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Enhancing Accuracy and Consistency in the Valuation of Plant and Equipment through Cubic Regression Models of Physical Deterioration

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Abstract

The valuation of plant and equipment often involves valuers deducting physical, functional, and economic depreciation from replacement cost estimates. Accuracy and consistency problems have plagued these calculations in determining the amount of physical deterioration to deduct. This study attempted to develop cubic regression models to resolve these accuracy and consistency problems in one industrial sector (the basic metal, iron and steel and fabricated metal product sector) in the two main industrial cities of the western zone of Nigeria (Sango Ota and Agbara). Questionnaires were administered to senior operators of plant and equipment in this sector to draw information on the degree of physical deterioration of plant and equipment over their service lives, using expenditure on repairs as a proxy for physical deterioration. The questionnaire sought information on the service lives of plant and equipment, the movement of the transition of physical depreciation over the service lives, and the degree to which various operational factors influence the movement of the transition. Data were analysed using mean, standard deviation, multiple linear regression, and cubic regression to produce what could be the first potentially accurate and consistent valuation model of physical deterioration in Africa. The service lives of various plants and equipment in selected sectors were found to range at various time points between 8 and 60 years. Cubic regression analyses showed that the pattern of the movement of expenditures on repairs (a proxy for physical deterioration) over the useful life of plants and equipment was not linear but cubic and generally followed S-shaped patterns. Multiple regression analyses showed that the S-shaped patterns were in turn influenced by operational factors (such as intensity of use

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and power outages). The study concluded that valuers' interests in accuracy and consistency in plant and equipment valuation were not served by any of the accounting methods hitherto used by valuers; accuracy in physical deterioration modelling follows an S-shaped transition over time. This S-shape is exuberated where there is inappropriate operational use of the plant and equipment.

Keywords: *plant and equipment, physical deterioration, service lives, pattern of physical deterioration*

1. Introduction

Professional services of an Estate Surveyor and Valuer are often required to determine the value of plant and equipment assets. Theoretically, in carrying out this valuation task, the five valuation methods (comparison, investment, replacement cost, profits, and residual methods) can be adopted. However, plant and equipment assets are often specialised assets. Specialised assets are 'property that is rarely, if ever, sold in the market, except by way of sale of the business or entity of which it is part, due to the uniqueness arising from its specialised nature and design, its configuration, size, location, or otherwise' (Royal Institute of Chartered Surveyors, 2005 3.2 p. 5; Plimmer and Sayce, 2006). The specialised nature of plant and equipment assets implies that the method of valuation that is most appropriate is Depreciated Replacement Cost (DRC). (International Valuation Standards, 2017). Depreciated Replacement Cost (DRC) is 'the current cost of reproduction or replacement of an asset less deductions for physical deterioration and all relevant forms of obsolescence and optimisation' (Ogunba, 2013 p. 73).

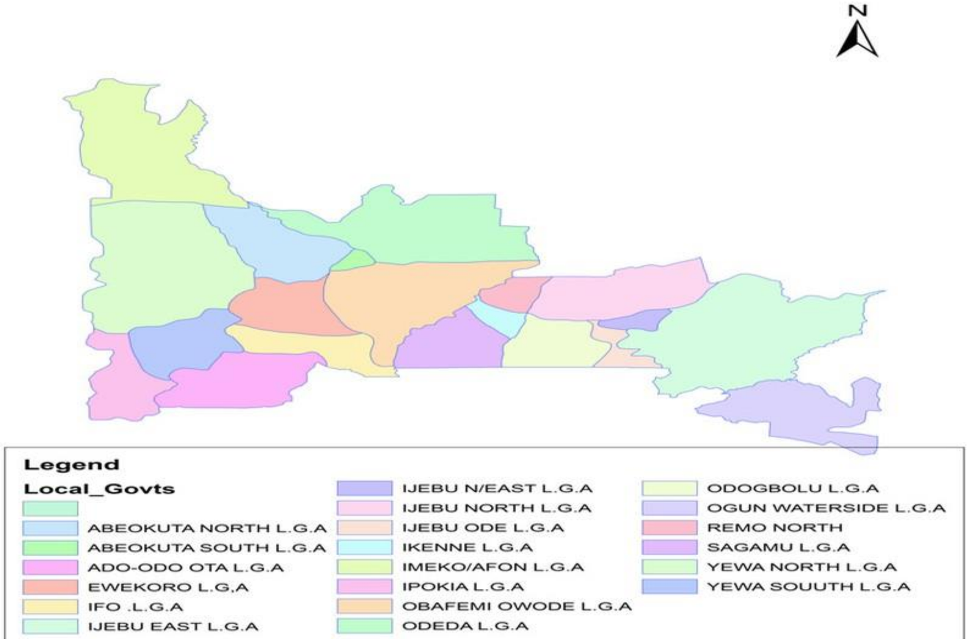
Depreciation, from the viewpoint of valuation standards, means a loss of value in a property/asset due to three types of deterioration: physical deterioration, economic obsolescence, and functional obsolescence. Physical deterioration is a situation where an asset (building or plant and equipment) suffers a reduction in value due to age, wear, and tear. Functional obsolescence in plant and equipment valuation is a loss in value of an asset caused by advances in technology that result in cheaper and more efficient plant and equipment assets than the one being valued. Economic obsolescence is a loss in value of an asset resulting from changed economic conditions that reduce the capacity utilisation of the asset being valued (Ogunba, 2013). A typical plant and equipment valuation involves the valuer determining the replacement cost of the plant and equipment asset, and then making deductions for physical deterioration, functional obsolescence, and economic obsolescence.

Experience has shown that the inaccuracy problem that usually occurs in plant and equipment valuation is not with the determination of replacement cost but with the quantum of deductions for physical deterioration, functional obsolescence, and economic obsolescence. Valuation is often viewed as both an art and a science. It is an art to the extent that it requires the use of a valuer's skill, judgement, and experience. However, it is also a science because it requires the valuer to use scientific modelling of the behaviour of property market participants in determining the values they would place on buildings, plants, and equipment. One implication of being an art is that valuations might never be exactly consistent (in terms of the valuations of different valuers tallying) or accurate (in terms of valuations being a true reflection of price or worthwhileness). Even where valuers have access to the same replacement cost data and operate contemporaneously, the use of judgement to determine the quantum of depreciation or using judgement to select from different models purporting to estimate the quantum of depreciation (where each model has different assumptions) would result in inaccuracy and inconstancy. Appraisers in the United States do not face the problem of accurate or consistent determination of functional and economic obsolescence, because the determination of functional and economic obsolescence has been scientifically modelled and documented in their standard textbook - 'the Appraisal of Real Estate' (Ogunniyi and Ogunba, 2019). Valuers in other parts of the world may consider adopting or modifying such models without seeking to, as it were, 'reinvent the wheel'.

One is not aware of any standard models for the valuation of the physical deterioration (wear and tear of assets) aspect of depreciation even in the United States. Rather, it appears that across the world, a variety of models have been put forward (and are in use) on how to measure the physical deterioration of assets. These include estimated percentage depreciation (Shapiro, Mackmin, and Sams, 2012), and several models borrowed from the field of financial accounting including accelerated methods such as the sum of the year's digit and reducing balance; the straight-line method; and the decelerated methods such as the sinking fund model. However, these financial accounting depreciation models have divergent assumptions about how physical deterioration is patterned over the service life of an asset. For instance, as Ogunba (2013) states, the straight-line depreciation model writes off the value of an asset at a constant rate throughout the useful life of the asset, while the reducing balance and sum of year's digit depreciation models assume higher depreciation at the early stage of the service life of an asset and a decreased depreciation at the later service life of the asset. The sinking fund depreciation model assumes a higher depreciation in the later years of an asset. On the other hand, the estimated percentage depreciation method (which is in popular use in African countries like Nigeria and Ghana) is not based on any definable assumptions or scientific modelling but relies on the valuer's skill, experience, and judgement. The accuracy of all these models in terms of reflecting the pattern of wear and tear of plant and equipment assets over service life is questionable (Aluko, 2007).

