PHYSICAL DEPRECIATION MODELLING IN THE USE OF DEPRECIATED REPLACEMENT COST FOR THE VALUATION OF PLANT AND MACHINERY

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Abstract
Perhaps the most challenging aspect of depreciated replacement cost valuation is that physical deterioration models popularly used in valuation (straight line depreciation estimated percentage depreciation etc.) are premised on assumptions which do not accurately model the pattern that physical deterioration of plant and machinery follow over useful life. Moreover, the influence of various factors such as intensity of use, power outages, level of maintenance, and design among others on pattern of physical deterioration are not adequately included in depreciation modelling. The aim of the study was accordingly to accurately model physical deterioration in the use of depreciated replacement cost for the valuation of plant and machinery with a view to providing information that would enhance depreciated replacement cost valuation practice.

The study sampled operators of plants and machinery in fourteen manufacturing firms, (two manufacturing firms each from seven manufacturing industries) to obtain data addressing the study's aim. Data were analyzed using means, weighted means, linear regression, multiple linear regression and multiple log-log regression.

It was found that the useful life of machinery fell between ten to fifteen years while the useful life of machinery fell between nineteen to twenty-two years. The pattern of physical deteriration was found to be initially flat in early years before assuming a convex upsweep pattern for both plant and machinery. The log-log beta coefficient results showed that increases in age, usage, power outage and fluctuation increased the level of physical deterioration of while increases in maintenance, operator's years of experience and availability of spare parts reduced the level of physical deterioration.

The study recommended the use of models formulated in this study to valuers for accurate estimation of physical deterioration in replacement of popular models.

Keywords: *Physical deterioration modelling, plant and machinery valuation*

Introduction

The valuer is often called upon to determine the value of plant and machinery assets. Machinery refers to an apparatus which is used for a particular process in connection with the operation of an enterprise. Plant refers to machinery assets which are inextricably combined with other asset(s). The method of valuation of plant and machinery often involves the use of depreciation of replacement cost values. The cost method of valuation is a method that seeks to determine value of an asset by summing up the cost involved in its construction. Depreciation is introduced into the cost approach because the cost involved in construction only address newly completed assets without accounting for the loss in the value of asset over time.

In international and national valuation standards, depreciation is considered a composite term made up of three basic components: physical deterioration, functional obsolescence and economic obsolescence (RICS, 2005; NIESV, 2006; IVSC, 2007; Ifediorra, 2009). Physical deterioration is the depreciation which is caused by wear and tear of an asset over time, including the lack of or inadequate maintenance. Economic obsolescence is a situation where changes in economic conditions negatively influence the supply and demand for goods and services produced by the asset or the cost of its operation. Functional obsolescence is a situation where advancement in technology results in new assets capable of more efficient delivery of good and services, rendering previously existing assets fully or partially obsolete in terms of its current cost equivalents.

Alico (1989) writing for the American society of appraisers modelled the calculation of functional and economic obsolescence. Economic obsolescence is modelled through an assessment of capacity utilization. The idea is that when the operating level of an asset (building or machinery) is less than its rated capacity, economic obsolescence (inutility) exists. The inutility penalty is calculated on percentage basis using the following formula:

Inutility (per cent) = {1 – [Actual production/ Rated Capacity]n} x 100, where n is the scale factor. (Alico, 1989)………………………….. (1)

Functional obsolescence is modelled as consisting of two components: first, excess capital costs and second, excess operating costs (operating obsolescence) of the asset being valued relative to more efficient modern plant and machinery. The first, excess capital costs, are calculated as the difference between reproduction cost and replacement cost. The other component, operating obsolescence, is calculated as the capitalization of future excess operating costs.

Functional obsolescence = (Reproduction cost – replacement cost) + (YP x excess operating cost over operating cost of modern assets)………….. (2)

With regard to physical deterioration, different models have been developed in an attempt to depreciate assets so as to account for depreciation suffered over the useful life of engineering assets. The choice of depreciation model among the options available is often left to the discretion or judgment of the valuer (Ogunba, 2010). However, each physical deterioration model has its assumptions and the assumptions in turn have different consequences on the value arrived at for the assets. For instance, straight line depreciation model assumes that the value of asset is written off in the same manner throughout the useful life of the asset. On the other hand, the reducing balance depreciation and sum of years digit models assume that there is more depreciation in the early useful life and a reduction in the later useful life of the asset. Conversely, models like sinking fund depreciation model assume that there is more depreciation in the later years of asset. The popularly used estimated percentage depreciation method does not even make any assumption, relying solely on the valuer's skill and experience in the estimation of depreciation. The variation in the assumptions governing various depreciation models leads to different depreciated replacement cost estimates. To compound the problem, it is questionable whether all these physical deterioration models take into consideration the estimation of functional and economic obsolescence.

