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A Mathematical Model for Monitoring Laboratory Revenue Accrued from Tests

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ABSTRACT
One challenge in the laboratory is the discrepancies in the revenue reported to have been generated and the actual revenue generated from laboratory tests. In this paper, a mathematical model for tracking and monitoring revenue from hospital-based laboratory was formulated, simulated, and evaluated.

The mathematical model was formulated using a multiple variable linear equation. The model was simulated using Matrix Laboratory (MATLAB) and evaluated for accuracy using the following performance metrics: Correlation coefficient, Mean absolute error, Root mean square error, Relative absolute error and Root relative squared error. Multivariate linear regression analysis method was used for the evaluation in Waikato Environment for Knowledge Analysis software (WEKA). Dataset for the simulation were retrieved from a government hospital-based laboratory in Idah, Nigeria.

The result of the study showed that a multiple variable linear equation is sufficiently adequate in relating the revenue generated with the tests performed in hospital laboratory. Furthermore, the study revealed discrepancies in the revenue reported to have been generated from the laboratory tests. The regression analysis showed that the distribution of data for the classes of datasets have strong statistical relationship between tests and the revenue generated with a correlation coefficient of 0.9985 and 0.8113 respectively.

In conclusion, the study established that the formulated multi-variate linear relationship between revenue and tests is appropriate in predicting revenue generated from hospital-based laboratory.

General Terms
Laboratory

Keywords
Laboratory, Hospital, Model, Revenue, Monitoring, Regression, multiple variable linear equation, simulation, mathematical model, evaluation, multivariate linear regression analysis

1. INTRODUCTION
The Clinical or Medical laboratory forms part of the total economic structure of the hospital. It generates revenue for the hospital to undertake various activities to uplift it [1]. The hospital's laboratory is constituted not only for service-seeking motive but apparently as an instrument of generating revenue and as such must work towards achieving the hospital's set objectives [2], [9]. The clinical laboratory makes the bulk of its revenue by performing physician ordered tests otherwise known as investigations which the hospital management always seeks to maximize [3], [4]. A typical laboratory's revenue stream is predictable when the laboratory manager knows the existing customer base and the rough number, or average volume of test orders usually placed for a given period of time. As the laboratory market continues to become more complex, laboratories make great efforts to be efficient and collect money expediently for the services they provide.

The role of hospital based laboratory in the overall development of the hospital cannot be over emphasised. As a revenue generating department, it is expected to be able to give accurate account of how many tests the laboratory runs and how much is accrued from them. One challenge though is that there are discrepancies in the revenue reported to have been generated and the actual revenue generated from the laboratory tests. This study designs a mathematical model that will track the number of laboratory tests in order to accurately determine how much revenue is generated from them and monitor revenue generated from these laboratory tests.

2. LITERATURE REVIEW
A clinical laboratory is where tests are done on clinical specimens in order to get information about the health of a patient as pertaining to the diagnosis, treatment, and prevention of disease [5]. Specimens are collected, tests are performed, and results are reported in the clinical laboratory. A typical workflow includes doctor ordering the test, collecting and labelling patient sample, delivering samples to the laboratory, processing sample, analysing test (sample), and reporting results to doctor.

There are basically four types of clinical laboratories: Hospital laboratories, Reference laboratories, Research laboratories, and Physician's office laboratories. Hospital laboratories serve the needs of the hospital, and provide testing services requested by the medical staff for their in-patients, out-patients, and non-patients. Reference laboratories are also called Private or Community laboratories. They are usually large commercial laboratories with locations everywhere. They perform both usual and specialized laboratory tests. These laboratories receive samples from general practitioners, insurance companies, clinical research sites and other health clinics for analysis. More unusual and obscure tests are performed in reference laboratories. A lot of samples are sent between different laboratories for uncommon tests. It is more cost effective if a particular laboratory specializes in a rare test, receiving specimens (and money) from other laboratories, while rejecting tests it cannot do. Reference laboratories often have small, satellite laboratories serving several communities that collect specimens to be sent to the larger "parent" laboratory for testing. For extremely specialised tests, samples may go to a research laboratory. Research laboratory is a laboratory for conducting research or investigation into science. Physician's office laboratories are often owned by a group of physicians and perform routine laboratory tests on their patients.

Laboratories provide important information support for the diagnosis, prevention, or treatment of any disease to assess the health of human beings and improve the wellbeing of patients [11]. The results of laboratory investigations provide invaluable tools for making decisions. They also facilitate the initiation and monitoring of appropriate clinical and public health interventions [10]. As revenue centres within the hospitals, saddled with the responsibility of bringing significant revenue streams, laboratories sometimes face data constrictions that prevent them from accurately measuring fiscal performance [9].

In most cases, laboratories experience a revenue leakage whereby laboratory investigations are done but not charged yielding into non-collection of payments for the services not charged or the full money is not collected. It is a universal phenomenon gnawing up the profit margin of services in the hospital-based laboratory. It can occur as a result of incorrect pricing, missing transactions, and uncollected revenue. Revenue leakage is common, but often unnoticed because it is not easily found in financial statements [6]. Revenue is the money that an organisation receives from its business. In essence, revenue accrued from the laboratory is the money that the hospital receives from the services rendered in the laboratory; in this case, the laboratory tests.

3. METHODS AND MATERIALS

3.1 Research Approach

This research used the empirical approach predicated on the need to get precise comprehensive and reliable information. Empirical approach is based on observed and measured phenomena, that is, acquiring data by means of observation or experimentation for statistical analysis [7].

3.2 Area of Study

The research was conducted in a government hospital in Idah, Kogi State, Nigeria. Kogi State is in the North Central geopolitical zone of the six states structure organised into six political configurations.