The pursuit of accuracy and consistency requires that valuation moves more in the direction of science than in the direction of art. Science requires the valuer to use scientific modelling of the behaviour of property market participants in determining the values they would place on assets. This study seeks to enhance accuracy and consistency in the valuation of plant and equipment through the development of polynomial regression models of physical deterioration.

Figure 1: Industrial Zones in Ogun State, Nigeria



Researchers use Nigeria to study how an African country can develop models to enhance its valuation practice. The locational scope of the study is the western industrial zone of Nigeria, and the subject scope is plant and equipment in the basic metal, iron steel, and fabricated metal product sectors. The paper is structured into six sections. The first section introduces the paper, outlining the problem and the aim of the paper. The second section provides a review of relevant literature. In the third section, a methodology is provided, while the results and discussion are the focus of the fourth section. The fifth section demonstrates the usage of the models developed, while the sixth concludes the paper and provides recommendations.

2. Review of Literature

The review of literature is focused on selected empirical papers that have examined depreciation patterns of plant and machinery over their service lives and related assets like buildings. This is due to the dearth of studies in this area.

Evidently, an assessment of previous studies on service life and the pattern of physical deterioration is paramount. In this regard, there have been few studies that examined the service lives of assets. For example, Sahu, Narang, Sahu & Sahu (2016) estimated the economic life of machines for use in the depreciation-replacement model and presented a straight-line depreciation method which could be used to determine the economic life of productive plant and equipment. However, given several studies which suggest that an S-shape pattern is more typical of asset depreciation, a straight-line model might not accurately represent the movement of the pattern of wear and tear over useful life. Moreover, the studies did not consider the influence of operational factors on the service life of plant and equipment. Koumanakoos and Hwang (1988) examined the forms and rate of economic depreciation of selected assets in the manufacturing and non-manufacturing sectors in Canada using the Hulten and Wykoff Box-Cox depreciation model. The researchers found that most assets have convex depreciation functions. The price-age behaviour of some assets was found to be volatile. Manufacturing industries had convex depreciation functions close to the geometric form for both buildings and plant and equipment with only a few exceptions. In non-manufacturing industries also, depreciation functions were of the convex geometric form, but with a less pronounced convexity in building construction than in plant and equipment. However, these findings were different from Sahu et al. (2016).

Related studies focused on the depreciation models adopted by valuers when valuing assets. Such studies include Wu and Perry (2004). The authors estimated farm equipment depreciation to ascertain which functional form is best for forecasting equipment depreciation. Observations were gathered from 16 years of auction sales (1984 to 1999) for 17 types of equipment, including tractors, combines, corn headers, balers, cotton harvesters, forage harvesters, mower-conditioners, mower-cutters, swathes, discs, ploughs, drills, planters, manure spreaders, skid steer loaders, and pickup trucks. According to the authors, the Box-Cox functional form allows for flexible changes in depreciation rates, which can be either positive, negative, or both. The changes were sometimes linear and sometimes decelerated in conformity with the Sum of the Years Digits. Plimmer and Sayce (2006) examined the methodology adopted by UK valuers when using the depreciated replacement cost (DRC) method in the valuation of building assets, with a view to creating a more consistent method for valuers to adopt. It was noted that DRC valuations were based on a variety of depreciation methods, resulting in a yearly variation in valuation estimates. The paper indicated that yearly variation should be the result of market-based factors rather than variation in the methods of valuing depreciation. The study also suggested that valuers require some form of guidance to ensure consistency in valuation output. However, the study was focused on buildings, not on plant and equipment.

A group of studies (Ogunba 2011; Bello 2014; Bello, Ogunba and Adegunle 2015; Ogunniyi and Ogunba, 2019) examined the choice of depreciation model valuers adopt in DRC valuation for buildings, perceptions of valuers on the accuracy and consistency of depreciation measurement, and the appropriateness of the depreciation approaches used by valuers in the depreciated replacement cost method of valuation of buildings. The authors found that cross-sectional models, breakdown models, and the S-curve model were the most rated depreciation models suitable for depreciation measurement. The use of depreciation measurement showed significant inaccuracy and inconsistency, particularly regarding estimated percentage depreciation. These studies found that an S-shaped pattern was the most accurate for estimating physical deterioration of buildings. However, instead of using this pattern, an estimated depreciation valuation, which was found to be inaccurate, inconsistent, and unable to differentiate between depreciation components, was predominantly applied. However, these studies were on buildings and not plant and equipment. Ogunniyi and Ogunba (2019) attempted to model plant and machinery in Osogbo, a state capital in Nigeria. They sampled machine operators in Osogbo to determine the physical deterioration trends of plant and equipment. These trends were then developed into physical deterioration models using log transformations. However, their study was focused on manufacturing companies in Osogbo, which is not an industrial city, meaning that only small-scale manufacturing companies could be sampled. Moreover, the use of log transformation regressions produced straight-line regression equations that did not reflect the wear and tear patterns suggested in their scatter diagrams. Moreover, the influence of operational factors on the physical deterioration models produced was not included in the analysis, which could lead to underestimations of the quantum of deterioration.

Overall, five gaps were discovered in the review of the literature. First, some of the papers focused on the use of DRC to value buildings rather than plant and machinery. For valuation purposes, it is unlikely that the pattern of physical deterioration (wear and tear) observable for buildings is necessarily the same as the pattern for plant and machinery. Second, some papers did not focus on the situation in African countries. It is necessary for research to have a separate look at the situation in Africa, where the wear and tear pattern might be exuberated by harsher operational factors. The third gap is that some papers stopped at criticising the accuracy and consistency of depreciation models in popular use but did not embark on model development. Fourth, the few papers that looked at model development used linear regression or log transformations. Linear regression and log transformations are linear approximations of scatter diagram patterns which inadvertently obscure the patterns of wear and tear. What is required is the modelling of non-linear regression relationships (polynomial regression model). This would better capture the actual pattern of wear and tear on plant and equipment. Fifth, papers that developed models of physical depreciation did not consider the influence of operational factors on the models they developed. For example, if the same type of plant is purchased for use in the United States and another in Nigeria, each one may encounter distinct operational conditions, such as frequency of power outages and frequency of maintenance. Consequently, they may experience varying degrees of physical deterioration (wear and tear). Therefore, the influence of operational factors should be included in modelling for greater accuracy.

3. Methodology

The use of plant and equipment in Sango Ota and Agbara (two of Nigeria’s foremost industrial towns located in Nigeria’s western industrial zone state) is used as a case study to demonstrate how physical deterioration modelling can enhance accuracy and consistency. The study focused on plant and equipment in the basic metal, iron and steel and fabricated metal product sectors. Discussions with officials of the Manufacturers Association of Nigeria (MAN) and reference to the association’s directory (MAN, 2019) showed that there are thirty-seven manufacturing companies registered under the basic metal sector in Ogun State, Nigeria.