This choice of physical deterioration model is the most challenging aspect of depreciated replacement cost valuation. The estimation of replacement cost of plant and machinery is usually a fairly straightforward procedure. Valuers would usually determine such costs by visiting the website of the plant and machinery manufacturer and from there obtain current replacement costs. The problem arises much more in the aspect of accurate estimation of the physical deterioration aspect of depreciation. As demonstrated above, the economic and functional obsolescence components of depreciation have been modelled and the modelling makes intuitive sense. The physical deterioration component of depreciation is inaccurately modelled by the existing age life models (straight line, sum of years digits etc.) both with regard to reliability and consistency

Which model of depreciation accurately captures the depreciation suffered by plant and machinery assets over their useful life? The accuracy of popular physical deterioration models is questionable because the assumptions of the models are themselves questionable. There has been no study to determine the accurate pattern of depreciation of plant and machinery assets over useful life so as to determine which of the models accurately captures physical deterioration. The usage by valuers of models which are ostensibly based on wrong assumptions for the depreciation of the plant and machinery doubtlessly leads to problems of non-reliability and variation (Bello, 2014; Kuye 2009 and Ogunba, 2011).

One other aspect of the problem refers to the useful life/ physical life of plant and machinery which is often not known by the valuer and not often documented. An accurate model must be based on a defined useful life. Useful life is the period beyond which the cost of repairs of the engineering asset exceeded the gains made from use of the asset. The useful life of many types of plant and machinery assets have not been determined. Yet another aspect of the problem is that the influence of various factors such as intensity of use, power outages, level of maintenance, design among others on the useful life and pattern of depreciation have not been determined so that they may be included by valuers in depreciation calculations.

There are virtually no study that has considered the accuracy of depreciation models used in depreciated replacement cost for the valuation of plant and machinery in Nigeria because earlier studies attempting to enhance valuation accuracy have largely focused on the income approach to property to the neglect of the cost approach. Accuracy studies focused on the income approach have identified the existence of valuation accuracy (for example: Aluko, 2000; and Ayedun, 2009). Other studies have examined the margin of error that exists before valuations can actually be described as inaccurate (for example Iroham & Ogunba, 2010). Still other studies have investigated the causes of valuation inaccuracy (for example: Ogunba, 1997; Aluko, 2000; Iroham, 2011 among others). Depreciated replacement cost studies that are available have largely focused on buildings without considering plant and machinery (for instance Ogunba 2011, Bello, 2014). The present study is probably a pioneering study on accurate depreciation modelling in depreciated replacement cost valuation of plant and machinery.

The aim of the study was accordingly to accurately model depreciation in the use of depreciated replacement cost for the valuation of plant and machinery with a view to providing information that would enhance depreciated replacement cost valuation practice. The objectives were:

1. To determine the useful life of plant and machinery in Osun State, Nigeria.
2. To determine the pattern that depreciation of plant and machinery follow over the useful life in the study area.
3. To determine the influence of use, design and maintenance factors on the pattern of depreciation in the study area.

The study was restricted in geographical scope to Osun State in Nigeria. Osun State is an inland state in south-western Nigeria with its capital at Osogbo. It is bounded in the north by Kwara State, in the east partly by Ekiti State and partly by Ondo State, in the south by Ogun State and in the west by Oyo State. Like many other states in the country, Osun is home to a sizable number of both small and medium scale manufacturing concerns. The subject scope was restricted to physical obsolescence, without dconsidering functional and economic obsolescence as these have already been modelled by the American Society of Appraisers (Alico 1989).

2.0 Literature Review

The literature review addresses empirical literature on each of the three objectives. The review is by no means an exhaustive consideration of all papers on the subject. Rather, the attempt is to provide a sample of empirical papers that are relevant to each of the objectives of the study and in the process demonstrate the gap in literature which this paper would fill.

2.1 Empirical Literature on Useful Life of Plant and Machinery

In United States, the government office of management and budget (2003) carried out research to determine the useful life of various machinery assets. The reported useful lives of the assets included: trailers (23years); tractors, full track, low speed (14 years); milling machines (20years); tractors (8 years); refrigerating equipment (11 years); storage tanks (7 years); electric lamps (10 years); musical equipment (12 years); typewriters

(12 years); kitchen equipment and appliances (18years) among other assets. However, the results of such studies might not be applicable in Nigeria.

