**
1	1st year	2nd Year	Yes = 1	Yes = 1
2	1st year	2nd Year	Yes = 1	Yes = 1
3	1st year	Probation-1	Yes = 1	Yes = 1
4	1st year	2nd Year	Yes = 1	Yes = 1
5	1st year	2nd Year	Yes = 1	Yes = 1
6	1st year	changDprg	Yes = 1	**No = 0**
7	1st year	2nd Year	Yes = 1	Yes = 1
8	1st year	2nd Year	Yes = 1	Yes = 1
9	1st year	2nd Year	Yes = 1	Yes = 1
10	1st year	2nd Year	Yes = 1	Yes = 1
11	1st year	Probation-1	Yes = 1	Yes = 1
12	1st year	2nd Year	Yes = 1	Yes = 1
13	1st year	deferADM	Yes = 1	**No = 0**
14	1st year	Probation-1	Yes = 1	Yes = 1
15	1st year	2nd Year	Yes = 1	Yes = 1
16	1st year	2nd Year	Yes = 1	Yes = 1
17	1st year	2nd Year	Yes = 1	Yes = 1
18	1st year	2nd Year	Yes = 1	Yes = 1
19	1st year	2nd Year	Yes = 1	Yes = 1
20	1st year	2nd Year	Yes = 1	Yes = 1
21	1st year	2nd Year	Yes = 1	Yes = 1
22	1st year	Suspended	Yes = 1	**No = 0**
23	1st year	Expelled	Yes = 1	**No = 0**
24	1st year	2nd Year	Yes = 1	Yes = 1
25	1st year	2nd Year	Yes = 1	Yes = 1
Mean determination of next academic state:			**X'_A = (total 'Yes')/ nA = 25/25 = 1 nA (total elements in A) = 25 s^2A = varaiance of A = 0**	**X'_B = (total 'Yes') / nB = 21/25 = 0.84 nB (total elements in B) = 25 s^2B = variance of B = 0.14**

Using the following t-test statistic for determining the difference in the two means (X_A' and X_B'), we have:

$$t = \frac{X'A - X'B}{\sqrt{\frac{1}{nA}+\frac{1}{nB}}\sqrt{\frac{(nA-1)s^2\mathrm{A}+(\mathrm{n}B-1)s^2\mathrm{B}}{nA+nB-2}}} = \frac{1-0.84}{\sqrt{\frac{1}{25}+\frac{1}{25}}\sqrt{\frac{(24)s^2\mathrm{A}+(24)s^2\mathrm{B}}{25+25-2}}} = \frac{0.16}{\sqrt{0.08}\sqrt{\frac{0+(24)0.14}{25+25}}} = 2.138$$

Now, at $\alpha = 0.05$, $t_{table} = 1.684$ with 48 degrees of freedom.

Decision rule: since $2.138 > 1.684$, we reject H_0 and accept H_1. This means that the FSM model is better than the AERPS technique in determining the true academic state of a student.

6. CONCLUSION

Based on the results of this study, the following conclusions were made: (i) the FSM model gives the true academic state of a student at any point in time for use by various stakeholders such as the school registrar, lecturers/academic advisers, parents/sponsors, and students. (ii) the multi determinants used by the FSM model ensures that students are properly screened in character and learning before graduating from school, (iii) the present bottlenecks experienced by many tertiary institutions in Nigeria and beyond in the use of the AERPS technique for monitoring students'

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

academic progression has therefore been solved by the FSM model. The model is therefore highly recommended for use by all the tertiary institutions in Nigeria and beyond for effective monitoring of students academic progression.