The intent of the study was to measure the pattern of physical deterioration (pattern of wear and tear) for each plant and equipment in this sector every two years until the end of their respective useful lives. The study adopted a quantitative (cross-sectional survey) design to model the path or movement of expenditure on wear and tear over plant and equipment service life rather than a longitudinal design. This is because an earlier study (Ogunba, 2011) had shown that a longitudinal survey would be impracticable for a study of this nature; it would have to span the entire service life of each plant and equipment. The study population appropriate for providing information on wear and tear costs were the most senior operators of the plants and machines in the thirty-seven companies. Questionnaires were accordingly self-administered on a cross-section of senior (most experienced) plant and equipment operators in the employ of manufacturing companies in the metal sector of the two most industrialised cities of the western industrial zone of Nigeria. The findings were analysed using polynomial (cubic) regression rather than linear regression so as not to obscure the accurate pattern of wear and tear.

The measurement of wear and tear was operationalised by measuring the yearly expenditure on repairs and maintenance for each plant/equipment captured every two years over the plant/equipment's service life. A pilot survey conducted in October 2021 indicated that there are nine types of plants and twenty-five types of equipment (machines) common to companies in this sectoral group. The measurement of wear and tear costs was done for each of these items of plant and equipment.

The procedure was to first inquire into the plant and equipment that are common to the thirty-seven manufacturing companies in the industrial sector and ascertain the service life of each item of plant and equipment for the purpose of determining the average service life. Next, the study investigated the pattern of physical deterioration over useful life, operationalised by measuring yearly expenditure at two-year intervals. The next step was to investigate operational factors that could increase or decrease the pattern of expenditure on repairs and maintenance. Finally, the study demonstrated the use of the model for readers of the paper and for plant and equipment valuers. The method of physical deterioration considered to be most appropriate for modelling non-linear regression relationships is polynomial regression. The alternative approach sometimes used for non-linear regression, namely log transformations, as used by Ogunniyi and Ogunba (2019), was discounted because it produces a linear relationship. Polynomial regression finds an equation that produces a curved line that closely fits the scatter plot lines. The curved lines are produced using an equation where the independent variables are raised to powers such as X^2 and X^3, depending on the number of inflections (bends). Where there is one bend in the regression line, a squared term (that is, a polynomial of degree two) is added to the independent variables. The polynomial regression equation is described as quadratic and takes the form.

$$Y = a + b_1X_1 + \dots + b_2X^2 \dotfill (1)$$

Where there are two bends in the line, the polynomial regression equation is described as cubic and takes the form:

$$Y = a + b_1X_1 + \dots + b_4X^4 \dotfill (2)$$

The R^2 results in the regression equation show the degree to which the independent variables explain the variation in the dependent variable. The p values show the degree of reliability of the alpha and beta coefficients. Generally, where p values are below 0.05, the results could be considered reliable, whereas when the p values are above 0.05, the results would have to be interpreted with caution.

4. Results and Discussion

The questionnaire was self-administered to senior operators in the basic metal, iron and steel, and fabricated metal product sectors in the two cities of Sango-Ota and Agbara in the last months (October to December) of 2021. The responses were analysed in the months of February and March 2022 using SPSS software.

As earlier stated, at the first level of inquiry, the study identified the plant and equipment that are common to the thirty-seven manufacturing companies in the industrial sector and investigated their respective mean service lives. The findings are documented in Table 1.

Table 1: Service Lives of Plant & Equipment in Basic Metal, Iron and Steel and Fabricated Metal Product Sectoral Group

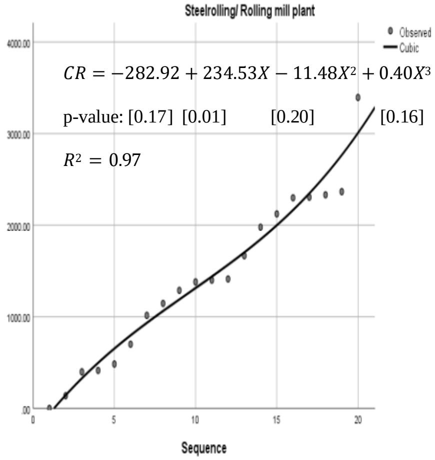
Plant	Mean of Service life	Standard deviation of service lives	Equipment	Mean of Service life	Standard deviation of service lives
Steel rolling/ Rolling mill plant	20	0	Straightening machine	15	5.77
Cutting plant	10	0	Blowers	60	0
Aida plant	10	0	Welding machine	23	1.73
Tube mill plant	10	0	Boiler	22	4.04
Water circulation/treatment Plant.	8	0	Compressor	28	11.5
Aluminium coil plant	13	1	Water circulation	36	5.29
			Corrugating machine	40	0
			Embossing machine	36	0
			Lathe Machine	45	0
			Crown making machine	20	0
			Industrial drilling machine	35	0
			Overhead crane/Fork lift	27	0
			Uncoilers	40	0
			Line motors, gear box, drivers	60	0
			Grinding machine	60	0
			Hydraulic machine	29	0
			Hard Diamond / Cutting machine	10	0
			Reversible cold rolling mill	30	0
			Reversible hot rolling mill	34	0
			Billet and slab casting machine	60	0
			Continuous casting machine	60	0
			Stagger blanking machine	60	0
			Melting and holding furnace	35	0
			Slitting line	60	0

	Flat line	60	0

Source: Field survey, 2021

From the data gathered, it was observed that the estimated service life of plants such as steel rolling/rolling mill plants, steel rolling/rolling mill plants, cutting aida and tube mill plants, aluminium coil plant and water circulation/treatment plant in the basic metal sector ranged from 8 to 20 years (standard deviations of 0 to 1), with the most typical service life (being 10 years standard deviations of 0). The mean service lives of equipment ranged from 15 to 60 years (standard deviations of 0 to 11.5 years), with the most typical service life being 60 years with standard a deviation of 0. These results largely conform with the service lives found in the study of Ogunniyi and Ogunba (2019).

Having identified the common plant and equipment and determined the service lives, the next level of inquiry was to investigate the pattern of physical deterioration of each item of plant and equipment over the service life. This was achieved by asking the senior operators in the thirty-seven companies to indicate their annual expenditure on repairs and maintenance of each plant/equipment every two years until the end of their service life. The data obtained were averaged and based on observation of scatter diagrams, model development was based on polynomials rather than linear or log regression. The results are depicted in Figures 2 to 28.

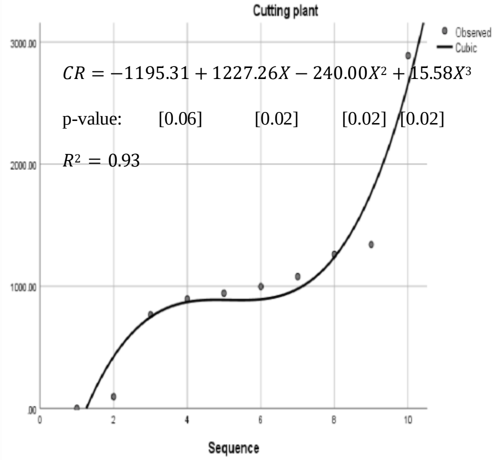


$CR = -282.92 + 234.53X - 11.48X^2 + 0.40X^3$

p-value: [0.17] [0.01] [0.20] [0.16]