3.3 Data Collection Method

Two months laboratory record books were collected from the hospital, in the Period February 2014 to March 2014 in order to observe the processes involved in a patient consulting a doctor, paying for laboratory tests, and getting a patient to perform laboratory tests. Secondary data were also collected from laboratory documents, laboratory journals, and the Internet.

3.4 Mathematical Model Formulation for Tracking and Monitoring Laboratory Revenue

The mathematical model to track and monitor revenue generated from the hospital's laboratory was formulated in this section based on the dataset collected from the hospital's laboratory under study. This is in view of simulating a process that can monitor the revenue generated from the tests conducted in the laboratory. Simulation is the process of using a model to study the behaviour and performance of an actual or theoretical system [8]. This is in order to predict the actual behaviour of the system.

3.4.1 Variable Description of the Datasets

There are three different classes of variables from the dataset got from the hospital used as case study. These variables were used in monitoring the revenue generated by the laboratory. The variables are as follows:

a. The daily number of tests performed in the laboratory;

b. The respective prices of each test; and

c. The revenue generated for each test performed.

Test price and the number of test performed are the Independent Variables while the revenue generated for each test performed is the Dependent Variable. The amount made from the laboratory depends on the number of tests performed and their respective prices.

3.4.2 The tests performed in the laboratory

There are a total of 30 tests which are performed out of which twenty-five (25) tests are paid for while five (5) tests are free. Three (3) out of the five (5) tests performed for free are totally free for all patients and the remaining two (2) free tests are free for only HIV patients. The remaining two (2) tests are free for only HIV patients. There are also two (2) different classes of patients for whom tests are performed – National Health Insurance Scheme (NHIS) patients and Non-National Health Insurance Scheme (Non-NHIS) patients (regular patients) and two (2) different classes of tests – paid tests and free tests. Hence, there are four (4) different classes of datasets which are monitored by the model. They are:

a. The tests performed for regular (Non-NHIS) patients;

b. The tests performed for NHIS patients;

c. The free tests performed for regular (Non-NHIS) patients; and

d. The free tests performed for NHIS patients.

The revenue of the dataset of the laboratory which is chosen will be monitored by the model in order to validate the value of revenue expected given the number of tests performed in a particular period of time and the prices of each test performed. The datasets for this research are tests performed within the period of February 2014 till March, 2014. Table 3.1 shows the breakdown of the different tests and their respective prices.

3.4.3 The Revenue Generated from the different Tests Performed in the Laboratory

The revenue generated by the laboratory staff is expressed as a sum of the daily cost of each test performed in Naira (₦). It is a polynomial equation of One (1) degree and multiple variables, $\mathbf{X}_i$ (the price of each test), and $\mathbf{a}_i$ (the number of unit test). The equation is otherwise referred to as a *multiple variable linear equation* with the output R as the total revenue while the intercept $\mathbf{a_0}$ = 0 was used to define the total revenue generated for any test performed for each day (See equation 3.1a).

Putting the variables together; Revenue generated for any test performed for each day is expressed as given in equation 3.1a.

$$Revenue, R = a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5 + \cdots + a_nx_n \quad --- (3.1a)$$

Or simply as

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$$\text{Revenue} = \sum_{i=1}^{n} a_i x_i \quad ---(3.1b)$$

Where $\{a_i\}_{for\ i=1}^{n}$ is the number of tests performed for every test, *i* (where 0 < *i* <= n) and n is the total number of tests performed and X_i is the price for each test, *i*.

Hence, n = 25 for regular tests, n=5 for free tests and X_i is the cost of each test, *i*. For any given time period, j (where 0 < j <= m), where m is the number of days for which tests were performed and R_j is the total revenue generated within a period of j days. (See Equation 3.2a).

$$Revenue, R_j = a_{j1}x_1 + a_{j2}x_2 + a_{j3}x_3 + a_{j4}x_4 + a_{j5}x_5 + \cdots + a_{jn}x_n \quad ---(3.2a)$$

Or simply as

$$\text{Revenue} = \sum_{j=1}^{m}\sum_{i=1}^{n} a_{ji} x_i \quad ---(3.2b)$$

Where

$\left\{\{a_{ji}\}_{for\ i=1}^{n}\right\}_{j=1}^{m}$ is the number of tests performed for every test, *i* (where 0 < *i* <= n); n is the total number of tests for every single day, j (where 0 < j <= m) and X_i is the cost of each test, *i*.

3.5 The Mathematical Model for Monitoring Laboratory Revenue

The mathematical model which was used in monitoring the revenue generated for every test performed in the laboratory requires certain variables. The variables needed by the monitoring model are:

a. The total number of tests performed for every day;

b. The price for each test performed; and

c. The total revenue generated for the tests.

Equations 3.2a and 3.2b can equally be expressed in matrix form in as represented in equation 3.3 from which the monitored revenue may be determined:

b

Such that:

$$A_{ji} = \begin{pmatrix} a_{11} & a_{12} \dots\dots\dots\dots & a_{1i} \\ a_{21} & a_{22} \dots\dots\dots\dots & a_{2i} \\ \vdots & \vdots & \vdots \\ a_{j1} & a_{j2} & a_{ji} \end{pmatrix}$$

A_{ji} = the amount (number) of tests, *i* that were performed within a specified period of time, j days.

$$X_i = \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_i \end{pmatrix}$$

X_i = the test price for each test, *i* and

$$R_M = \begin{pmatrix} r_1 \\ r_2 \\ \vdots \\ r_j \end{pmatrix}$$

$\mathbf{R_M}$ = the revenue monitored by the model over a period of j days.

