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Determination of Kaduna Refining and Petrochemicals Company Limited (KRPC) Safety and Cost Reduction Models

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Abstract: *In this thesis we consider four multivariate models (i.e. three multiple regression models respectively) that captures the forecast mechanism of yearly total observation (YTO) of Man-Hour Worked for accident, man-hour lost for cost reduction, maintenance trend and Cost Reduction Linear Programming (LP) Model at the Kaduna Refining and Petrochemical Company (KRPC). Data were collected from Health, Safety and Environment Department (HSED), Planning Budget and Monitoring Department (PBMD) of KRPC records and classified into purposeful and logical categories for analysis. Multiple regression model was adopted as the suitable model for predicting the yearly total observation of man-hour worked as a result of accident in the system, man-hour lost as a result of accident which will assist the management in putting resources in place that will reduce cost in the system and maintenance models that will inform progressive routine maintenance plan in the system.*
Keywords: *KRPC, Safety, Accident, Maintenance, Man-hour Loss, Man-hour worked, Fire incident, Oil spillage, work permit.*

I. Introduction

The decision to construct the third refinery in Kaduna was taken in 1974 along with that of the second NNPC refinery located at Warri. However, it was decided that work would commence on the construction of the third whenever the projection of the consumption of petroleum products justified it.

By early 1977 in view of the fuel shortages experienced then, the federal government decided that work on the third refinery should be advanced. It was envisaged that the refinery was to be a hydroskimming type refinery in order to meet up with fuel demand then.

Based on the feasibility studies carried out which took into consideration the consumption of the various petroleum products within the Northern zone, and adequate means of disposal for the surplus products, a crude oil capacity of 42,000 barrels per day (BPD) could be easily justified. Hence the refinery was designed for a capacity of 60,000 BPSD.

It was much later that the Federal government decided that the capacity for any refinery in Nigerian should not be below 100,000 BPD.

However, this would have led to the production of large quantity of heavy ends and on one practical and viable solution is reprocessing the heavy fuel oils in order to do this, the whole project plan had to be modified so that what initially was planned to be a simple hydroskimming type refinery developed into an integrated refinery. The refinery would now be able to produce a wider variety of petroleum products, some of which should be lubricating base oil. Hence it became necessary to import suitable paraffinic based crude oil from Venezuela, Kuwait or Saudi Arabia.

Products from refinery are to include fuels using such as liquidified petroleum gas (LPG), petrol, Automotive gas oil (AGO), kerosene, fuel oil and sulpur, and those from the lubricating oils complex are base oils, Asphalt and waxes.

The lubricating oil complex of KRPC is the first of its kind in West Africa and one of the largest in Africa.

The consulting firm, KING WILKINSON of Hague, Holland in conjunction with NNPC engineers developed the plan for the refinery. The contract for the construction was awarded to CHIYODA CHEMICAL ENGINEERING AND CONSTRUCTION COMPANY OF YOKOHAMA, JAPAN in 1977.

The project was completed and commissioned in 1980. However, the lubes plant and petrochemical plant were commissioned in 1983 and 1988 respectively. The initial operation and maintenance carried out by Nigerian Staff and expatriate personnel as technical backup.

By 1985, Nigerian staff had virtually taken over all the maintenance and operations.

For the past three (3) years there had been an increase in accident(s) cases leading to plant and equipment breakdown.

This fragment plant failure and industrial accidents have militated against high productivity and also affecting the company budget, planning negatively consequent to lack of forecast mechanism in place to capture the negative effect of accident(s) in the system (both to staff/equipment) with respect to man-hour worked/lost and lack of progressive maintenance in place in KRPC.

As part of the contribution to the way forward, there is the need in solving the problems of poor planning/budgeting/maintenance in KRPC, which may assist in curbing the challenges of petroleum products need in the Northern part of the country and also reducing the problem of importation of petroleum products into the country. This study is out to empirically provide model that will assist in forecasting man-hour worked, man-hour lost and maintenance trend. In KRPC, all these will assist in checking/reducing cost in the system in order to boost productivity in KRPC and hydro carbon industry in Nigeria that optimizes current level of compliance to safety audit in KRPC.