$R^2 = 0.97$

Figure 2: Physical Deterioration of Steel rolling/ Rolling mill plant

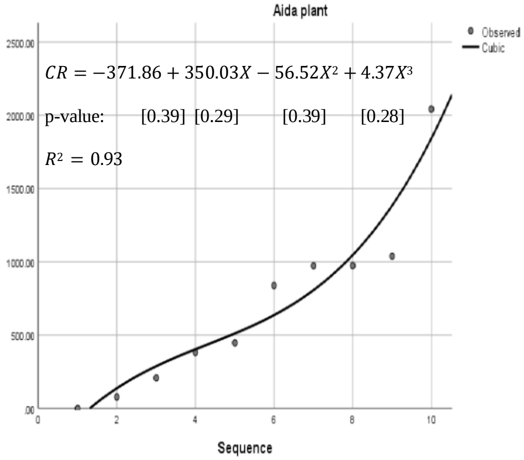


$CR = -1195.31 + 1227.26X - 240.00X^2 + 15.58X^3$

p-value: [0.06] [0.02] [0.02] [0.02]

$R^2 = 0.93$

Figure 3: Physical Deterioration of Cutting plant

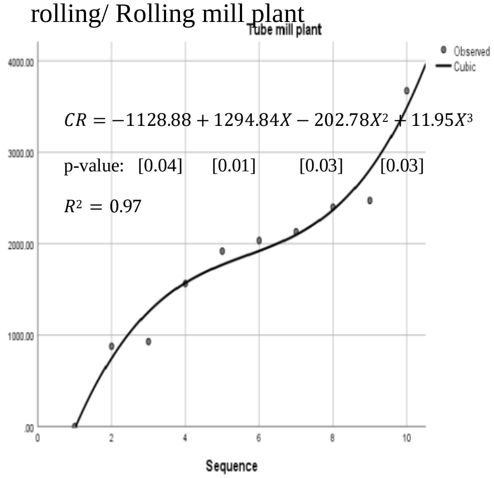


$CR = -371.86 + 350.03X - 56.52X^2 + 4.37X^3$

p-value: [0.39] [0.29] [0.39] [0.28]

$R^2 = 0.93$

Figure 4: Physical Deterioration of Aida plant

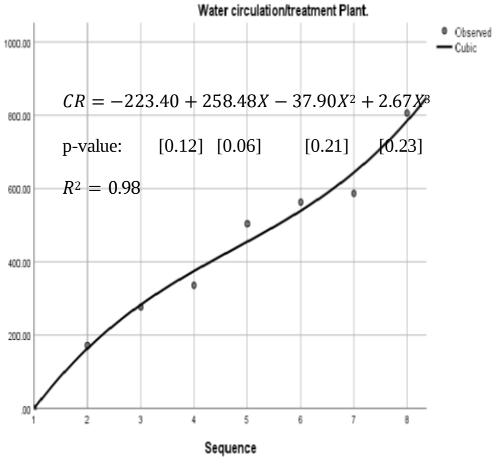


$CR = -1128.88 + 1294.84X - 202.78X^2 + 11.95X^3$

p-value: [0.04] [0.01] [0.03] [0.03]

$R^2 = 0.97$

Figure 5: Physical Deterioration of Tube mill plant

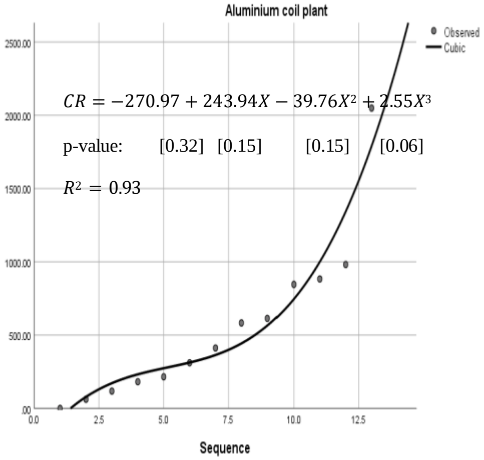


$CR = -223.40 + 258.48X - 37.90X^2 + 2.67X^3$

p-value: [0.12] [0.06] [0.21] [0.23]

$R^2 = 0.98$

Figure 6: Physical Deterioration of Water circulation/treatment plant

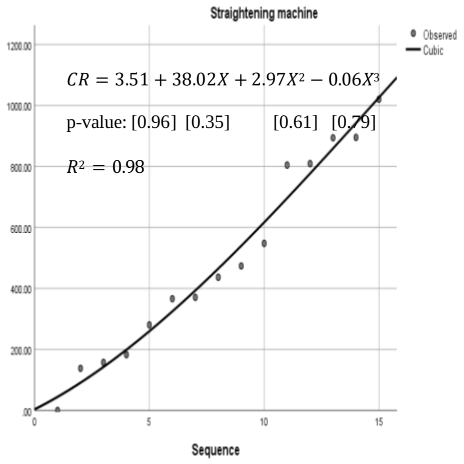


$CR = -270.97 + 243.94X - 39.76X^2 + 2.55X^3$

p-value: [0.32] [0.15] [0.15] [0.06]

$R^2 = 0.93$

Figure 7: Physical Deterioration of Aluminium coil plant

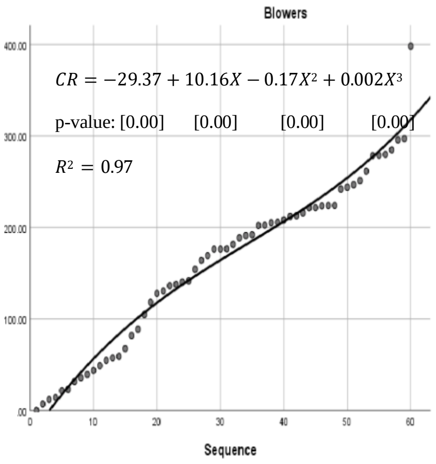


$CR = 3.51 + 38.02X + 2.97X^2 - 0.06X^3$

p-value: [0.96] [0.35] [0.61] [0.79]

$R^2 = 0.98$

Figure 8: Physical Deterioration of Straightening machine

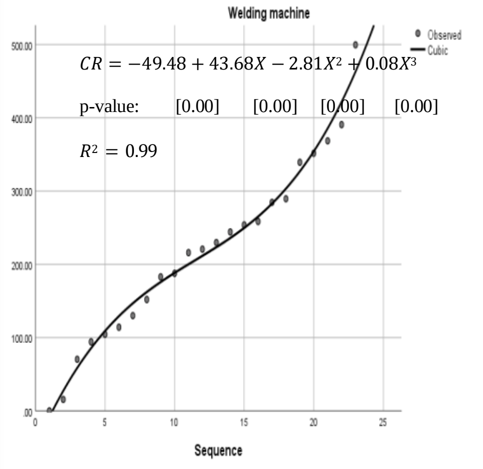


$CR = -29.37 + 10.16X - 0.17X^2 + 0.002X^3$

p-value: [0.00] [0.00] [0.00] [0.00]

$R^2 = 0.97$

Figure 9: Physical Deterioration of Blowers

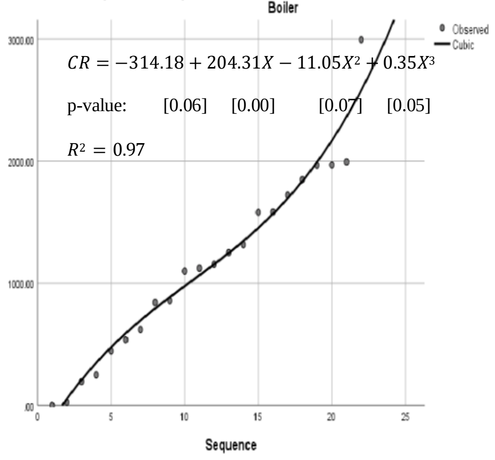


$CR = -49.48 + 43.68X - 2.81X^2 + 0.08X^3$

p-value: [0.00] [0.00] [0.00] [0.00]