O'Connor (2004) in United State investigated the actual service lives of North American buildings. She collected survey information for a total 227 buildings (105 commercial/institutional buildings and 122 residential buildings), finding that the largest concentration of buildings have a service live of 76 – 100 years. However, the study did not consider plant and machinery and moreover, her study might not be applicable in Nigeria.

In Canada, Statistics Canada (2007) employed two methods to determine asset's length of life. The first approach involved the use of micro data from investment surveys to arrive at `ex-ante' estimates of service life. In this regard, they drew data based on businesses' prior expectations from the Annual Capital and Repair Expenditures Survey. The second approach involved `ex-post' information on asset life are derived by using data on sales and disposals of fixed assets. They used econometric techniques to assess the correlation with market-based service lives. Some of the useful lives of assets reported were: photocopiers (9 years); railroad equipment (28 years); furniture (14 years); steam engines (32years); office computing and accounting machinery (8 years); software (5 years); ships & boats (27 years); farm tractor (9 years) among others. However, the results of such studies might not be applicable in Nigeria.

In the United States, the Bureau of Economic Analysis (BEA, 2008) used a forward-looking profit model, and data on annual industry output and Research and Development (R&D) investments between 1987– 2007 to determine industry-specific R&D business depreciation rates. It was possible to get the service life of building from the data. They found that building has a useful life of 60 years while computer software has useful life of 5 years. However, the results of such studies might not be applicable in Nigeria.

In the Netherlands, Statistics Netherlands (2008) drew information from discard surveys, capital stock benchmarks, fiscal sources, and statistics on gross fixed capital formation to determine the useful lives of property. They reported that that the average service life of buildings is 75 years in all industries. Ships were found to have an asset life is 25 years in most industries, while seagoing water transport had service life up to 35 years. Inland water transport has service up to 40 years. The service life of other assets were Airplanes (16 years); computers soft (5 years); manufactured petroleum products (8 years), and furniture (10 years). However, the results of such studies might not be applicable in Nigeria.

Erumban (2008) estimated the useful life and discard pattern of capital assets in Netherland using information directly taken from capital stocks and patterns of retirement of assets in firms. Econometric techniques was used to estimate service lives. The estimated expected service lives of the three capital categories were 24, 9 and 6 years, respectively, but there was substantial variation in the estimated service lives between different manufacturing sectors.

In the United States, the Department of Assessment Standards (2010) determined the useful lives of various assets so as to provide a basis for taxation in Carson City. They made use of Marshall and Swift's (2009) Valuation Service life expectancy Guideline. They recommended that the life expectancy for short life property such as glassware, barware, silverware etc. is 3 years; while taxable software that was not associated with computer - integrated machinery had life expectancy of 3 years; High – Tech Medical Diagnostic Equipment had a life expectancy of 5 years; furniture and trade fixtures, air conditioning had life expectancy of 15 years; mailing machines had life expectancy of 7 years; office furniture (desk, chair, cabinet) has expectancy life of 15 years; typewriter has expectancy life of 12 years, textile mills had life expectancy of 15 years among other items listed. However, the results of such studies might not be applicable to plant and machinery in Nigeria.

In Nigeria, Ogunba (2013) carried out research to clarify depreciation issues on the useful life of plant and machinery needed to ensure accuracy in the depreciated replacement cost in Ibadan. He administered questionnaire on engineers and machine operators employed in four types of production facilities. The responses were analyzed by means of frequency distributions mean. He found that the average useful life of process plant for bottling companies is 25 years; food processing plant – 30years; sachet water production – 30 years; average useful life of process plant for water- 20 years and allied producing companies and agro allied firm is 30 years. His findings therefore suggested that the average useful life of plant range between 10 – 30 years. However, the study was limited to only four manufacturing company. In addition, there is need to update the results in his study.

In Lagos, Bello (2014) carried out research on depreciation in the use of the cost method of valuation to value residential buildings. The responses were analyzed through frequency distributions (mean). He found that the physical life of residential and commercial property is 41-45 years. However, his study was focused on buildings rather than on plant and machinery.

Nini, Adne, Terje, Steinar and Thom (2016) conducted studies on depreciation lives in Norway. They administer web design questionnaire on 1100 firms from 7 industries. They found significant variation in the expected life of many capital asset types. For assets relating to transportation, the variation was fairly low while on the other hand, mining and manufacturing assets, tools furnishes and building, structure and fixed installations showed greater variation in the expected service lives. However, this study was not conducted in Nigeria and might not have applicability..