7. RESEARCH CONTRIBUTION

The developed finite state machine (FSM) model for monitoring the academic progression of undergraduate students is an improvement over the automated examination result processing system (AERPS) in various ways such as,

(i) The FSM model uses multi factors which are expressed in Boolean algebraic form for effective determination of the transition of a student from one academic state to another

(ii) The FSM model ensures that every student is properly screened in character and learning before graduating from school, or otherwise exterminated

(iii) The FSM model can be used by the following stakeholders for various purposes: (a) the school registrar, (b) lecturers/academic advisers, (c) parents/sponsors, (d) students, and (e) NGOs

8. FUTURE WORK

The scope of this work is delimited to undergraduate students. Further work on it can be undertaken by other researchers on how it can be used to monitor the academic progression of post graduate students according to the following three categories: (i) postgraduate diploma, (ii) masters, and (iii) PhD

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ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

APPENDIX A

A Java function for implementing the transition of a student from "1st year" to another academic state

```
public String transitionV(string a-value, string b-value, string c-value, string e-value, string f-value, string h-value,
string i-value, string L-value, string m-value, string n-value, string q-value, string t-value, string v-value)
{
  boolean a;          //for end of academic session
  boolean b;          //for CGPA ≥ 1
  boolean c;          //for committed character misconduct
  boolean e;          //for end of 1st semester
  boolean f;          //for end of 2nd semester
  boolean h;          //for committed type-A exam malpractice
  boolean i;          //for committed type-B exam malpractice
  boolean L;          //for probation count ≤ 1
  boolean m;          //for registered 1st semester courses for the session
  boolean n;          //for registered 2nd semester courses for the session
  boolean q;          //for current state
  boolean t;          //for permitted to defer admission
  boolean v;          //for permitted to change degree programme

  If (a-value.equals("Y"))
  {
    a = true;
  }
  else
  {
    a = false;
  }
  If (b-value.equals("Y"))
  {
    b = true;
  }
  else
  {
    b = false;
  }
  If (c-value.equals("Y"))
  {
    c = true;
  }
  else
  {
    c = false;
  }
  If (e-value.equals("Y"))
  {
    e = true;
  }
  else
  {
    e = false;
  }
  If (f-value.equals("Y"))
  {
    f = true;
  }
  else
```

```
{
  f = false;
}
If (h-value.equals("Y"))
{
  h = true;
}
else
{
  h = false;
}
If (i-value.equals("Y"))
{
  i = true;
}
else
{
  i = false;
}
If (L-value.equals("Y"))
{
  L = true;
}
else
{
  L = false;
}
If (m-value.equals("Y"))
{
  m = true;
}
else
{
  m = false;
}
If (q-value.equals("1"))
{
  q = true;
}
else
{
  q = false;
}
If (t-value.equals("Y"))
{
  t = true;
}
else
{
  t = false;
}
If (v-value.equals("Y"))
{
  v = true;
}
else
{
  v = false;
```

```
  }

  /* determine a student's transition variable for the next academic state
     by  applying the following Boolean expressions:

  q.e.m′.c′.t = J
  q.a.m′.n′.(t′+v′+c′+h′+i′) = Q
  q.(e+f).i = U
  q.(e+f).(h+c) = T
  q.a.L.(t′+v′+c′+h′+i′).(m+n).b′ = A1
  q.a.L′.(t′+v′+c′+h′+i′).(m+n).b′ = E
  q.a.L.(t′+c′+h′+i′).(m+n).b.v = N
  q.a.L.(t′+v′+c′+h′+i′).(m+n).b = H2

as given by the Java code below */

  If((q && e && !m && !c && t) == true)
  {
    return "J";        //i.e. deferAdm
  }
  else if((q && a && !m && !n && (!t || !v || !c || !h || !i)) == true)
  {
    return "Q";        //i.e. unauthWdl
  }
  else if((q && (e || f) && i) == true)
  {
    return "U";        //i.e. Suspension
  }
  else if((q && (e || f) && ( h || c)) == true)
  {
    return "T";        //i.e. Expulsion
  }
  else if((q && a && L && (!t || !v || !c || !h || !i) && (m || n) && !b) == true)
  {
    return "A1";       //i.e. 1st year probation
  }
  else if((q && a && !L && (!t || !v || !c || !h || !i) && (m || n) && !b) == true)
  {
    return "E";        //i.e. acadWdl
  }
  else if((q && a && L && (!t || !c || !h || !i) && (m || n) && b && v) == true)
  {
    return "N"         //i.e. changDprg
  }
  else if((q && a && L && (!t || !v || !c || !h || !i) && (m || n) && b) == true)
  {
    return "H2"        //i.e. promoted to 2nd year
  }
}
```