$R^2 = 0.99$

Figure 10: Physical Deterioration of Welding machine

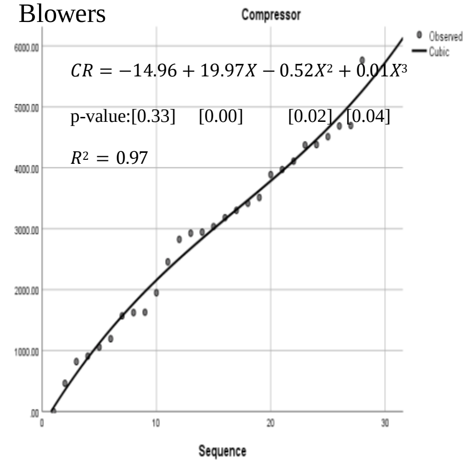


$CR = -314.18 + 204.31X - 11.05X^2 + 0.35X^3$

p-value: [0.06] [0.00] [0.07] [0.05]

$R^2 = 0.97$

Figure 11: Physical Deterioration of Boiler

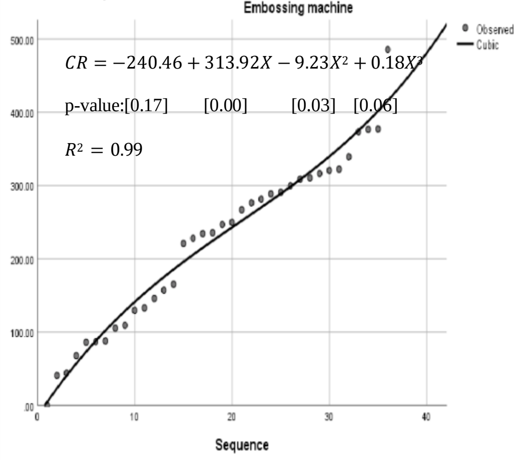


$CR = -14.96 + 19.97X - 0.52X^2 + 0.01X^3$

p-value:[0.33] [0.00] [0.02] [0.04]

$R^2 = 0.97$

Figure 12: Physical Deterioration of Compressor

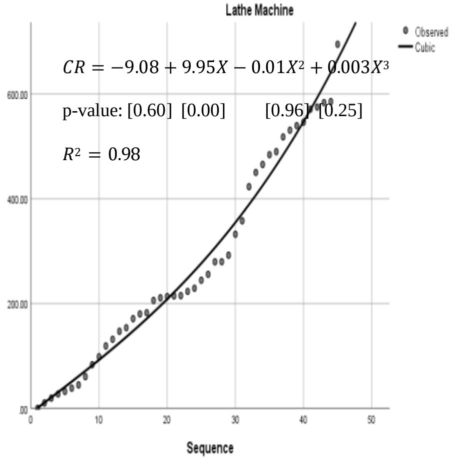


$CR = -240.46 + 313.92X - 9.23X^2 + 0.18X^3$

p-value:[0.17] [0.00] [0.03] [0.06]

$R^2 = 0.99$

Figure 13: Physical Deterioration of Embossing machine

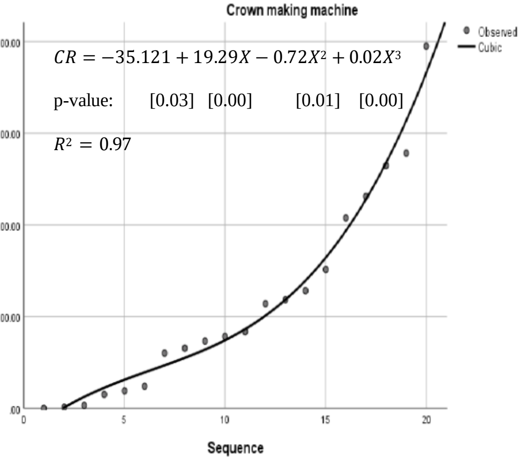


$CR = -9.08 + 9.95X - 0.01X^2 + 0.003X^3$

p-value: [0.60] [0.00] [0.96] [0.25]

$R^2 = 0.98$

Figure 14: Physical Deterioration of Lathe Machine

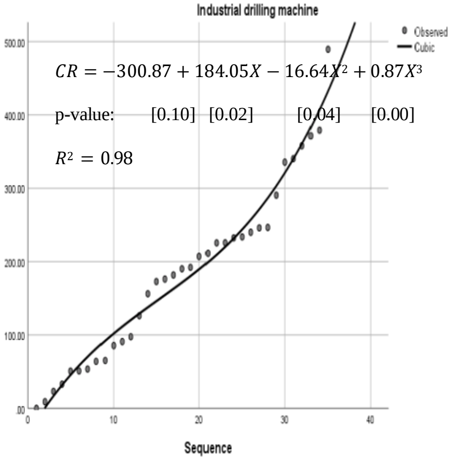


$CR = -35.121 + 19.29X - 0.72X^2 + 0.02X^3$

p-value: [0.03] [0.00] [0.01] [0.00]

$R^2 = 0.97$

Figure 15: Physical Deterioration of Crown making machine

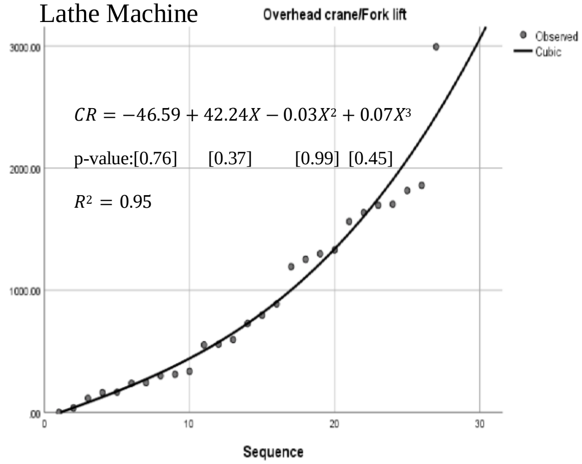


$CR = -300.87 + 184.05X - 16.64X^2 + 0.87X^3$

p-value: [0.10] [0.02] [0.04] [0.00]

$R^2 = 0.98$

Figure 16: Physical Deterioration of Industrial drilling machine

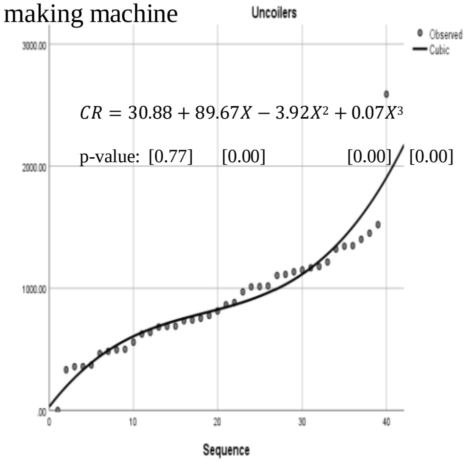


$CR = -46.59 + 42.24X - 0.03X^2 + 0.07X^3$

p-value:[0.76] [0.37] [0.99] [0.45]