Rinco-Aznar, Riley and Young (2017) carried out research to determine whether asset lives in United Kingdom have significantly changed over the last 20 years. They make use of the Perpetual Inventory Method (PIM). They found that asset lives assumed by United Kingdom Office of National Statistics are in many cases longer than those assumed in other countries. However, the study was not focused on Nigeria.

Overall, the gap discovered in the review of literature is that research has not focused on discovering the useful life of plant and machinery in Nigeria. This study intends to fill this gap in literature with a focus on Osun State in Nigeria.

2. 2 Empirical Literature on Patterns of Physical Deterioration of Plant and Machinery

In Canada, data was collected on scrapping patterns and depreciation profiles for 36 groups of tangible capital using the perpetual inventory model (PIM). They arrived at two findings that the depreciation profiles are convex that is the depreciation is largest in the initial years of the asset. However, this study was not done in Nigeria.

In the United Kingdom, Plimmer and Sayce (2006) considered four depreciation models: estimated percentage depreciation, reducing balance depreciation, straight line depreciation and the S-curve method. The straight line method was criticized as simplistic and unreliable. The reducing balance model was criticized as unrealistic because it assumed a constant percentage rate of depreciation. Generally, the authors observed a high degree of inconsistency in the use of the depreciated replacement cost methodology because some valuers allowed for both functional and operational obsolescence while others did not. Subsequent review paper (the RICS Valuation Information Paper, 2007) was derived from a research by Plimmer and Sayce (2006) above and contained the same views. However, these studies generally focused on building rather than plant and machinery.

Ogunba (2011) administered questionnaire surveys on 195 valuation firms in Lagos metropolis to determine the pattern of depreciation for buildings. He proceeded by using time series and cross sectional analysis of progressive costs of repairs in five year periods over useful life to deduce S-shaped pattern of depreciation for buildings. He also attempted to determine which of seven depreciation models was in most usage in Nigeria. However, his study generally focused on buildings rather than plant and machinery.

Ogunba (2013) carried out research on plant and machinery depreciation in Ibadan to clarify depreciation issues relating to depreciation pattern so as to ensure accuracy in depreciated replacement cost of valuation. He administered questionnaire on engineers and machine operators using four types of production facilities. He found that the pattern that depreciation follows over useful life is initially flat in early years before assuming a convex upsweep pattern. However, the research considered only four manufacturing firms and did not determine the influence of use, design and maintenance factors on the pattern of depreciation. Also, there is need to update the results of that study.

In Nigeria, Bello (2014) extended the research of Ogunba (2011) by comparing the results of the S curve with the other depreciation models such as straight line depreciation and estimated percentage depreciation in use. He used time series and relatively importance index. He found that these other depreciation models produced substantially different results from the S curve and concluded that substantial inaccuracy occur when these other models are used despite their apparent user friendliness in Lagos. However, the research did not consider plant and machinery and did not determine the influence of use, design and maintenance factors on the pattern of depreciation

Bello, Ogunba and Adegunle (2015) conducted research to determine the pattern that depreciation of residential property. Questionnaires were distributed to registered estate surveyors and valuers firms in Lagos metropolis. They found that the depreciation pattern of building has S shape. However, their study focused on buildings and did not consider plant and machinery. Moreover, their study did not determine the influence of use, design and maintenance factors on the pattern of depreciation.

Overall, the gap discovered in this aspect of review of literature is that research has largely focused on buildings to the neglect of plant and machinery and has not determined the influence of use, design and maintenance factors on the pattern of depreciation, This study intends to fill this gap in literature with a focus on plant and machinery assets in Osun State, Nigeria.

3.0 Conceptual Framework

Seven categories of manufacturing firms were identified in Osun State identified from a pilot survey. These are: basic metals, chemical and pharmaceuticals, pulp and paper products, wood and wood products, food and beverages, industrial / domestic plastic, and water purification industries. Each of these use plant and machinery in their operations. The expected useful life of plant (as suggested by literature in other countries) is 20 years and for machinery is 10 years. Literature also leads one to expect that the pattern of depreciation of the plant and machinery would follow an S shape over the useful life rather than the convex depreciation pattern (assumed by decelerated models such as sinking fund model), the straight line depreciation pattern or the concave depreciation pattern (assumed in sum of years digit and reducing balance models). The S shaped physical deterioration pattern is in turn expected to be negatively affected by higher levels of use, and power supply fluctuations as well as by lower levels of maintenance, repair and design. These conceptual expectations are depicted in figure 1.