The rest of the paper is structured as follows: Section two (2) provides interactive review and theoretical framework for the study while section three (3) is on the methodology. Section four (4) focuses on results and discussion and the last section concludes the paper.

AIM:

To derive models for forecasting Man-hour worked, Man-hour loss and Maintenance schedule.

SCOPE:

The study covers maintenance trend, safety audit and accident rate/prevention in KRPC operation from 1996-2009.

Study area: The study was conducted in the Northern part of the country in Pardama Jarki-Rido village in the Southern part of the Kaduna state in Chikun Local Government Area where the third refinery of the country is sited. It is clear that the setting of the refinery in Kaduna had also contributed to providing employment to not less than 1500 Nigerians a means of livelihood to local entrepreneurs by awarding them petty contract jobs, on the whole, the impact of Kaduna refinery to the people of Kaduna state and other part of Northern states is very significant.

STATEMENT OF THE PROBLEM

For the past three (3) years there had been an increase in accident(s) cases leading to plant and equipment breakdown. This fragment plant failure and industrial accidents have militated against high productivity. Safety audit of plant and equipments are carried out twice a year in KRPC to determine their operational status.

The safety audit is also to check any possible deviation and to ensure uninterrupted operations and accident prevention. Non compliance to the recommendations made is now the major challenges that inform this study.

OBJECTIVES OF THE STUDY

1. To collate and tabulate records from KRPC.
2. To derive mathematical models required using Statistical Package for the Social Science (SPSS) and Excel Solver.
3. Use derived models for forecasting.
4. Analyse results.

SIGNIFICANCE OF THE STUDY

The refinery also contributed it quota in the field of technological transfer by providing ensuring students from Polytechnics, Monotechnics, Universities and other institutions of higher learning with relevant industrial work experience. The refinery was also used to train and develop local staff in the field of petroleum refinery technology that saw to the phasing out of hired foreign expatriate and consultants.

The exposure of the staff of the refinery put them at the forefront of developing our petroleum industries today in the country.

Management performance enhancement, prompt handling of technical problems and cost savings.

II. Literature Review And Theoretical Framework

The first analysis of industrial accident causation and prevention started with Heinrich (1931) who affirmed that 88% of accidents are caused by "unsafe acts of person" and put forth what often is referred to as Heinrich accident triangle or pyramid. In a group of 330 accidents result on minor injuries, result on minor injuries, 29 will result on minor injuries and 1 will result on a major accident. His famous theories on industrial accidents include unsafe acts of persons are responsible for mort accidents and the 300:29:1 ratio of work place accident. (Heinrich 1931)

British safety council public (1972:13) James Staples equally states that 90% of all accidents are attributed to human behaviours. Taubitz (1980) question the Heinrich model. He and his colleagues noticed that the exposures causing fatalities had nothing to do with sprains, strains or other reportable injuries "and use intuitively understand the Heinrich model didn't fit because it cannot help to forecast severe accident and fatalities" he said and that Heinrich model is just a foundation for accident prevention. Taubitz (1980) therefore said each system will have to derive and adapt its own models.

However, over the years Heinrich's methodology though widely applied has been undergoing many refinement and improvement.

We shall also borrow leaf from the work of JAMES T. REASON (1990) a British psychologist of the University of Manchester propounded a model of accident causation termed SWISS MODEL. A model used in risk analysis and risk management of human systems commonly used in aviation engineering and health care. It likens human systems as to multiple stress of Swiss cheese stacked together, side by side. The system as a whole produces failure when all of the holes in each of the slices momentarily align, permitting (In Reason words) "a trajectory of accident opportunity" so that a hazard passes through all of the holes in all of the defences leading to a failure. Frosch (2001) describes Reason Model in mathematical terms as being a model in percolation theory which he analyses as a "Bethe lattice".

Lubnau, Okray (2004) apply Reason's Swiss model to the engineering of human systems in the field of fire fighting, with the aim of reducing human errors by "inserting additional layers of cheese in the system" namely the techniques of crew resources management. In this Swiss model individual weaknesses are model as holes in slices of Swiss cheese such as Emmental. They represent the imperfections in individual safeguards or defences which in the real world rarely approach the ideal of being completely proof against failure.

Crew Resource Management for the Fire Service, Pennwell Books pp. 20-21 ISBN 1593700067.