$R^2 = 0.95$

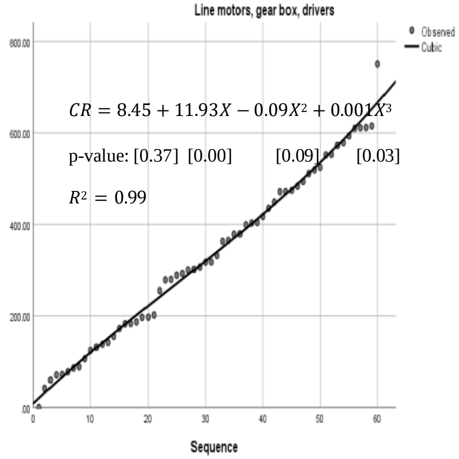
Figure 17: Physical Deterioration of Overhead crane/Fork lift



$CR = 30.88 + 89.67X - 3.92X^2 + 0.07X^3$

p-value: [0.77] [0.00] [0.00] [0.00]

Figure 18: Physical Deterioration of Uncoilers

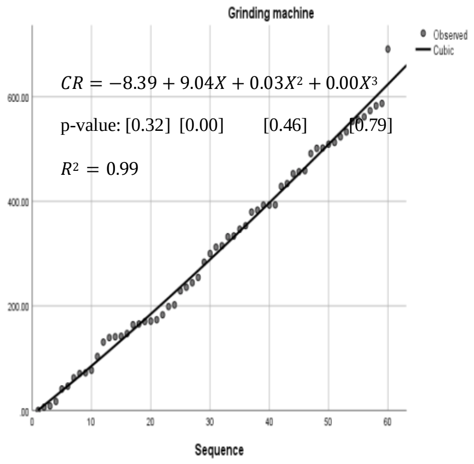


$CR = 8.45 + 11.93X - 0.09X^2 + 0.001X^3$

p-value: [0.37] [0.00] [0.09] [0.03]

$R^2 = 0.99$

Figure 19: Physical Deterioration of Line motors, gear box, drivers

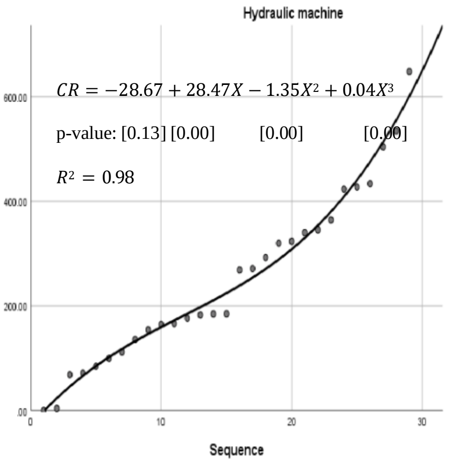


$CR = -8.39 + 9.04X + 0.03X^2 + 0.00X^3$

p-value: [0.32] [0.00] [0.46] [0.79]

$R^2 = 0.99$

Figure 20: Physical Deterioration of Grinding machine

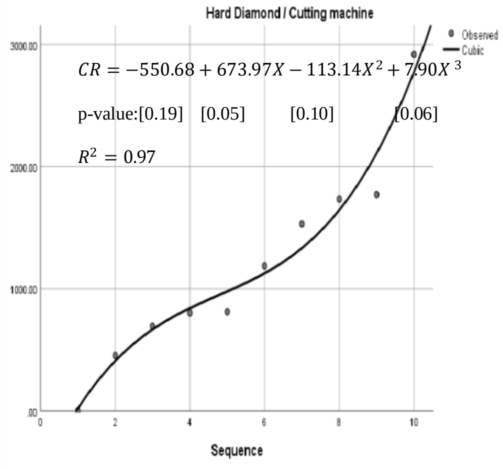


$CR = -28.67 + 28.47X - 1.35X^2 + 0.04X^3$

p-value: [0.13] [0.00] [0.00] [0.00]

$R^2 = 0.98$

Figure 21: Physical Deterioration of Hydraulic machine

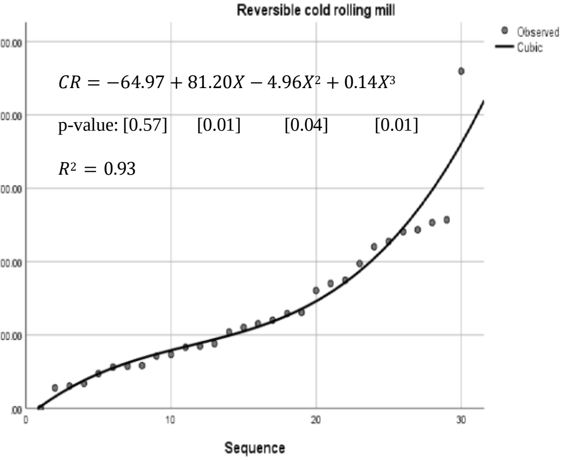


$CR = -550.68 + 673.97X - 113.14X^2 + 7.90X^3$

p-value:[0.19] [0.05] [0.10] [0.06]

$R^2 = 0.97$

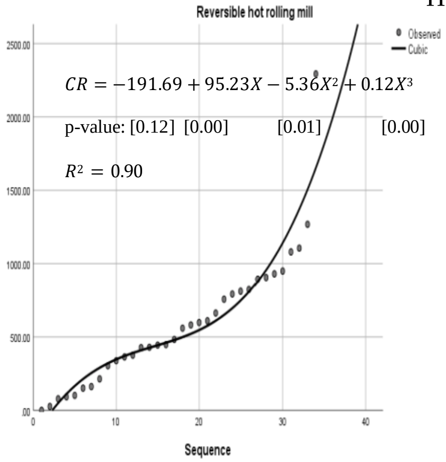
Figure 22: Physical Deterioration of Hard Diamond / Cutting machine



$CR = -64.97 + 81.20X - 4.96X^2 + 0.14X^3$

p-value: [0.57] [0.01] [0.04] [0.01]

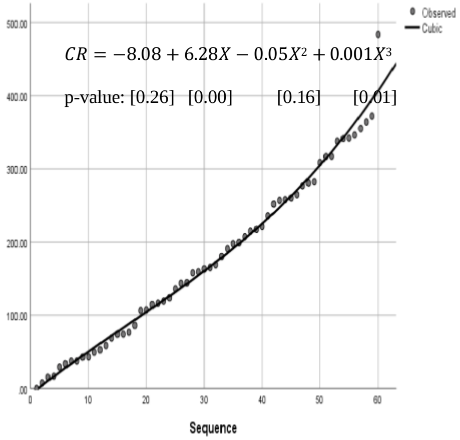
$R^2 = 0.93$



$CR = -191.69 + 95.23X - 5.36X^2 + 0.12X^3$

p-value: [0.12] [0.00] [0.01] [0.00]

$R^2 = 0.90$



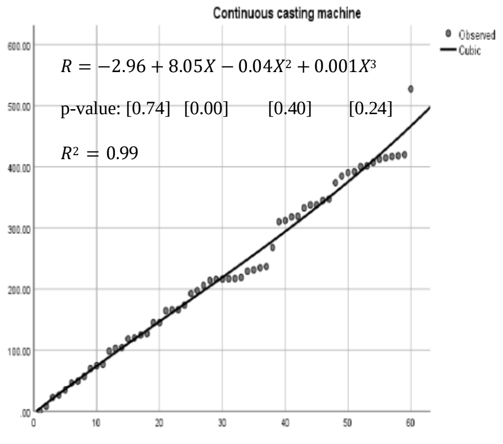
$CR = -8.08 + 6.28X - 0.05X^2 + 0.001X^3$

p-value: [0.26] [0.00] [0.16] [0.01]

