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Mathematical Approach To Estimating Passenger Freight And Income Generated By The Nigerian Railway System

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Abstract

This paper work highlights the effect of an improved railway system on the performance of the national economy. The main objective is to evaluate the relationship between railway performance and the income generated per annum in Nigeria. A substantial effect of the study involved building a regression model to predict with 90% certainty, the income that would be generated per annum in the near future. The estimation function was specified in a linear form. The adequacy of the model was then statistically tested using standard error estimates. Further test conducted was to measure the strength of the association that exists between the annual railway performance and income generated which tend to increase per annum. The study also revealed that the variation in the annual estimates of passengers and freight (the independent variables 'X') transported by rail explains the 99.9% of the variation in the income generated per annum (the dependent variable 'Y'). The paper recommends measures to improve the railway system which include the adoption of standard gauge track, provision of more coaches, wagons and high speed locomotives.

Keyword: *Railway system, National Economy, Regression Model*

Introduction

Despite the Federal government's huge expenditure on rail transport, the transport infrastructural facilities have been deteriorating on daily basis and this has impacted negatively on service delivery. And this has made the Nigerian railway transport system inefficient and hardly developed over the years compared to what is obtainable in other part of the world. As a result of this, the nation's economy has been denied the rapid growth and desired boost that is expected [1]. In the last decade, measures and policy initiatives had been invented purposely to resuscitate and revive the Nigerian railway system from a non-performing, debt-ridden entity to a dynamic, vibrant and efficient system which eventually will reduce congestion on roads and vehicle emission.

Over the years, the railway system has metamorphosed from the primitive level to a more advanced and efficient one. Paving way for a more, efficient, effective and reliable delivery of transportation services comprising both human and haulage transportation from one location to another.

Among the other modes of transportation, the economy impact of good rail transportation cannot be overemphasized. Not only is it reliable, safe, and relatively affordable, rail transportation is capable of high level of passengers, cargo utilisation and energy efficiency. [2] highlighted that rail still offers the most cost-effective solution to transportation of non-time-sensitive bulk freight on distances over 500 km.[6], [8] and [4] also highlighted the importance of density to leverage rails cost effectiveness over longer distances due to rails high fixed infrastructural

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component. The density of railroads in Africa has however decreased since the 1970's due to the increasing shift of freight traffic from rail transport to road transport [9]

In the context of freight rail transport, economies of density describe the relationship between inputs and outputs with a fixed rail network [5] or the phenomenon that an increase in traffic over a given infrastructure will be met by a less than proportionate increase in costs [7]. [3] also studied the rail transport service in Lagos metropolis with emphasis on its terminal facilities, operation, patron's perceptions and challenges. This paper aims at highlighting the importance of an efficient, effective railway system to the economic growth of a nation like Nigeria.

Data collection and Analysis

The method or the mechanism designed for the data collection was chosen based on the type of data or information required. Information and data were obtained from the Nigerian railway corporation (NRC) Minna branch office and the Federal Ministry of transportation Abuja. Data were collected on available and tractable routes, number of locomotives, number of passengers, etc.

The study used annual data pertaining to variables such as number of passengers and tonnage of freight transported yearly and the annual income generated from this operation, covering a period of 7 years i.e. from 2004-2010. These data collected reflect the effect of railway rehabilitation causing an annual increase in the number of passenger and tonnage of freight carried or transported. Time series analysis was used to detect patterns of change in statistical information over a regular interval of time, thus, an estimate for the future was obtained by projecting these patterns.

From the equation of straight line

$$Y = a + bX \qquad (1)$$

Where:

Y = estimated value of the dependent variable

X = independent variable (time in trend analysis)

a = Y – intercept (the value of Y when X=0)

b = slope of the trend line

The general trend of time series can be described using a straight line equation, thus, using least square method, the equation of the best fit is given as:

$$b = \frac{\sum XY - n\overline{X}\,\overline{Y}}{\sum X^2 - n\overline{X^2}} \qquad (2)$$

Y – Intercept of the best fit regression line,

$$a = \bar{Y} - b\bar{X} \quad (3)$$

Where;

$Y = values\ of\ the\ dependent\ variables$
$X = values\ of\ the\ independent\ variables$
$\bar{Y} = mean\ of\ the\ values\ of\ dependent\ variables$
$\bar{X} = mean\ of\ the\ values\ of\ the\ independent\ variables$
$n = number\ of\ data\ points\ in\ the\ time\ series$
$a = Y - intercept$
$b = slope$