NNPC has Group Health Safety Policy Statement (2012) which states that NNPC is committed to conducting its activities in a manner that promotes the Health and safety of her Employees, Assets and public as well as the protection of the Environment.

This policy shall be of uniform application throughout the NNPC group in which KRC is in part.

KRPC has an accident prevent policy which recognizes that in the design stage of the process and manufacturing plants, appropriate design conditions effective control system and reliable construction materials have been selected on the basis of their suitable scientific relationship Abdulkadir, Aguba 2008:6 (chief officers MDP course 054) unpublished.

Yaya (2006:8 chief officers MDP course 052) unpublished propounded that: Ageing workforce, obsolete equipments, poor maintenance and lack of professionalism was responsible for increased frequent fire incidences in KRPC.

On this work we shall digress a little from their works but to describing in a mathematical terms how we can forecast the consequence of accidents in the system in relation to man-hour worked/loss and maintenance rate applying regression model; this will assist the management team of KRPC and other NNPC group in attaining accurate planning/budgeting and maintenance monitoring in the system that will lead to high production activities.

Therefore, a Cost Reduction (LP) Model shall be considered also on this work because safety depends on equipments and measures which require controlled finance.

Prediction or estimation is one of the major problems in almost all spheres of human activities. The prediction of future activities are important to businessman. Thus the statistical device which estimate or predict the unknown values of one variable from the known values of another variable is known as regression.

Pillai, Bagaiathi (2012) the regression line describes the average relationship existing between X and Y variable. Siegel (2002) stated that once R^2 is greater than or equal to 0.60 or 60% the model is an accurate one and can be used for prediction or estimation.

The regression model which was independently proposed by Meyers (2002) is given thus:

$\hat{Y}_i := \hat{\alpha} + \hat{b}_1 x_1 + \hat{b}_2 x_2 + b_3 x_3 + \cdots + \hat{b}_k x_k + \ell$

Where

$\hat{Y}_i$ = estimated value of Y given a specific value of X.

$\hat{\alpha}$ = estimate of the true intercept b

$\hat{b}_1$ = estimate of the true parameter bi

ℓ = estimate of the true random terms μ

III. Materials And Methods

This involves derivations of the models using SPSS package and data from KRPC.

Types of data collected:

The data used were secondary: the data were collected from the records of the Health Safety and Environment (HSED) and Planning Budget and Monitoring Department (PBMD) of the Management authorities of Kaduna Refinery and Petrochemical Company (KRPC).

METHODS OF DERIVATION OF SOLUTION AND ANALYSIS:

Methodology:

Tabulated data were fed into the computer package software SPSS and run several times. The values of the regression coefficients were obtained. These values of (β) were used to express the models as required.

Table 1: Data on accident, man-hour worked and loss

W	X_1	X_2	X_3	X_4	X_5	X_6	X_7
1	28	1760	5	31	19	2265	3398066
2	12	524	11	39	10	2111	3397542
3	5	120	6	43	15	2823	3392442
4	15	1112	20	34	15	2072	3391330
5	9	268	9	24	16	2101	3392241
6	7	248	7	36	15	2073	3392440
7	5	168	7	23	32	2122	3392436
8	3	232	6	32	18	2193	3299101
9	6	520	0	13	10	2300	3299302
10	3	96	6	25	11	2216	3299336
11	0	0	1	6	14	2166	3299436
12	5	264	1	9	10	2206	3299172
13	2	56	2	0	12	2741	3299368
14	3	96	7	0	7	2986	3299336
TOTAL	103	5464	88	315	204	32375	46851548

Where:

X_1 = No of Accident (personnel)
X_2 = Man hour Loses (hrs)
X_3 = Property Damage Accident
X_4 = Fire Incidents (No. of cases)
X_5 = Oil Spills (No. of cases)
X_6 = Training of Personnel (No. of Personnel)
X_7 = Total Man-hour Worked

i. **Man Hour Worked Model with respect to accident. Table 1**

$\hat{Y}_i$: = $\hat{\alpha} + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \hat{\beta}_3 X_3 + \cdots + \hat{\beta}_6 X_6$

Where:-

$\hat{Y}_1$ = Yearly total observation of man-hour worked for accident.
X_1 = Yearly observation on numbers of accidents (personnel)
X_2 = Yearly observation on man-hour loses (hrs)
X_3 = Yearly observation on property damage accident
X_4 = Yearly observation on fire incidents (No. of cases)
X_5 = Yearly observation on oil spills (No. of loses)
X_6 = Yearly observation on training of personnel (No. of persons)

ii. **Man-Hour Lost Model based on available data. Table 1**

$\hat{Y}_2$ = $\hat{\alpha} + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2$

Where

$\hat{Y}_i$ = Yearly total estimation of man-hour lost.