The monitoring model collects all the daily total tests performed and expresses them as a square matrix (of dimension-n, where n > 25 for regular tests and n>5 for free tests). Hence, the daily number of tests performed in the laboratory is expressed as a matrix of dimension-n; the price of each test is also expressed as a column matrix of dimension-n. The monitored revenue, R_{Mj} is the result of the product of both matrix which results in a column matrix of similar dimension - n = j. (See equation 3.4).

$$\begin{pmatrix} a_{11} & a_{12} \dots\dots\dots\dots & a_{1i} \\ a_{21} & a_{22} \dots\dots\dots\dots & a_{2i} \\ \vdots & \vdots & \vdots \\ a_{j1} & a_{j2} & a_{ji} \end{pmatrix} * \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_i \end{pmatrix} = R_{Mj} --(3.4)$$

Where

$$R_{Mj} = \begin{pmatrix} r_1 \\ r_2 \\ \vdots \\ r_j \end{pmatrix} = \begin{pmatrix} a_{11}x_1 + a_{12}x_2 + \dots\dots\dots + a_{1i}x_i \\ a_{21}x_1 + a_{22}x_2 + \dots\dots\dots + a_{2i}x_i \\ \vdots \qquad \vdots \qquad \vdots \\ a_{j1}x_1 + a_{j2}x_2 + \dots\dots\dots + a_{ji}x_i \end{pmatrix} --\mathbf{3.5}$$

After determining the monitored revenue, R_{Mj} by the model; this value was compared with the actual revenue, R_A collected from the laboratory for all four (4) classes of data. The difference between the monitored and actual revenue is determined in order to find out any likely difference. If there is any difference recorded, the date that corresponds with the record is checked for errors. So, the difference is defined by a column matrix of dimension-n stated as follows:

$$Difference = Monitored\ Revenue - Actual\ Revenue$$

$$= \begin{pmatrix} R_{M11} - R_{A11} & R_{M12} - R_{A12} \dots & R_{M1n} - R_{A1n} \\ R_{M21} - R_{A21} & R_{M22} - R_{A22} \dots & R_{M2n} - R_{A2n} \\ \vdots & \vdots & \vdots \\ R_{Mn1} - R_{An1} & R_{Mn2} - R_{An2} \dots\dots\dots & R_{Mnj} - R_{Anj} \end{pmatrix} --(3.6)$$

Hence, if

$$Difference = \begin{cases} empty\ column\ matrix; then\ no\ query\ else \\ non-empty\ column\ matrix; then\ query\ records \end{cases}$$

Thus, equation 3.3 is the mathematical model for monitoring laboratory revenue.

Table 3.1Breakdown of the different tests and their respective prices

I	Test (Xi)	Amount (₦)
1.	Packaged Cell Volume (PCV)	200
2.	+Malaria Parasite (MP)	200
3.	Widal	250
4.	Blood Group	200

5.	Genotype	500
6.	Pregnancy Test (PT)	250
7.	Pregnancy Test (PT)-Serum	300
8.	Hepatitis B Virus	300
9.	Hepatitis C Virus	300
10.	Syphilis	300
11.	Culture tests	700
12.	Urinalysis (Urine)	200
13.	Urine M/C/S	500
14.	Sputum M/C/S	500
15.	Semen M/C/S	700
16.	Semen Analysis	500
17.	Stool Analysis	200
18.	High Vaginal Swab (HVS)	500
19.	Ante Natal Care (ANC) services	1000
20.	ESR (Erythrocyte Segmentation Rate)	500
21.	Full Blood Count (FBC)	500
22.	Fasting Blood Sugar (FBS)	300
23.	Random Blood Sugar (RBS)	300
24.	Liver Function Test (LFT)	2000
25.	Kidney Function Test (KFT)	2000
26.	Electrolyte, Urea & Cretinin	3000
27.	+Prostrate Surface Antigen (PSA)	1500
28.	*Acid-Fast Bacilli (AFB) Sputum (Tuberculosis test)	2500
29.	* Human Immunodeficiency Virus screening (HIV test)	700
30.	*Cluster of Differentiation 4 CD4 (HIV test)	1000

*Free tests for all patients+ Free for only HIV patients.

3.6 Model Assumptions

The following assumptions were made in the formulation of the mathematical model.

a. Consumables, Reagents and Drugs are available.

b. Equipment, Apparatus, Water Supply and Power Supply are set.

c. All tests taken are paid for except for the eligible patients for free tests.

d. All tests paid for are performed.

3.7 Software Used for Simulation and Evaluation

The software used for simulating and evaluating the mathematical are:

a. Matrix Laboratory software (MATLAB)

The MATLAB software is basically a collection of different toolboxes which can be used to perform a variety of different functions and the version used is the MATLAB R2009a version 7.8.0. The variables in MATLAB are stored as arrays and matrices. This is suitable for monitoring the revenue generated in the laboratory for the respective classes of tests. The MATLAB software was used in simulating the monitoring of the revenue generated for each class of tests performed using the value of the difference calculated and

b. Waikato Environment for Knowledge Analysis software (WEKA). The WEKA software is java-based software which performs various types of data mining tasks such as; classification, clustering, association etc. The version of software used is WEKA 3.7.1 and the software's regression modelling algorithm (classifiers) is suitable for evaluating the performance of the monitoring model by performing the least squares algorithm in order to generate the linear regression equation used in plotting the revenue generated and in determining the correlation and error rates. WEKA uses least square method in developing the linear regression model.

4. RESULTS AND DISCUSSION

This section discusses the findings from the hospitals under survey. It describes the datasets used in monitoring the revenue generated from the laboratory. It also presents the results of the simulation and the performance evaluation of the mathematical model.