Normally, the independent variable time is measured in years. These traditional measures of time were converted to a form that simplifies the computation through coding. Coding eliminated the problem of squaring numbers as large as 1992, 1993 and so on. The mean year is also set to null, hence the coded variable x, X is replaced by $\bar{X}$ and x by $\bar{x}$ in equation (2) and (3), setting the mean year, $\bar{x} = 0$ equations (2) and (3) becomes

$$b = \frac{\sum xY}{\sum x^2} \quad (4)$$

$$a = \bar{Y} \quad (5)$$

Discussion of Result

The performance profile which is the total estimation of the number of passengers and the magnitude of freight (in tons) transported by rail in a year and the corresponding income generated are presented in Table 1

Table 1: Total annual Estimation of Passengers, Freight and Income generated

Year	Passenger	Income generated (₦)	Freight (tonnes)	Income generated (₦)
2004	798,802	2,468,698	36,758	235,326
2005	1,285,080	3,786,110	41,495	265,651
2006	1,514,215	4,678,681	47,409	303,512
2007	1,678,700	5,188,022	52,489	336,035
2008	1,996,324	6,160,639	62,575	400,605
2009	2,050,112	6,335,871	106,00	678,612
2010	2,288,000	7,071,064	141,247	1,223,263

Source: NRC, Abuja

It can be observed that there was annual increase in the number of passengers and tonnage of freight transported from 2004-2010. This reflects a progress in the railway performance which

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could be attributed to some of the railway infrastructures which have been undergoing rehabilitation. Thus, the railway performance reflects a progress in the activity of railway as an effective mode of transportation. This progress is no doubt as a result of the rehabilitation of the railway infrastructure that is being put in place.

Time series analysis

Table 2: Least square method analysis

Year (X)	Passenger $(Y)\times10^6$	$X-\overline{X}$	(x)	(xY)	$(x)^2$
2004	0.798802	2004-2007	-3	-2.396406	9
2005	1.285080	2005-2007	-2	-2.570160	4
2006	1.514215	2006-2007	-1	-1.514215	1
2007	1.678700	2007-2007	0	0	0
2008	1.996324	2008-2007	1	1.996324	1
2009	2.050112	2009-2007	2	4.100224	4
2010	2.288000	2010-2007	3	6.86400	9
$\sum X = 14049$	$\sum Y = 11.611233$			$\sum XY = 6.479767$	$\sum X^2 = 28$

The general linear equation describing the trend of passengers transported annually is thus;

$$Y = 1.6587 + 0.2314x$$

$$Y = estimated\ annual\ number\ of\ passengers\ transported$$

$$x = coded\ time\ value$$

To estimate passengers transported for the year 2012, 2012 is converted to coded time.

Thus;

$$x = 2012 - 2007 = 5$$

Whence;

$$Y = 1.6587 + 02314(5) = 2.5843$$

This implies that about 2,815,700 passengers would be transported in year 2012. In the same manner, 3,278,500 and 4,666,900 passengers in the years 2014 and 2020 respectively were forecast. Similarly, the regression model for freight is given as

$$Y = 0.067 + 0.0163x$$

While the model for predicting income from passenger and freight transportation are respectively given as

$Y = -0.053 + 3.1145x$ and

$Y = 0.0004291 + 6.3970x$

Table 3: Summary of Income Predicted

Year	Passenger	Income generated (₦)	Freight (tonnes)	Income generated (₦)
2012	2,815,700	8,769,497.65	151,200	967,655.5
2014	3,278,500	10,157,888.25	183,800	1,176,197.7
2020	4,666,900	14,182,060.05	281,600	1,801,824.3

The estimates revealed the probability of obtaining an annual increase in the number of passenger and the tonnage of freight to be transported by railway. These forecast values will represent the expected level of services that would likely be rendered in future if the system actually maintains its trend without any statistically noticeable variation. Thus, it is relevant and logical to know the effect of this progress on the economy by making a forecast of the future estimation of the corresponding income generated from the railway operation.

However, it is important to check the reliability of the estimating equations developed by obtaining the value of the standard error of estimate, (S_e), this measures the variability of the observed values around the regression line. Thus,

$$S_e = \sqrt{\frac{\sum (Y - \bar{Y})^2}{n-2}} \qquad (6)$$

Where;

$Y = values\ of\ the\ dependent\ \text{var}\ iables$

$\bar{Y} = estimated\ values\ from\ the\ estimating\ equation\ that\ corresponds\ to\ each\ Y\ value$

$n = number\ of\ data\ po\ \text{int}\ s\ used\ to\ fit\ the\ regression\ line$

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Table 5: The standard error estimates (passenger)

Passenger (X) 10^6	Income (Y) 10^6	$\bar{Y} = 0.053 + 3.1145x$	$(Y - \bar{Y})$	$(Y - \bar{Y})^2$
0.798802	2.468698	2.434858	0.03384	0.001145
1.255080	3.786110	3.855947	-0.069837	0.004877
1.514215	4.679681	4.663023	0.016658	0.000277
1.678700	5.188022	5.175311	0.012711	0.000162
1.996324	6.169639	6.164551	0.005088	0.000026
2.050112	6.335871	6.332073	0.003798	0.000014
2.288000	7.071064	7.072976	-0.001912	0.000004
				$\sum\left(Y - \bar{Y}\right)^2 =$ 0.006505

Therefore, (S_e) = 0.036069, which implies that the standard error estimate is ₦ 36,069

Assuming that the observed points are normally distributed around the regression line, we can apply prediction intervals by using the t-distribution.