X_1= Year to year total Nos of accident to personnel/property.

Table 2: Data used for Maintenance Model

Y	X_1	X_2	X_3	X_4	X_5
1	1320	181	1452	11	7
2	1665	363	2112	19	5
3	6483	3450	4608	33	2
4	1935	1771	2376	37	0
5	3019	2112	2641	36	0
6	3014	2160	2905	43	0
7	3432	2279	3168	49	0
8	5472	2277	3432	40	0
9	6003	2904	3269	46	1
10	6063	2530	3300	87	1
11	6103	2662	4140	97	0
12	6206	3872	3696	123	2
13	6758	5223	6600	166	3
14	4752	1593	4140	102	0
Total	62,225	33,377	47,839	889	21

X_1 = Hot work permit (HWP) Total: year by year.
X_2 = Vessel Entry Permit (VEP) Total: year by year.
X_3 = Cold Work Permit (CWP) Total: year by year.
X_4 = Excavation Work Permit (EWP) Total: year by year.
X_5 = Acid Area Work Permit (AAWP) Total: year by year.
X_T = Period under review

iii. **Maintenance Model based on available data. Table 2**

$\hat{Y}_3 = \hat{\alpha} + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \hat{\beta}_3 X_3 + \hat{\beta}_4 X_4 + \hat{\beta}_5 X_5$

$\hat{Y}_i$ = Yearly total observation of VEP
X_1 = Yearly observation of Hot Work Permit (HWP) year by year total
X_2 = Yearly observation of Cold Work Permit (CWP) year by year total
X_3 = Yearly observation of Excavation Work Permit (EWP) year by year total
X_4 = Yearly observation of Acid Area Work Permit (AAWP) year by year total
X_5 = Period under review.

The α and β coefficients are unknown parameters to be estimated along with the x_i = (i = 1,2,…) independent regressors.

The parameters of the models were obtained through estimation method using the computer software programme; statistical package for social science (SPSS).

Table 3: Data used for Cost Reduction (LP) Linear Model

NNPC (CAS) **(OPERATION: STAFF ONLY) AS AT 2011**

GRADE LEVEL	CONSOLIDATED ANNUAL SALARY SCALE		NO. OF PERSONNEL		GROUP TOTAL	GROUP AVERAGE	REMARKS
	RANGE	$\bar{x}$	N	Total ($n\bar{x}$)			
DMS AND ABOVE	18.0m – 24.0m	21m	54	1134m	4641.5m	12.93m	TOP MANAGEMENT OFFICERS
SS1 (CHIEF OFFICERS)	9.0m – 14.0m	11.5m	305	3507.5m			EXPERTS
SS3 – SS2	8.0m – 12.0m	10.0m	200	2000m	4100m	8.2m	TECHNICIANS
SS7 – SS4	6.0m – 8.0m	7.0m	300	2100m			TECHNICIANS
JSS4 – JSS1 AND GRADUATE TRAINEES	1.2m – 3.6m	2.4m	540	1296m	1296m	2.4m	GRADUATE TRAINEES AND OTHERS
TOTAL NO. OF STAFF			1,399				

Remarks: Experts personnel = 359
Technicians = 500

GTS and others = 540
Total nos. of personnel 1,399

iv. **Cost Reduction (LP) Model**

$$\min \mathbf{w} = c_1x_1 + c_2x_2 + c_3x_3 \geq b_1$$
$$\text{Sjt:} \quad a_{11}x_1 + a_{12}x_2 + a_{13}x_3 \geq b_2$$
$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 \geq b_3$$
$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3$$
$$x_1,\ x_2,\ x_3, \geq 0$$