4.1 Classification of Laboratory Data

The data collected at the laboratory were classified into four (4) different categories which are described as follows:

a. Daily tests and revenue generated for regular patients;

b. Daily tests and revenue generated for NHIS patients;

c. Daily free tests and revenue generated for regular patients; and

d. Daily free tests and revenue generated for NHIS patients.

4.2 Revenue generated for the daily tests performed on regular (Non-NHIS) patients

As stated earlier, the mathematical model was simulated using MATLAB software. The monitoring model collects and stores the data collected for the total tests performed in a 25 by 25 matrix – so the dataset for regular patients was stored in two different Matlab files. The test price for each test was also stored in a column matrix (25 by 1):

a. dailyTests1.mat: which contains tests performed for the first 25 days;

b. dailyTests2.mat: which contains tests performed in the last 25 days; and the test price stored as

c. TestsPrice.mat

Following is a section of the Matlab code used in executing the process:

To generate the revenue for the first 25 days

```
>>> dailyTests1=load ('dailyTests1.mat')
>>>TestsPrice=load ('TestsPrice.mat')
>>>Revenue1=dailyTests1*TestsPrice
```

To generate the revenue for the first 25 days

```
>>> dailyTests2=load ('dailyTests2.mat')
>>>TestsPrice=load ('TestsPrice.mat')
>>>Revenue2=dailyTests2*TestsPrice
```

The results of the Matlab implementation of the value of the revenue generated for each dataset is shown in Table 4.1.

Table 4.1 Results of the Monitoring Model for Regular (Non-NHIS) Patients' Tests

Actual Revenue1 (given by the lab staff) ₦	Monitored Revenue1 (given by the mathematical model) ₦	Actual Revenue2 (given by the lab staff) ₦	Monitored Revenue2 (given by the mathematical model) ₦
21150	20950	**40000**	40300
10150	10150	8850	8650
10800	10000	12300	12300
9000	9000	2350	2350
9600	9600	13950	13950
10800	21600	9100	9100
6900	6900	7050	7050
5150	5150	800	800
20500	20500	23950	23950
5400	5450	16500	16500
40000	40300	**6950**	6750
8850	8650	10500	10500
12300	12300	6400	6400
2350	2350	1850	1850
13950	13950	14250	14250
9100	9100	**10300**	8600
7050	7050	6950	6950
800	800	**10800**	10600
23950	23950	8750	8750
16500	16500	20450	20450
6950	6750	3350	3350
10500	10500	7000	7000
6400	6400	**6550**	4550
1850	1850	6400	6400
14250	14250	2900	2900

It can be concluded from the results presented in table 4.1 that if the calculated value is equal to the actual value of the revenue; one can say that the revenue collected is not questionable and free from errors and if the calculated value is different from the actual value of the revenue; then the revenue collected is questionable.

The results of the monitoring model above shows that there are six (6) errors out of the total 25 data provided by the laboratory staff which can be queried for difference in values – in some cases the value is less while in some the value is greater. For the second data set which contains tests performed for the last 25 days – five (5) errors were observed. It therefore means that the monitoring model was able to detect errors in the revenue provided by the laboratory staff.

4.3 Revenue generated for the daily tests performed on NHIS patients

The monitoring model collects and stores the data collected for the total tests performed in a 25 by 25 matrix – so the dataset for NHIS patients was stored into two different Matlab files. The test price for each test was also stored in a column matrix (25 by 1):

a. NHISTests1.mat: which contains tests performed for the first 25 days;

b. NHISTests2.mat: which contains tests performed in the last 25 days; and the test price stored as

c. TestsPrice.mat

Following is a section of the Matlab code used in executing the process:

To generate the revenue for the first 25 days

```
>>> NHISTests1=load ('NHISTests1.mat')
>>>NHISPrice=load ('TestsPrice.mat')
>>>NHISRevenue1=NHISTests1*TestsPrice
```

To generate the revenue for the first 25 days

```
>>> NHISTests2=load ('NHISTests2.mat')
>>>NHISPrice=load ('TestsPrice.mat')
>>>NHISRevenue2=dailyTests2*TestsPrice
```

The results of the Matlab implementation of the value of the revenue generated for the dataset is shown in Table 4.2.

Table 4.2Results of the Monitoring Model for NHIS Patients' Tests

Actual Revenue1 (given by the lab staff) ₦	Monitored Revenue1 (given by the mathematical model) ₦	Actual Revenue2 (given by the lab staff) ₦	Monitored Revenue2 (given by the mathematical model) ₦
3200	3200	2100	2100
750	750	**3350**	2550
2500	2500	1400	1400
1150	1150	5500	5500
1800	1800	300	300
1800	1800	1100	1100
1000	1000	1500	1500
2100	2100	600	600
2550	2550	1100	1100
1400	1400	700	700
5500	5500	650	650
300	300	300	300
1100	1100	300	300

1500	1500	1850	1850
600	600	1650	1650
1100	1100	3700	3700
700	700	1350	1350
650	650	1100	1100
300	300	1200	1200
300	300	3000	3000
1850	1850	2350	2350
1650	1650	1450	1450
3700	3700	700	700
1350	1350	1200	1200
1100	1100	2550	2550

Again, it can be concluded from the results presented in table 4.2 that if the calculated value is equal to the actual value of the revenue; one can say that the revenue collected is not questionable and free of errors and if the calculated value is different from the actual value of the revenue; then the revenue collected is questionable.

The results of the monitoring system show that there are no errors out of the total 25 data provided by the laboratory. For the second data set which contains tests performed for the last 25 days – only one (1) error was observed from the results plotted by the monitoring system; hence, the data may be queried for the respective error. This also follows again that the monitoring system was able to detect errors in the revenue provided by the laboratory staff.