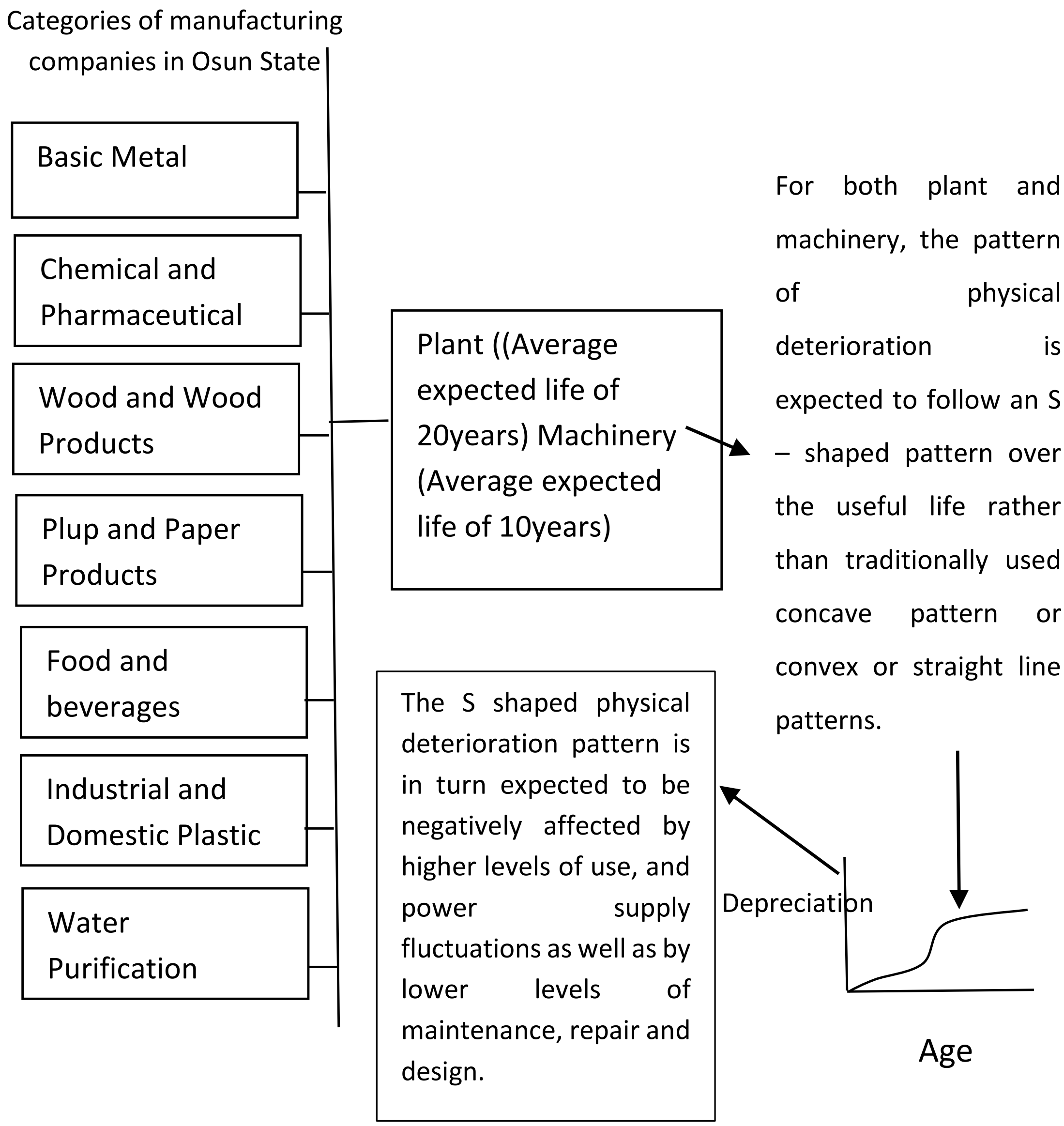


Figure 1: Conceptual Framework

4.0 Research Method

The appropriate study population unit that was considered to be in position to provide information on the three research questions were the operators and/or engineers of plant and machinery in the study area (Osun State). Contact was made with the Manufacturers Association of Nigeria which revealed that a large number of manufacturing companies in Osun State are not registered. Therefore, the researchers had to determine sample frame by means of a pilot survey of industries in the major towns in the state. The decision was to settle for two manufacturing firms from each of seven available industries in the study area. The sample frame for this study are accordingly 14 manufacturing companies in Osun State. The names of the Industries and manufacturing firms are presented below.