From NNPC CAS table: $(c_1,\ c_2,\ c_3,) = (12.93, 8.30, 2.40)$
(See Appendix 21)
$x_1 = 359$
$x_2 = 500$
$x_3 = 540$

c_1= 12.93
c_2= 8.30
c_3= 2.40

$$\begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} 4.64905 \\ 4.10010 \\ 1.29600 \end{pmatrix}$$

$x_1 \geq 359$
$x_2 \geq 500$
$x_3 \geq 540$
1399 total personnel

$$A = \begin{pmatrix} 89.65 & 17.7 & 39.5 \\ 36.8 & 29.5 & 19.9 \\ 59.9 & 58.7 & 66.3 \end{pmatrix}$$

Using Excel Solver (page 56-59 of Operation Research an Introduction 8th Edition by Hamdy A. Taha) after feeding necessary data, results were obtained.

IV. Results

Table 3: Summary of models result

Model	R^2	Prob. Level	F-ratio	Power test	Durbin-watson	AAPE	CAAPE
Man-hour worked for accident model (1)	0.8349	0.0172	5.899	0.8582	1.320662135	0.481	0.000015%
Maintenance model (2)	0.8852	0.0014	12.341	0.9958	2.06164561	26.548	1.11%
Man-hour lost for cost reduction model (3)	0.9410	0.0000	87.761	1.0000	1.984312607	38.493	9.86%

Table 4: Cost Reduction (LP) Model Result Using Excel Solver: Based on table 3

Global optimal solutions found			
Objective value		49448.44	
Infeasibilities		0.000000	
Total solver iterations		1	
Model class:		LP	
Total variables:	3		
Nonlinear variables	0		
Integer variables	0		
Total constraints	7		
Nonlinear constraints	0		
Total nonzero	15		
Nonlinear nonzero	0		
	Variable	**Value**	**Reduced cost**
	X1	0.000000	8.491809
	X2	0.000000	4.742211

	X3	20603.52	0.000000
	Row	**Slack or surplus**	**Dual price**
	1	49448.44	-1.000000
	2	348933.9	0.000000
	3	0.000000	-0.1206030
	4	1236413.	0.000000
	5	0.000000	0.000000
	6	0.000000	0.000000
	7	20603.52	0.000000

Actual safety cost - N23.446bn
Optimal high cost - N49.448bn

Optimal Solution - $x_1 = 0$
$x_2 = 0$
$x_3 = 2060.4$

This is optimal model solution but in reality, this is not true or feasible, because $x_1 = 0$, $x_2 = 0$.
However, in reality:

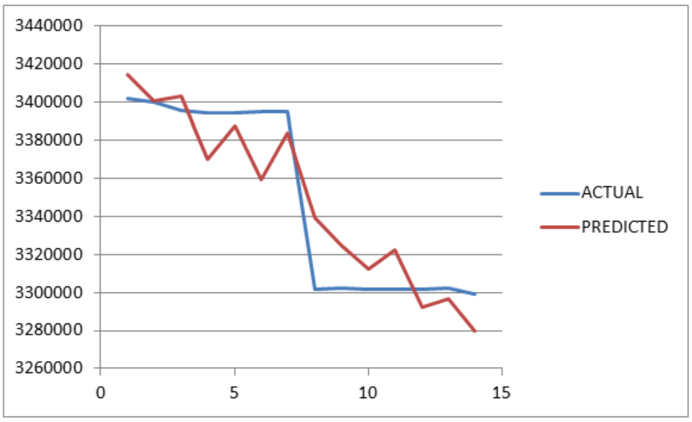
$$x_1 = 359 \quad (Experts)$$
$$x_2 = 500 \quad (Technicians)$$
$$x_3 = 540 \quad (Trainees)$$

There is the need to conduct a thorough research to determine accurate values that would be required to obtain optimal solutions. This procedure would involve investigation.
The derived models are as follows:

1. **Man-Hour Worked Model:**
$\hat{Y}_1 = 3455783.8463 - 27.5042X_1+270.3397X_2-1032.3357X_3+1335.9143X_4+5.8721X_5 -14439.0721X_6$