4.4 Model Evaluation

The revenue generated is expressed as a linear equation of one degree. The monitoring model was evaluated using the multi-variate linear regression analysis method. The value of the monitored revenue generated was compared with the actual revenue generated with the aim of measuring the error rate (which determines the accuracy) of the generated regression model.

The standard linear regression model has the form:

$$f(X) = \beta_0 + \sum_{j=1}^{p} x_j \beta_j \qquad 4.1$$

Where the β_j 's are unknown parameters or coefficients and the idea is to have a set of data of the form; (x_1, y_1), (x_2, y_2),..,(x_p, y_p) from which the value of β_j for j=1…p can be determined.

Least squares method is the most widely used procedure for developing estimates of the model parameters. Thus it was used to estimate the values of the parameters (coefficients) of the model based on the observed n sets of values. βs are values to be estimated.

There are two important things to note when using least squares method for modeling:

i. **Prediction Accuracy:** least squares estimates often provide predictions with low bias but high variance; and

ii. **Interpretation:** when the number of regressors, I is too high, the model is difficult to interpret. One seeks to find a smaller set of regressors with higher effects.

The model used in monitoring the revenue generated from the tests performed in the laboratory for regular patients and NHIS patients was evaluated using WEKA software. The dataset used for the analysis was partitioned as:

a. The dataset containing the revenue for tests performed for regular patients; and

b. The dataset containing the revenue for tests performed for NHIS patients.

The results of the evaluation of the model using WEKA is shown in Table 4.3 and 4.4. The error values, correlation coefficient, mean absolute error, mean square error, relative absolute error and the root absolute square error were also determined (see Table 4.5).

Table 4.3 Results of Regression Analysis of the Dataset for the Tests Performed on Regular Patients

Actual Revenue Generated (₦)	Regression Calculations(₦)	Error Values(₦)
21150	21150.00	0
10150	9775.28	-374.72
10800	10546.65	-253.35
9000	8697.77	-302.23
9600	9925.85	325.85
10800	10800.00	0
6900	6841.18	-58.82
5150	4862.21	-287.79
20500	20842.14	342.14
5400	5377.40	-22.6
40000	40000.00	0
8850	8735.00	-115
12300	12830.35	530.35
2350	2326.19	-23.81
13950	13256.00	-694
9100	8969.78	-130.22
7050	7029.01	-20.99
800	1099.77	299.77
23950	24220.49	270.49
16500	16621.47	121.47
6950	6717.83	-232.17
10500	10555.74	55.74
6400	7256.79	856.79
1850	2571.61	721.61
14250	14163.68	-86.32
10300	9399.99	-900.01
6950	6947.61	-2.39
10800	10478.92	-321.08
8750	9236.93	486.93
20450	20470.67	20.67
3350	3753.24	403.24
7000	7165.19	165.19
6550	5373.88	-1176.1
6400	6291.71	-108.29
2900	3409.68	509.68

Table 4.4Results of Regression Analysis of the Dataset for the Tests Performed on NHIS Patients.

Actual Revenue Generated (₦)	Regression Calculations(₦)	Error Values(₦)
3200	3401.84	201.84
750	750.00	0
2500	2442.35	-57.65
1150	1122.11	-27.89
1800	1776.581	-23.419
1800	1995.29	195.29
1000	1213.30	213.3
2100	2948.17	848.17
3350	2550.00	-800
1400	1309.04	-90.96
5500	3549.15	-1950.9
300	246.64	-53.36
1100	1029.06	-70.94
1500	1623.29	123.29
600	674.83	74.83
1100	1754.99	654.99
700	629.83	-70.17
650	654.03	4.03
300	246.64	-53.36
300	258.26	-41.74
1850	2000.54	150.54
1650	1246.04	-403.96
3700	841.307	-2858.7
1350	1263.06	-86.94
1100	1754.99	654.99
1200	1017.139	-182.86
3000	3057.37	57.37
2350	2529.78	179.78
1450	1674.35	224.35
700	629.83	-70.17
1200	1200.00	0
2550	2442.35	-107.65

4.5 The Performance or Evaluation Metrics

The performance or evaluation metrics used by the WEKA software to evaluate the regression model are: Correlation coefficient, mean absolute error, root mean square error, relative absolute error and root relative squared error.

4.5.1 Correlation coefficient

The correlation coefficient (r) measures the strength and the direction of a linear relationship between two variables. The linear correlation coefficient is sometimes referred to as the Pearson Product moment correlation coefficient in honour of its developer Karl Pearson.

4.5.2 Mean absolute error (MAE)

Mean absolute error is used to forecast accuracy by comparing the forecast value to the actual value. The mean absolute error is the mean of the absolute errors. The absolute error is the absolute value of the difference between the forecast value and the actual value. MAE tells us how big of an error we can expect from the forecast on average. MAE calculates the mean absolute error function for the forecast and the eventual outcomes.

4.5.3 Root mean square error (RMSE)

Root mean square error is calculated to adjust for large rare errors. This is done by squaring the errors before we calculate their mean; we arrive at a measure of the size of the error that gives more weight to the large but infrequent errors than the mean. RMSE is used to measure the differences between values predicted by a model and the value actually observed. The RMSE serves to aggregate the magnitudes of the errors in predictions for various times into a single measure of predictive power. It is a good measure of accuracy, but only to compare forecasting errors of different models for a particular variable and not between variables, as it is scale dependent.

4.5.4 4.5.4 Relative absolute error (RAE)

Relative absolute error is relative to a simple predictor which is just the average of the actual values. The error is the total absolute error. Thus, the relative absolute error takes the total absolute error and normalises it by dividing by the total absolute error of the simple predictor.