- Chemical and pharmaceutical company: Jostade pharmaceutical Ltd., Ilesa and Sam-Ace Ltd., Osogbo.
- Water Purification Factory: OAU Water, Ile Ife and Alba food and drink Ltd. Osogbo
- Food Industry: Tuns international Ltd., Osogbo and Fortunate bread, Osogbo.
- Feed mill: Trimeb Investment Feed mill, Osogbo and Top Feed mill, Osogbo
- Paper and pulp Company: Atman limited, Osogbo and Luking Print, Osogbo
- Domestic and Industrial plastic: Lopin limited, Osogbo and Dipson Plastic and Recycle plant, Osogbo
- Basic Metal Company: Ife Iron and Steel Nigeria limited, Ile-Ife and Olaoluwa Aina wire industry, Osogbo.

The methods of data measurement and data analysis for each of the paper's objective are detailed in Table 1

Table 1: Data Measurement and Analysis by Objectives

Objectives	Data Requirement	Data Measurement	Data Analysis
To determine the useful life of plant and machinery in Osun State.	Useful life of plant and machinery of the 20 manufacturing firms	Ratio Scale	Frequency Counts and Averages (Mean)
To determine the pattern that depreciation of plant and machinery follow over the useful life in the study area.	Pattern of physical deterioration every 2 years (represented by amount of repair needed)	Ratio Scale	Regression analysis
To determine the influence of use, design and maintenance	Influence of Usage, Maintenance and	Seven point ordinal scale	Multiple Regression Analysis and

Objectives	Data Requirement	Data Measurement	Data Analysis
factors on the pattern of depreciation in the study area.	Design variable on depreciation		double log regression

For the second objective, the normal linear regression model was expressed in the following form

Y= $a + \beta 1X1$…………………………………………………………………. (1)

Where Y was the dependent variable (physical deterioration), a was the alpha constant and X is the independent variable (age) and $\beta 1$ was the beta coefficient

For the third objective, the Multiple Regression Analysis model took the following form

Y=a + b_1X_1 + b_2X_2 + b_3X_3+…..+ bnXn ……………………………………………….. (2)

Where Y was the value of the dependent variable (physical deterioration), a (Alpha) the Constant or intercept, and b_{1-n} were the Beta coefficients for age, number of times maintenance was carried out, response time to repairs, operator years of experience. power outages, country of manufacture, availability of spare parts, experience of servicing personnel, quantity of maintenance material and voltage fluctuations

The log-log regression model was employed to complement the multiple linear regression model. This was because scatter diagram relationship was found to be non-linear. The double log multiple regression linear model is expressed in the following manner:

lnY = $\beta 0 + \beta 1lnX1 + \beta 2lnX2 + \beta 3lnX3 + \beta 4lnX4 + \beta 5lnX5 + \beta 6lnX6$ + $\beta 7lnX7 + \beta 8lnX8$ + $\beta 9lnX9 + \beta 10lnX10$ + $\beta 11lnX11$ ………………. (3)

Where: Y= Physical deterioration, X1-11 were the independent variables: age, number of times maintenance was carried out, response time to repairs, operator years of experience. power outage, country of manufacture, availability of spare parts, experience of servicing personnel, quantity of maintenance material and voltage fluctuations.

5.0 Data Analysis

Questionnaires were administered in December 2019. All 14 questionnaires administered were returned and found useful for analysis.

Analysis of the preliminary sections of the questionnaires showed that 85.71% of the respondents (operators and/or engineers) are male with 14.29% are female. Most of the respondents fell within the age group of 36-45. 78.57% of the respondents were married. 35.71% of the respondents had HND diplomas while 28.57% had B. Sc. Degrees. 71.43% of the respondents were associate or graduate engineers while 28.57% are fellow level member of COREN. 35.71% of the respondents had 10 years' experience, while 50% had 11-20 years' experience.

5.1 Useful Life of the Plant and Machinery

This section focused on the first objective which was to determine the useful life of the various type of plant and machinery. The useful life was defined to respondents as the period beyond which the cost of repairs of the engineering asset exceeded the gains made from use of the asset. The mean responses are presented in the table below.