Table 4: Actual and Predicted values for Man-Hour Worked Model

Row	Actual C7	Predicted C7
1	3402174.000	3414486.467
2	3400249.000	3400961.402
3	3395454.000	3403013.522
4	3394598.000	3369956.087
5	3394668.000	3387586.377
6	3394826.000	3359268.347
7	3394793.000	3383448.252
8	3301585.000	3339401.674
9	3302151.000	3324974.740
10	3301693.000	3312274.108
11	3301623.000	3322452.253
12	3301667.000	3292546.297
13	3302181.000	3296854.025
14	3299336.000	3279774.449



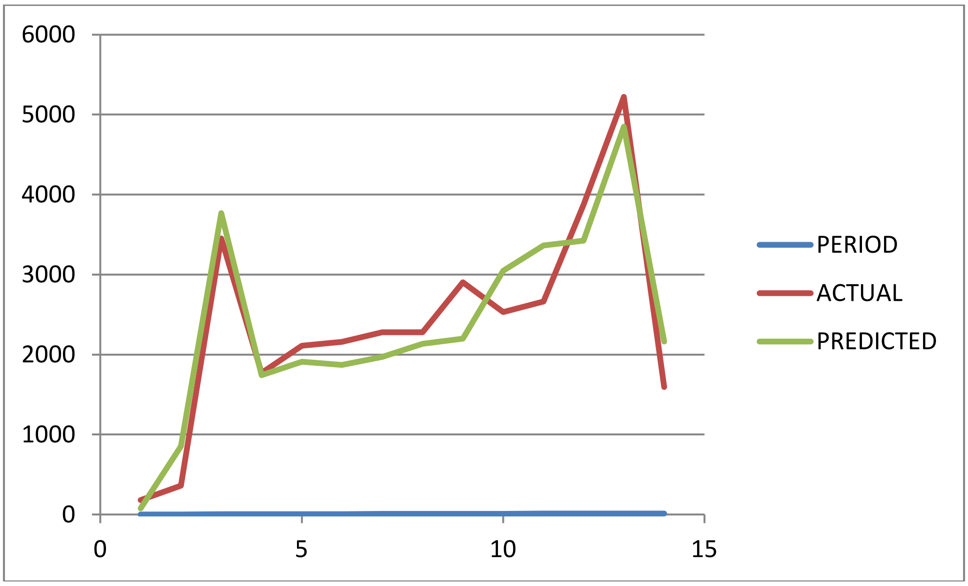
Plot of Actual and Predicted value of accident (man-hour worked) Fig. 1

2. **Maintenance Model**

$\hat{Y}_2 = 683.2055 + 0.3868X_1 + 0.1723X_2 + 26.5234X_3 - 160.684X_4 - 269.725X_5$

Table 5: Actual and Predicted values for Maintenance Model

	Actual	Predicted
Row	**C2**	**C2**
1	181	75.97
2	363	852.193
3	3450	3768.247
4	1771	1743.508
5	2112	1912.229
6	2160	1871.715
7	2279	1972
8	2277	2133.609
9	2904	2200.345
10	2530	3046.631
11	2662	3363.012
12	3872	3424.879
13	5223	4848.804
14	1593	2163.858



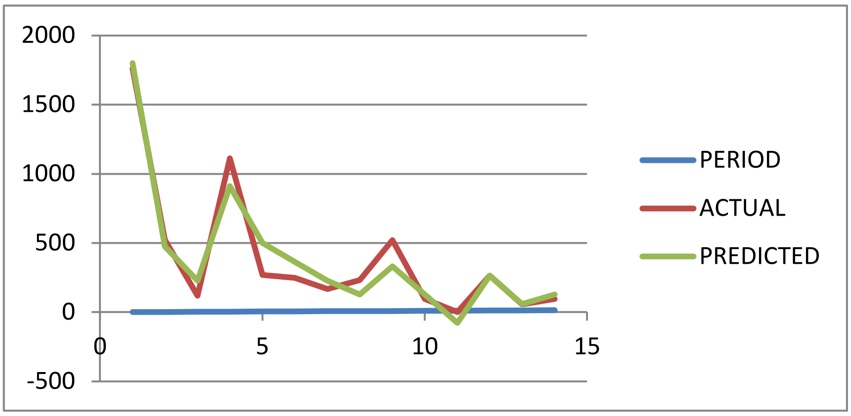
Plot of Actual and Predicted value for maintenance fig. 2