4.5.5 4.5.5 Root relative squared error (RRSE)

Root relative squared error is computed by dividing RMSE by the RMSE obtained by just predicting the mean of target values (and then multiplying by 100). Therefore, smaller values are better and values greater than 100% indicate a scheme is doing worse than just predicting the mean. RAE is computed in a similar manner.

Table 4.5 Results of the evaluation metrics

Performance metrics	Regular Tests data	NHIS Tests data
Correlation Coefficient	0.9985	0.8113
Mean absolute error	291.9947	318.0787
Root mean square error	410.3096	670.2791
Relative absolute error	5.717%	35.6456%
Root relative squared error	5.4965%	57.5625%

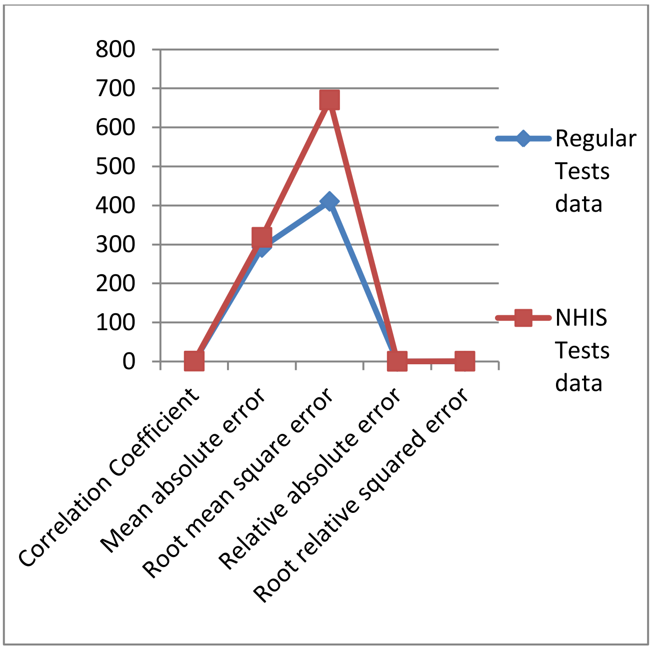

Figure 4.1 Line chart representation of the results of the evaluation metrics

From the results of the regression analysis, the distribution of data for both classes of datasets (regular and NHIS patients) showed strong positive relationships between the tests and the revenue generated with a correlation coefficient of 0.9985 and 0.8113 respectively. In statistics, a correlation expresses the strength of relationship between two variables in a single value between -1 and +1. High correlation coefficient increases the accuracy of prediction. The regression model is statistically significant if the level of significance (ρ-value) < 0.01 and the regression model is statistically insignificant if the level of significance (ρ-value) > 0.01. Thus, the regression analysis for regular patients shows a high level of significance of 0.0015. MAE measures how far predicted values are away from observed values. Lower values of RMSE indicate better fit.

The larger the error the less relationship between the tests and the revenue generated. The RMSE was calculated to adjust the large rare errors.

5. CONCLUSION

The focus of this research is to design a mathematical model for monitoring revenue in a hospital-based laboratory. This was done by tracking the number of tests and their corresponding amounts. To actualize the aim and objectives in this research, a mathematical model was formulated to track and monitor laboratory revenue. Findings from the hospital under study showed that there are discrepancies in the revenue reported to have been generated and the actual revenue generated from the laboratory tests as shown in the simulation results. This is as a result of improper documentation of the laboratory tests performed and the revenue generated from them. Due to this, revenue is misstated because of loss of track of laboratory tests counts. Some laboratory staff collect money from the patients to pay on their behalf. These staff do not make the payments and as such they do not have evidences of payment. This is revenue leakage. This study had used only two (2) months records, further study should utilise records for more years to get large data set in order to determine the trend of the revenue and for a more detailed analysis.

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7. AUTHOR'S PROFILE

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8. APPENDIX I

Results of the regression analysis on the regular patients' tests

```
=== Run information ===

Scheme:     weka.classifiers.functions.LinearRegression -S 0 -R 1.0E-8
Relation:   dailyRevenue
Instances:  35
Attributes: 26
          PCV
```

MP
Widal
Blood group
HP-Genotype
PT
PT-serum
HPV-B and C
Syphillis
CT
Urine
Urine M/C/S
Sputum M/C/S
semen M/C/S
Semen
Stool
HVS
ANC
ESR
FBC
FBS
RBS
LFT
KFT
Electrolyte
Total Revenue (N)

Test mode: evaluate on training data

=== Classifier model (full training set) ===

Linear Regression Model

Total Revenue (N) =

190.326 * PCV+
251.5078 * MP +
176.7534 * Widal +
421.2725 * HP-Genotype +
284.8327 * PT +
-4340.1466 * HPV-B and C +
1755.2226 * semen M/C/S +
468.5118 * HVS +
988.4857 * ANC +
3313.1218 * FBC +
377.3805 * FBS +
1656.5604 * LFT +
3273.599 * Electrolyte +
719.1165

Time taken to build model: 0.01 seconds
=== Predictions on training set ===

inst#	actual	predicted	error
1	21150	21150	0
2	10150	9775.279	-374.721
3	10800	10546.647	-253.353
4	9000	8697.765	-302.235
5	9600	9925.852	325.852
6	10800	10800	0
7	6900	6841.182	-58.818
8	5150	4862.213	-287.787
9	20500	20842.137	342.137
10	5400	5377.401	-22.599
11	40000	40000	0
12	8850	8735	-115
13	12300	12830.349	530.349