Table 2: List of Machines and Their Estimated Useful Life

Production firm	**Typical machines available**	**Mean estimated useful life**
Chemical and Pharmaceutical • Jostade Pharmaceutical Limited, Ilesa • Sam-Ace Limited, Osogbo.	Filling Machine Blistering Machine Capping Machine Roller Machine Tableting Machine Sieving Machine Coding Machine	10 years 15 years 15years 10 years 10 years 10 years 15 years
Feed Mill • Trimeb Investment Feed mill • Top Feed mill, Osogbo	Grinder Mixer Pelletizer Extruder	15 years 10 years 10 years 10 years

Water Purification Factory • OAU Water, Ile Ife • Alba Food and Drink Limited, Osogbo	Reverse Osmosis Machine Sachet Water Machine Automatic Rinser Automatic Capping Shrinking Tunnel Automatic Cutter Wrapping Machine Blower	10 years 10 years 10 years 10 years 10 years 10 years 10 years 10 years
Food Industry • Tuns International Limited, Osogbo • Fortunate Bread, Osogbo.	Dough Mixer Baking Oven Cooling Band Packaging Machine Wet Dough Plant Proving Cabinet Siever Dough Divider Weighing Scale	10 years 15 years 10 years 10 years 15 years 10 years 15 years 10 years 15 years
Domestic and Industrial Plastic • Lopin Limited, Osogbo • Dipson Plastic and Recycle Plant	Injection Mixer UPVC Extruder Casing Mk Crushers Foaming Compressor Generator Cooling Unit Pressure Tester Tensil Strenght Laboratory Equipment Film Exclusion Machine Cutting Machine	12 years 15 years 10 years 15 years 10 years 12 years 15 years 15 years 10 years 15 years 10 years 10 years 10 years 15 years

Paper And Pulp • Atman Limited, Osogbo • Luking Print, Osogbo	3 Knives Trimmer Cutting Machine Sharpening Machine Paper Shredding Machine Color Machine Ruling Machine Laminating Machine Printing Machine	10 years 15 years 10 years 12 years 10 years 12 years 15 years 10 years
Basic Metal • Ife Iron and Steel Nigeria Limited, Ile Ife • Olaoluwa Aina Wire Industry, Osogbo.	Furnace Intermill Cooking Bed Drawing Machine Building Wire Machine Generator	10 years 12 years 10 years 10 years 12 years 12 years

The table shows that generally, the useful lives of the various machines were between ten and fifteen years.

Table3: Estimated Useful Life of Plants

Process plant	Mean Useful life
Chemical and pharmaceutical • Jostade pharmaceutical limited, Ilesa • Sam-ace limited, Osogbo.	18 years 22 years
Feed mill • Trimeb Investment feed mill • Top feed mill, Osogbo	20 years 20 years
Water purification factory • OAU water, Ile Ife • Alba food and drink limited, Osogbo	21 years 20 years
Food industry • Tuns international limited, Osogbo • Fortunate bread, Osogbo.	21 years 19 years
Domestic and industrial plastic • Lopin limited, Osogbo • Dipson plastic and recycle plant	20 years 20 years

Paper and pulp • Atman limited, Osogbo • Luking print, Osogbo	 21 years 19 years
Basic metal • Ife iron and steel Nigeria limited, Ile Ife • Olaoluwa Aina Wire Industry, Osogbo.	 20 years 20 years

The table shows that the useful lives of plant vary depending on the type of production facility. Generally, the useful lives were estimated to be between eighteen and twenty-two years. This is a confirmation of conceptual expectations.

4.2 Pattern of Depreciation of the Plant and Machinery over the Useful Life

This section focused on the second objective which was to determine the pattern of depreciation of plant and machinery over useful life. This objective was pursued by asking respondents to estimate the percentage amount spent on repair/maintenance every two years over the useful life of the plant and machinery. The mean responses were calculated and then represented in diagrams where the x axis represented time and the y axis depreciation (physical deterioration). The resulting scatter diagram lines are presented in figures 2 to 8 as follows.

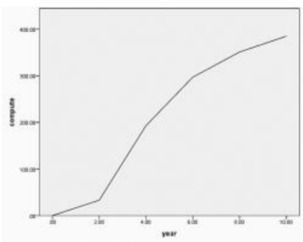


Fig 2: Depreciation (Physical Deterioration) Feed mill Machines

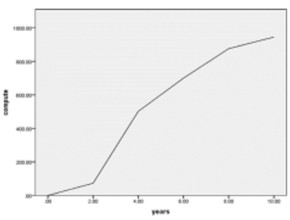


Fig 3: Depreciation (Physical Deterioration) Chemical and Pharmaceutical Machines