3. **Man-Hour Lost Model**

$\hat{Y}_3 = 1227.7165 + 68.4422X_1 - 0.0004X_2$

Table 6: Actual and Predicted values for Man-Hour Lost Model

Row	Actual C2	Predicted C2
1	1760.000	1799.131
2	524.000	474.697
3	120.000	227.194
4	1112.000	912.048
5	268.000	501.035
6	248.000	364.071
7	168.000	227.189
8	232.000	127.247
9	520.000	332.494
10	96.000	127.153
11	0.000	-78.213
12	264.000	264.103
13	56.000	58.699
14	96.000	127.153



Plot of actual and predicted value of man-hour lost for cost reduction model. Fig. 3

Cost Reduction Linear Programming (LP) Model

Cost Reduction (LP) Model Result Using Excel Solver

Global optimal solutions found			
Objective value		49448.44	
Infeasibilities		0.000000	
Total solver iterations		1	
Model class:		LP	
Total variables:	3		
Nonlinear variables	0		
Integer variables	0		
Total constraints	7		
Nonlinear constraints	0		
Total nonzero	15		
Nonlinear nonzero	0		
	Variable	**Value**	**Reduced cost**
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$$x_2 = 500 \quad (Technicians)$$
$$x_3 = 540 \quad (Trainees)$$

There is the need to conduct a thorough research to determine accurate values that would be required to obtain optimal solutions. This procedure would involve investigation.

V. Discussion

From the above analysis of variance the models it is established and evidently clear that the three models developed for the determination of man-hour worked w.r.t accident model, maintenance level activities and man-hour lost w.r.t cost reduction model have good prediction power and therefore good for predicting their respective purposes.

The research work has achieved its main objectives among others four (4) multivariate models was objectively built respectively (i.e. (i) Man-hour worked for Accident model (ii) Maintenance model (iii) Man-hour lost for Cost reduction model (iv) Cost Reduction (LP) Model which were empirically compared to ascertain their prediction powers and all found capable of predicting their inherent purpose.

On a general research note, however, other relevant research issues were isolated to give a broad spectrum of understanding of the research objectives and how they were fully achieved. These relevant research issues were set to choose a more robust model for predicting safety models that enhance productivity in Kaduna Refining and Petrochemical Company Limited (KRPC LTD) among others.

Moreover, in order to achieve the research objectives, some relevant and related literature were duly consulted and cited herein. The consultations of the related literatures have really acquainted the researcher of the work done so far and how he could plan for the study in order to achieve his research objectives with ease.

In a nutshell, the works of Heinrich, H.W. et al (1931) Dupont, et al (1950), Sunil, S.R. et al (2004), James T. Reason (1990), Lubnau and Okray (2004), Abdulkadir and Aguba (2006), Yaya (2006), Colin Chen, et al (2011), Siegel (2002), Meyers (2002), among others, were reviewed and mainstreamed into the study.

Furthermore, the detailed methodology for the study was clearly outlined. Data were collected through documentary method with a sample size of 14yrs. The relevant data were collected and objectively analysed using multiple regression analysis.

The data collected and used for the study were initially displayed on a table for easy access and to facilitate analysis.

The data was divided into two parts. One part was used to build the models while the other part was used to ascertain empirically their respective prediction accuracy of the various models.

The data analysis was conducted objectively and in factual manner using the tables.
Therefore, the multiple regression models built was as follows:

$$\hat{Y}_1 = 3455783.8463 - 27.5042X_1 + 270.3397X_2 - 1032.3357X_3 + 1335.9143X_4 + 5.8721X_5 - 14439.0721X_6$$
$$\hat{Y}_2 = 683.2055 + 0.3868X_1 + 0.1723X_2 + 26.5234X_3 - 160.684X_4 - 269.725X_5$$
$$\hat{Y}_3 = 1227.7165 + 68.4422X_1 - 0.0004X_2$$

Moreover, this method has satisfied all the validation and diagnostic test of goodness of fit, autocorrelation, homoscedascicity and multicollinearity. Consequently, the models was used to predict the yearly total observation of man-hour worked for accident, maintenance and man-hour lost for cost reduction mechanism in the system.