14	2350	2326.189	-23.811
15	13950	13256.002	-693.998
16	9100	8969.784	-130.216
17	7050	7029.007	-20.993
18	800	1099.768	299.768
19	23950	24220.49	270.49
20	16500	16621.468	121.468
21	6950	6717.834	-232.166
22	10500	10555.744	55.744
23	6400	7256.79	856.79
24	1850	2571.606	721.606
25	14250	14163.682	-86.318
26	10300	9399.991	-900.009
27	6950	6947.606	-2.394
28	10800	10478.917	-321.083
29	8750	9236.925	486.925
30	20450	20470.674	20.674
31	3350	3753.237	403.237
32	7000	7165.191	165.191
33	6550	5373.883	-1176.117
34	6400	6291.71	-108.29
35	2900	3409.675	509.675

=== Evaluation on training set ===
Time taken to test model on training data: 0.04 seconds
=== Summary ===

Correlation coefficient	0.9985
Mean absolute error	291.9947
Root mean squared error	410.3096
Relative absolute error	5.717 %
Root relative squared error	5.4965 %
Total Number of Instances	35

9. APPENDIX II

Results of the regression analysis on the NHIS patients' tests

=== Run information ===
Scheme: weka.classifiers.functions.LinearRegression -S 0 -R 1.0E-8
Relation: NHISRevenue
Instances: 32
Attributes: 26

PCV
MP
Widal
Blood group
HP-Genotype
PT
PT-serum
HPV-B and C
Syphillis
CT
Urine
Urine M/C/S
Sputum M/C/S
semen M/C/S
Semen
Stool
HVS
ANC
ESR
FBC
FBS
RBS
LFT
KFT
Electrolyte
Total Revenue (N)

Test mode: 10-fold cross-validation

=== Classifier model (full training set) ===

Linear Regression Model

Total Revenue (N) =

```
  255.9122 * PCV +
  128.1614 * MP +
  348.5625 * Widal +
  418.0404 * HP-Genotype +
  432.0782 * PT +
  244.831  * Urine +
 1086.4857 * ANC +
  408.71   * FBS +
  322.1076 * RBS +
 2045.0851 * LFT +
 2861.8998 * Electrolyte +
 -154.2175
```

Time taken to build model: 0 seconds

=== Predictions on test data ===

inst#	actual	predicted	error
1	700	1034.626	334.626
2	2550	2480.845	-69.155
3	1100	1754.994	654.994
4	1400	1309.038	-90.962
5	1450	1674.345	224.345
6	1800	1776.581	-23.419
7	700	629.833	-70.167
8	2500	2442.35	-57.65
9	300	258.255	-41.745
10	3700	841.307	-2858.693
11	600	674.828	74.828
12	3350	2550	-800
13	750	750	0
14	1200	1200	0
15	1100	1029.06	-70.94
16	1100	1029.06	-70.94
17	300	243.419	-56.581
18	1200	1017.139	-182.861
19	1800	1995.289	195.289
20	1650	1246.044	-403.956
21	300	246.64	-53.36
22	650	654.03	4.03
23	3000	3057.366	57.366
24	5500	3549.153	-1950.847
25	2350	2529.779	179.779
26	1850	2000.544	150.544
27	1500	1623.293	123.293
28	1000	1213.304	213.304
29	1150	1122.111	-27.889
30	2100	2948.166	848.166
31	3200	3401.844	201.844
32	1350	1263.057	-86.943

=== Cross-validation ===
=== Summary ===

Correlation coefficient	0.8113
Mean absolute error	318.0787
Root mean squared error	670.2791
Relative absolute error	35.6456 %
Root relative squared error	57.5625 %
Total Number of Instances	32