Figure 23: Physical Deterioration of Reversible cold rolling mill

Figure 24: Physical Deterioration of Reversible hot rolling mill

Figure 25: Physical Deterioration of Billet and slab casting machine

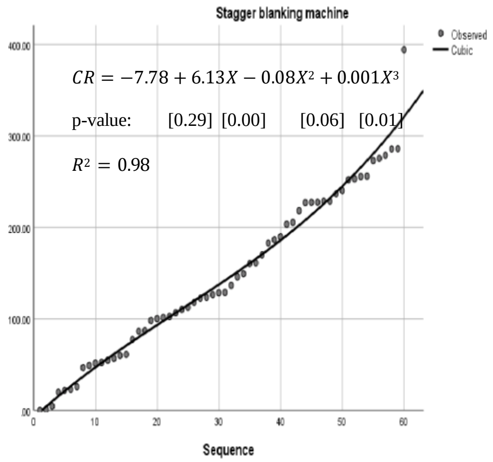


$R = -2.96 + 8.05X - 0.04X^2 + 0.001X^3$

p-value: [0.74] [0.00] [0.40] [0.24]

$R^2 = 0.99$

Figure 26: Physical Deterioration of Continuous casting machine

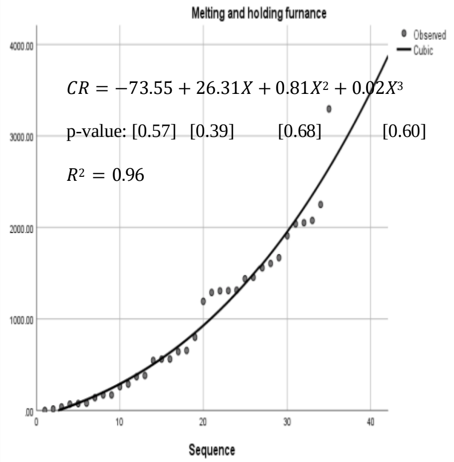


$CR = -7.78 + 6.13X - 0.08X^2 + 0.001X^3$

p-value: [0.29] [0.00] [0.06] [0.01]

$R^2 = 0.98$

Figure 27: Physical Deterioration of Stagger blanking machine



$CR = -73.55 + 26.31X + 0.81X^2 + 0.02X^3$

p-value: [0.57] [0.39] [0.68] [0.60]

$R^2 = 0.96$

Figure 28: Physical Deterioration of Melting and holding furnace

The regression equations produced from scatter diagrams are somewhat S-shaped, typically having two bends. The regression equations were therefore cubic in form.

$$CR = a + b_1X + b_2X^2 + b_3X^3 \quad (3)$$

The R^2 results showed the degree to which the independent variable (time) explains the variation in the dependent variable (cost of repairs). In the physical depreciation models of the plant and equipment (Figures 2 to 28), most R^2 results were above 90 percent. This indicates that a significant amount of the variation in the cost of repairs may be attributed to the passage of time until the end of the service life. The p-values showed the degree of reliability of the alpha and beta coefficients. Generally, most of the p-values were below 0.05, meaning most of the results are considered reliable. In the few cases where the p-values were above 0.05, the modelling results would have to be interpreted with caution.

Typically, the first one or two years of the S-shape patterns showed zero cost of repair. This is reasonable because brand new plant and equipment would incur minimal or no cost of repair, except where there is a factory fault. Plant and equipment, just like cars, do not develop faults in the first few years (say, 0 to 4 years). The patterns then show an upward swing (the first bend) from about the 2nd to the 4th year when costs of repairs and maintenance begin to increase, indicating an upswing in wear and tear. Between the 4th and 6th years, the increase in the cost of repairs stabilises, increasing at a decreasing rate before finally upswinging again. This was the case with most plants and equipment across the basic metal sectors.

This S-shape pattern of physical deterioration agrees with the pattern in a related study of physical depreciation on buildings by Bello, Ogunba and Adegunle (2015), which also showed an S-shape pattern. It is also in agreement with the scatter diagrams in the study of Ogunniyi and Ogunba (2019), that there have been very few studies conducted on the pattern of physical deterioration of plant and equipment.

The study's third level of inquiry was to model the influence of operational factors on the pattern of physical depreciation. Respondents (plant and equipment operators) were presented with various factors potentially influencing the pattern of physical deterioration (that is, level of maintenance, intensity of use of the plant and equipment, workload imposed on the plant and equipment, availability of spare parts, occurrence of power outages, and overly high electricity voltage). Respondents were presented with a five-point scale of scenarios of these factors (for example, scenarios ranging from overly high intensity of use of machines to scenarios of low intensity of use, and from very frequent maintenance of machines to very infrequent maintenance, etc.). Respondents (plant and equipment operators) indicated on a five-point scale how much the cost of repairs (wear and tear) would increase in each scenario. The conceptual expectation was that with higher workloads on the plant and equipment, higher intensity of use beyond recommended use, higher or very low electricity voltage, and frequent power outages, the result would be an increase in physical deterioration (represented in this study by the cost of repairs). Data obtained from this inquiry were averaged and modelled using multiple regression analysis. In the regression equation, the increase in the cost of repairs was the dependent variable, while the various factors causing the increase were the independent variables. The beta coefficient of each independent variable showed the degree of influence each factor had in increasing the cost of repairs. The findings are presented in Tables 2 and 3, which pertain to plant and equipment, respectively.

Table 2: Regression Results on Increase in Cost of Repair of Plant as a Result of Operational Factors

Sector		**Alpha**	**LM**	**IU**	**WL**	**AS**	**PO**	**EV**		***R*²**
Basic metal, iron	**Beta**	-8.933	-1.574	4.554	9.077	-6.212	6.432	-3.238		0.96
and steel fabricated metal product	**Coefficient P-value**	0.002	0.395	0.027	0.000	0.006	0.003	0.085	0.00	

Table 3: Regression Results on Increase in Cost of Repair of Equipment as a Result of Operational Factors

Sector		**Alpha**	**LM**	**IU**	**WL**	**AS**	**PO**	**EV**		***R*²**
Basic metal, iron	**Beta**	-8.933	-0.157	0.455	0.908	-0.621	0.643	-0.324		0.96
and steel fabricated metal product	**Coefficient P-value**	0.002	0.395	0.027	0.000	0.006	0.003	0.085	0.00	

Source: Field survey 2021

Keys:
LM = level of maintenance
IU = Intensity of use
WL = Workload
AS = Availability of spare parts
PO = Power outage
EV = Electric voltage

Tables 2 and 3 present the regression beta coefficients of the relationship between operational factors and costs of repairs (physical deterioration). Where there are negative coefficients, this indicates that the higher the value of the independent variable on a five-point scale, the lower the value of the dependent variable. Positive coefficients indicate that the higher the value of the independent variable, the higher the cost of repairs. For example, where there is a very high intensity of use with a rating of 5 over 5 and the beta coefficient is 3.591, the increase in the cost of repairs would be 5 x 3.591 naira, which is 18 naira. Where the beta coefficient is negative, for example, -4.515 for the level of maintenance, and assuming a higher level of maintenance with a rating of 5 over 5, then the additional cost of repair would be -4.515 x 5, which is minus 23 naira (reducing the cost of repairs).

The R^2 result ($R^2 = 0.97$) indicates that a high (97%) level of variation in the dependent variable (cost of repairs) is explained by the independent variables. The p-value of the beta coefficients for QM, FM, SO, and CM are less than 0.05, meaning that these beta coefficients are reliable. The p-values of the beta coefficient for LM and RM are more than 0.05 but less than 0.10, meaning that the beta coefficients are only reliable at the 90 per cent confidence level and should be interpreted with caution.