This is expressed as $\bar{Y} \pm t(S_e)$,

The predicted results of the income are shown in Table 7

Table7: Summary of Result of Income predicted

Year	Passengers	Predicted income interval (₦)	Freight (tonnes)	Predicted income interval (₦)
2012	2,584,300	8,821,819.13	134,900	968,338.78
		8,611,176.17		966,972.22
2014	3,278,500	10,263,209.73	151,200	1,176,880.98
		10,052,566.77		1,175,514.42
2020	4,666,900	14,376,738.57	281,600	1,801,141.02
		14,376,738.57		1,802,507.58

From the results above, it is 90% certain that the annual expected income that will be generated from both passengers and freight transportation for the years 2012, 2014 and 2020 will fall between the corresponding predicted income interval respectively.

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Correlation Analysis

Using correlation analysis, we can measure the strength of the association that exist between the annual estimates of passengers transported 'X' and the annual income generated 'Y'

Table 8 Correlation Analysis (Passenger and Income)

Year	Passenger $(X*10^6)$	Income $(Y*10^6)$	$\left(Y-\bar{Y}\right)$	$\left(Y-\bar{Y}\right)^2$	$\left(Y-\bar{y}\right)$	$\left(Y-\bar{y}\right)^2$
2004	0.798802	2.468698	0.03384	0.001145	-2.631202	6.923224
2005	1.255080	3.786110	-0.069837	0.004877	-1.313790	1.726044
2006	1.514215	4.679681	0.016658	0.000277	-0.420219	0.176584
2007	1.678700	5.188022	0.012711	0.000162	0.088122	0.007765
2008	1.996324	6.169639	0.005088	0.000026	1.069739	1.144342
2009	2.050112	6.335871	0.003798	0.000014	1.235971	1.527624
2010	2.288000	7.071064	-0.001912	0.00004	1.971164	3.885488
				$\sum\left(Y-\bar{Y}\right)^2 =$ 0.006505		$\sum\left(Y-\bar{y}\right)^2 =$ 15.391071

Sample coefficient of determine $r^2 = 1 - \frac{\sum (Y-\bar{Y})^2}{\sum (Y-\bar{y})^2} = 0.999$

The sample coefficient of determination is therefore 0.999. This implies that the regression line representing our estimating equation to predict the future incomes estimates to be generated particularly for 2012, 2014, and 2020 respectively is a perfect estimator.

Hence the coefficient of correlation $r = \sqrt{r^2} = 0.9$

This indicates a direct relationship between the annual estimates of passengers transported per annum and the amount of income generated per annum. In other words, the more the passengers transported by rail in a year, the more the income generated and vice versa.

Using the same analysis, the strength of the association that exists between the annual tonnage of freight hauled by rail and the annual estimates of income generated can be measured. The annual freight in tonnes hauled and income generated per annum are denoted by the independent variable 'X' and the dependent variable 'Y' respectively

Conclusion

This paper has examined the present state of the Nigeria railway transportation which encompasses the rail inventory and the present railway performance profile. It also evaluates the relationship between railway performance and the income generated per annum.

The paper predicts with 90% certainty the annual estimates of passengers for the years 2012, 2014 and 2020to be 2,815,700, 3,278,500, 4,666,990 passengers respectively. This would generate a corresponding annual income of ₦8,769,497.65, ₦10,157,888.25 and ₦14,182,060.05 respectively. The tonnages of freight to be transported per annum for those same years are 134,900, 151,200 and 281,600 with corresponding income of ₦967,655.5, ₦1,176,197.7 and ₦1,801,824.3 per annum respectively.

However, the result proved that the variation in the annual estimates of passengers and freight (the independent variables 'X') transported by rail explains the 99.9% of the variation in income generated per annum (the dependent variable 'Y'). Thus, indicating a strong correlation between the variables. This paper confirmed that the annual estimates of passengers and freight transported by rail across the nation will increase in the near future with a yearly accompanied increase in the annual income to be generated. Hence, an improved railway system would contribute significantly to the transport share of the national income generated by a nation. This will no doubt represent a tangible boost to the growth of the nation's economy.

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