It is therefore, very important to critically examine each of the models with a view to understanding the extent of applicability of the models. This critical examination will enable us to have a detailed analysis of the models so as to explore the advantage or otherwise their prediction powers in term of goodness of fit or probability of miscalculation.

1. The multiple regression model for man-hour worked for accident model with six predictor variables has a coefficient of determination of R^2= 0.8349 or simply 83.49%.

   This implies that the six predictor variables included in the model can explain at least 83.49% of change in the yearly total observation of man-hour worked which is good enough for the model.

   In the test run, the model has predicted the yearly total observation of man-hour worked w.r.t accident for fourteen (14) years whose actual yearly total observation were already known with an Average Absolute Percent Error (AAPE) of 0.481. To express it in another form, using Coefficient of Average

   Absolute Percent Error (CAAPE), with the value of 0.000015%, implies that the model can predict yearly total observation of man-hour worked w.r.t accident in the system.

   The model prediction power was very good with R^2 of 0.8349, Probability level of 0.0172, F-ratio of 5.899, Power test of 0.8582 and Durbin-watson of 1.320662135. This implies that the model can predict total observation of man-hour worked with a CAAPE of only 0.000015% on the average.

2. The multiple regression model of Vessel Entry Permit (VEP) for maintenance with five predictor variables has a coefficient of determination of $R^2 = 0.8852$ or simply 88.52%.

   This implies that the five predictor variables included in the model can explain at least 88.52% of change in the yearly total observation of Vessel Entry permit (VEP) for maintenance activities which is good enough for the model.

   In the test run, the model has predicted the yearly total observation of maintenance activities for fourteen (14) years, whose actual yearly total observation were already known with an Average Absolute Percent Error (AAPE) of 26.548.

   To express it in another form, using the Coefficient of Average Absolute Percent Error (CAAPE), with value of 1.11%, implies that the model can predict yearly total observation of Vessel Entry Permit (VEP) for maintenance activities.

   The model prediction power is very good with R^2 of 0.8852, Probability level of 0.0014, F.Ratio of 12.341, Power test of 0.9958 and Durbin-Watson of 2.06164561. This implies that the model can predict total observation of Vessel Entry Permit (VEP) for maintenance activities with a CAAPE of only 1.11% on the average.

3. The cost reduction model as a template for reducing cost of operation in dwindling budgetary allocation in the system with two (2) predictor variables has a coefficient of determination of R^2= 0.9410 or simply 94.1%.

   This implies the two predictor variables included in the model can explain at least 94.1% of change in the yearly total observation of man-hour lost for cost reduction which is good enough for the model.

   In the test run, the model has predicted the yearly total observation of man-hour lost for fourteen (14) years, whose actual yearly total observation were already known with an Average Absolute Percent Error (AAPE) of 38.493. To express it in another form, using the Coefficient of Average Absolute Percent Error (CAAPE), with value of 9.86%, implies that the model can predict yearly total observation of man-hour lost in the production operation.

The model prediction power is very good with R^2 of 0.9410, Probability level of 0.0000, F.Ratio of 87.761, Power test of 1.0000 and Durbin-Watson of 1.98431261. This implies that the model can predict total observation of man-hour lost for cost reduction in the production operation with a CAAPE of only 9.86% on the average.

From the available values of the three (3) models, Average Absolute Percent Error (AAPE), Coefficient of Average Absolute Percent Error (CAAPE) and graph of forecast of the models, it is evidently clear that the multiple regression model has high prediction power.

4. Global optimal solutions found considering the model result obtained through the Excel solver. (See table 4)

VI. Conclusion

Objectively, this study has applied to all the laid down procedure to collect, analyse and interpret safety data for the purpose of evaluating the trend of accidents and maintenance in the system.

The outcome of the analysis has produced four (4) separate mathematical models each capable of independently predicting yearly total nos. of man-hour worked as a result of accident, maintenance and man-hour lost for cost reduction.

Conclusively, the multiple regression models should be used for predicting yearly total observation of man-hour worked resulting from accident, maintenance activities and man-hour lost for cost reduction mechanism in the system.

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