Generally, the results are consistent with common sense. It makes sense to see that the higher the level of maintenance and availability of spare parts, the less the wear and tear (proxied by the cost of repairs). It also makes sense to find that the more the intensity of use and power outages, the more the wear and tear (cost of repairs).

5. Demonstration of the Use of the Modelling of Physical Deterioration

The paper will now proceed to demonstrate the use of the physical deterioration model developed. Ogunba (2011) had earlier pointed out that valuers tend to use the easiest models rather than more suitable ones. The authors are anxious to point out the usability of the model produced; potential users need not be put off by apparently complex models, which may appear to them to be another demonstration of academic wizardry.

For demonstration purposes, we may suppose a valuer is asked to value an industrial drilling machine in the basic metal sector (using DRC). We may assume further that the valuer has consulted with the manufacturer and ascertained that the replacement cost is 500,000 naira. Physical inspection and inquiries from the operators indicate that the machine has used four years of its service life.

The relevant valuation equation is:

Depreciated Replacement Cost = Replacement cost minus (physical deterioration + functional obsolescence + economic obsolescence)..................... (4)

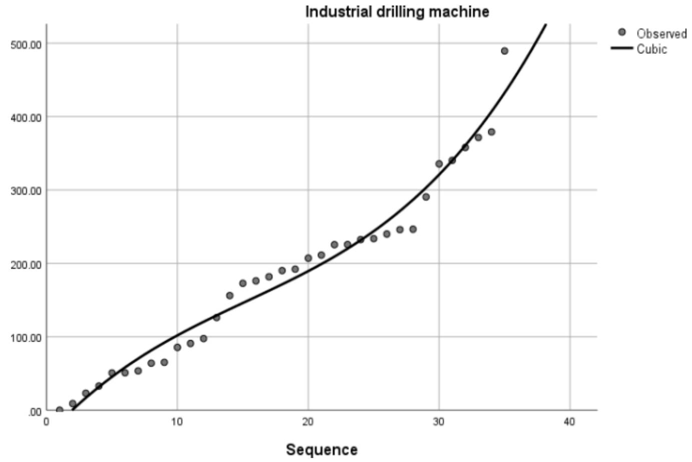
For simplicity, we may assume that the machine is neither functionally nor economically obsolete. The equation then becomes:

Depreciated Replacement Cost = N500,000 - (physical deterioration + 0 + 0)............(5)

In the model developed in this paper, physical deterioration is operationalised by the cost of repairs. The relevant cubic regression equation for physical depreciation is:

$$CR = -300.87 + 184.05x - 16.64x^2 + 0.87x^3 \ldots\ldots\ldots\ldots (6)$$

where x is the number of years used out of the service life of 20 years (in this case, 4 years), alternatively, instead of using the formula, the amount of wear and tear (cost of repairs) can simply be read off from the regression line in Figure 15, as shown below.



Thus, given that the plant has used four years of its service life, the physical deterioration (represented by cost of repair) would be:

$$CR = -300.87 + 184.05x - 16.64x^2 + 0.87x^3 = N264.77 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

However, this cost of repair is a generalised cost of repair that has not considered the influence of operational factors peculiar to the machinery being valued. The findings have shown that wear and tear (and cost of repairs) is influenced by levels of maintenance, intensity of use, workload, availability of spare parts, power outages, and electricity voltage peculiar to the usage of the P and M. The valuer using the model would rate each of these operational issues on a five-point scale, drawing from his or her inspection of the plant or equipment and discussions with the operators. In the regression equation, each factor's rating multiplies the corresponding beta coefficient.

In the model, the additional cost of repairs is represented by multiplying the ratings with the beta coefficients in the following equation:

$$\text{Additional costs of repair} = -8.93 - 1.57LM + 4.55IU + 9.08WL - 6.21AS + 6.43PO - 3.24EV \ldots\ldots\ldots\ldots (8)$$

In a worst-case scenario (that is, where the plant or equipment is found to be very badly used), the ratings would be as follows: the level of maintenance is extremely low (1 on a 5-point scale), the intensity of use of machine is very high (5 on a 5-point scale), workload on machine is very high (5 on a 5-point scale), the availability of spare parts is very low (1 on a 5 point scale), the power

outages are very frequent (5 on a 5-point scale), and the level of conformity of the electricity supply with voltage specifications (220 volts) is low (1 on a 5-point scale),
When these ratings are multiplied by the beta coefficients, the equation becomes:

$$\text{Additional costs of repair} = -8.93 - (1.57\ x\ 1) + (4.55\ x\ 5) + (9.08\ x\ 5) - (6.21\ x\ 5) + (6.43\ x\ 5) - (3.24\ x\ 1) = -8.93 - (1.57) + (22.75) + (45.4) - (31.05) + (22.15) - (3.24\ ) = 45.51\ \text{naira}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (9)$$

The physical deterioration of the crown-making machine in the basic metal sector that has been badly used for 4 years of its service life of 20 years is therefore:

$$(CR = -300.87 + 184.05X - 16.64X^2 + 0.87X^3) + (-8.93 - 1.57LM + 4.55IU + 9.08WL - 6.21AS + 6.43PO - 3.24EV) = \text{N}264.77 + 45.51 = \text{N}310.28\ldots\ldots\ldots\ (10)$$

The valuation is, therefore. concluded as follows:

Depreciated Replacement cost = N500,000 - (N310.28 + 0 + 0) = 499,689.72.51 naira.................. (11)

6. Conclusion

The study started with a focus on the problem of inaccuracy and inconsistency in the valuation of plants and equipment which are often valued using the depreciated replacement cost method. The problem was narrowed down to inaccuracy and inconsistency in the determination of physical obsolescence, where valuers make use of varied methods such as estimated percentage depreciation or methods borrowed from the field of financial accounting. It was noted that financial accounting methods are based on different assumptions of the pattern that physical deterioration follows over service life, ranging from straight lines to convex or concave patterns.

The pursuit of accuracy and consistency requires that valuation move more in the direction of science than in the direction of art. Science requires the valuer to use scientific modelling of the behaviour of property market participants in determining the values they would place on assets. This study has developed a cubic regression model for physical deterioration by tracing the path of costs of repair experienced in the use of plants and equipment over their service life. This model can be combined with mathematical models for economic obsolescence and functional obsolescence already in use by the American Society of Appraisers to have a holistic coverage of the three components of depreciation when conducting plant and equipment valuation.

The paper, accordingly, recommends that in the use of DRC method of valuation, there should be a paradigm shift away from the use of depreciation models like estimated percentage depreciation (which is in popular use in African Commonwealth countries like Nigeria, Kenya, and Ghana), as this model is not based on any definable assumptions or scientific modelling. It is largely an art, relying on the valuer’s skill, experience, and judgement. This method obviously cannot guarantee consistency and accuracy. There should also be a shift away from the use of financial accounting methods for estimating physical deterioration since the straight line, concave, and convex depreciation patterns suggested by these accounting methods do not reflect the S-shaped path of costs of repair experienced by machine operators.

The study would also advise that valuers should not be put off by what looks like statistical complexity in the use of the cubic regression models; as has been demonstrated, the amount of wear and tear (cost of repairs) for an asset can simply be read off from the regression curve. There are, however, additional costs to be added after reading off the regression curve. The study has found that factors like poor maintenance, intensity of use, excess workload, non-availability of spare parts, power outages, and electric voltage fluctuations can increase the wear and tear (and cost of repairs) of plant and equipment.

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