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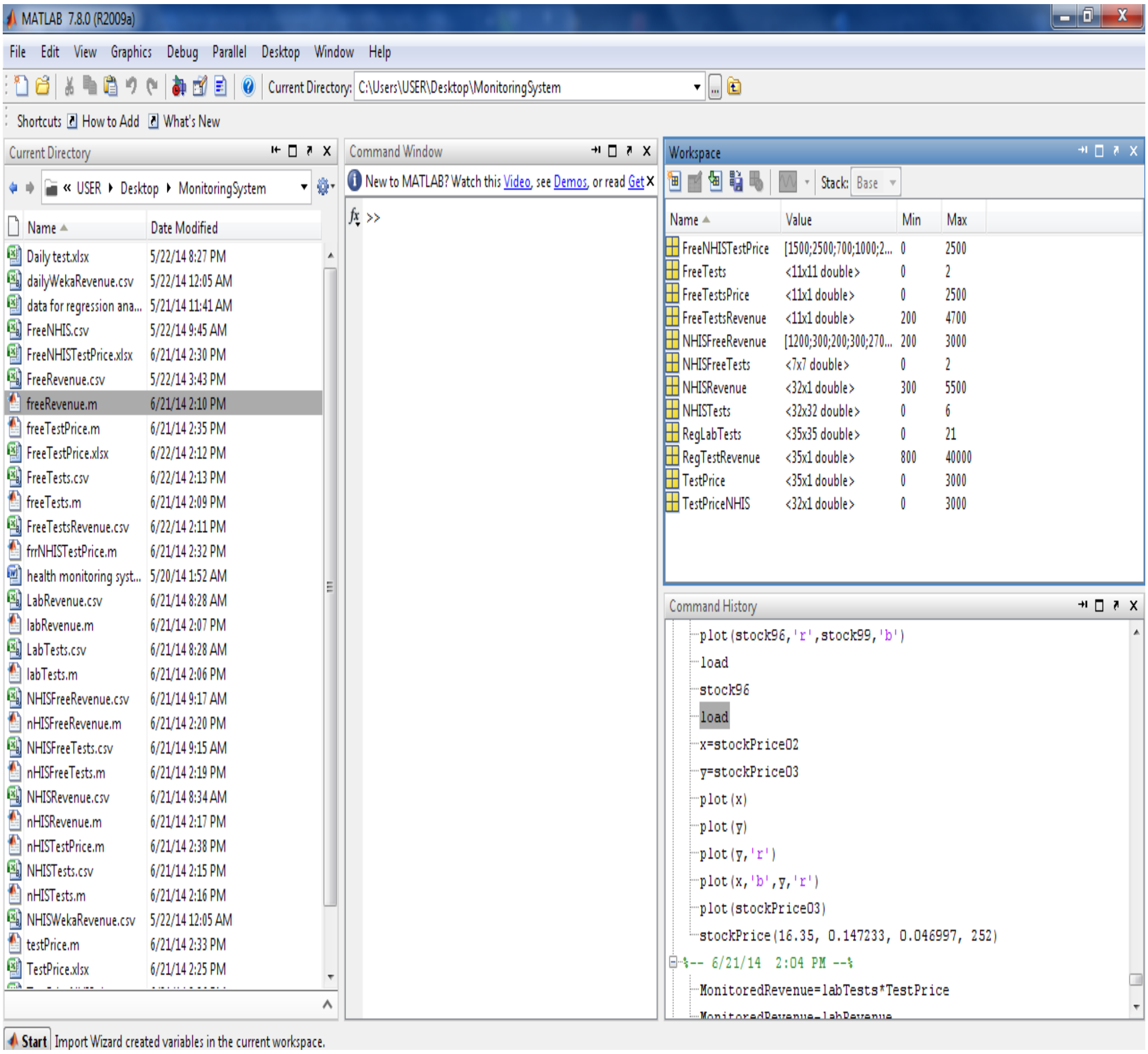
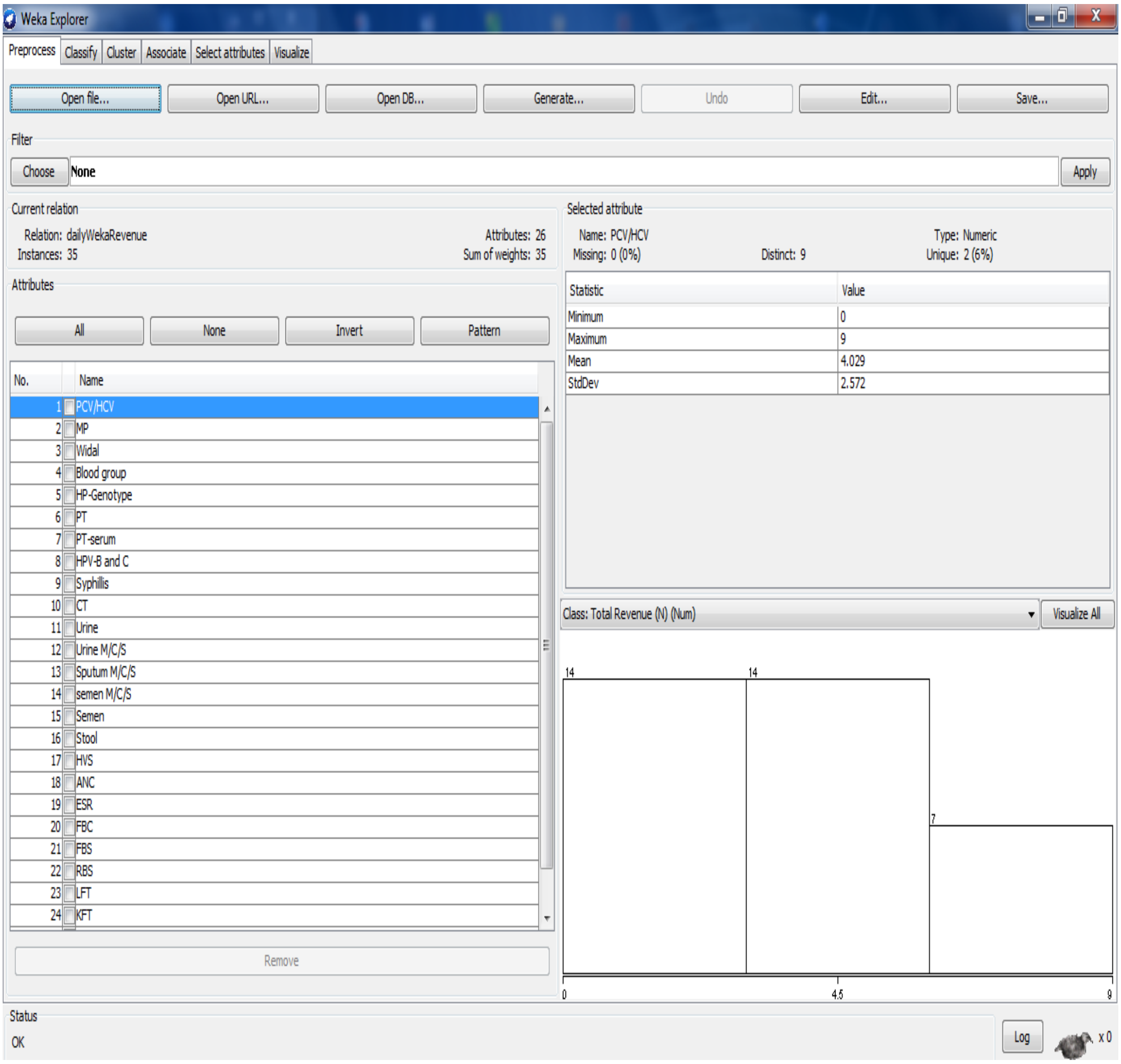
10. APPENDIX III



Simulation Interface of the MATLAB software

11. APPENDIX IV



Screenshot of WEKA Interface