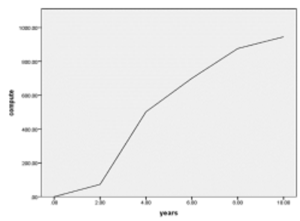


Fig 4: Depreciation (Physical Deterioration) Food industry machines

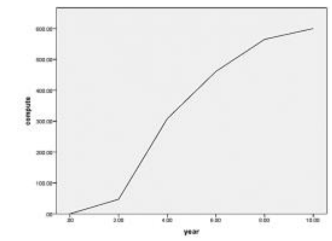


Fig 5: Depreciation (Physical Deterioration) Water Purification Machines

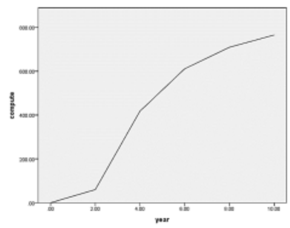


Fig 6: Depreciation (Physical Deterioration) Paper and Pulp Machines

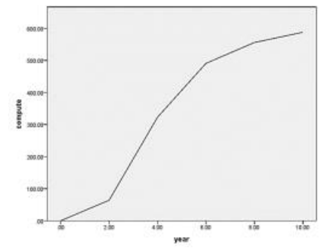


Fig 7: Depreciation (Physical Deterioration) Metal Machines

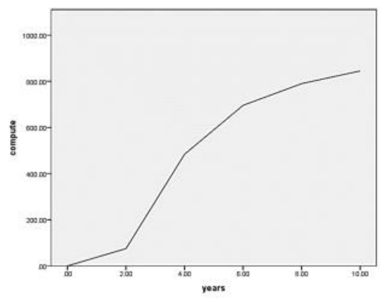


Fig 8: Depreciation (Physical Deterioration) Domestic and Industrial Plastic machines

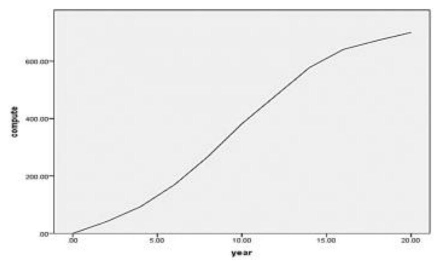


Fig 9: Depreciation (Physical Deterioration) Plants for all 7 industries

Figures 2-8 show that the pattern of physical depreciation for machinery is initially flat in early years before assuming a convex upsweep pattern. This suggests that the machinery initially experience little wear and tear and require very minimal repairs and maintenance. Subsequently, the physical deterioration accelerates (around midlife) and then the rate of deterioration slows somewhat as the machinery reach the end of their useful life. The above provides compelling evidence that popular models such as the straight line depreciation model (which assumes that the value of asset is written off in a constant manner throughout the useful life of the asset) or reducing balance depreciation and sum of years digit models (which assume that there is more depreciation in the early useful life and a reduction in the later useful life of the asset) or models like sinking fund depreciation model (which assume that there is more depreciation in the later years of asset) are wrong in their assumptions. Figure 9 shows that the pattern of depreciation for plants in the seven industries shows a similar S shaped pattern as those for machinery.

However, the linear regression equations do not capture the scatter diagram patterns in figures 2-8 accurately. Therefore, the study resorted to a double log transformation of the regression to more accurately represent the regression relationship. The results of double log regression are presented in Table 4 alongside the linear equations.

The linear regression equations that approximates these scatter lines are presented in table 4

Table 4: Linear and Log-log approximations of the Scatter Lines

	Linear Regression Equation	Log log transformation
Feedmill industry	Y= 40X + 0	lnY= 6lnx + 5
Chemical and Pharmaceutical Industry	Y = 70X + 0	lnY= 12.5lnx +3.75
Food Industry	Y= 100x + 0	lnY= 3.75lnx + 7.5
Water Purification Industry	Y= 60x + 0	lnY= 10lnx +5
Paper and Pulp Industry	Y= 80x + 0	lnY= 3.125lnx +8.75
Metal Industry	Y = 60x + 0	lnY= 7lnx +10.5
Domestic and Industrial Plastic industry	Y= 100x + 0	lnY= 15lnx +7.5
Plants	Y= 35x + 0	lnY= 10lnx +5

4.3 Influence of usage, design and maintenance factors on the pattern of depreciation of plant and machinery

This section focused on the third objective which was to determine the influence of usage, design and maintenance factors on the S shaped pattern of physical deterioration of plant and machinery. The responses in this regard were measured on 7-point likert scales.

First, the study measured the influence of number of times maintenance is carried out on physical deterioration. The results revealed that extremely low frequency of maintenance will increase the cost of repair/ pattern of depreciation by 5.36% while a very sufficient frequency of maintenance would result in only a 1% increase.

Second, the study measured the influence of number of years of experience of servicing personnel on physical deterioration. The results revealed that use of servicing personnel with less than one year experience will result in increases in the cost of repair/ pattern of depreciation of up to 5.57%. Use of servicing personnel with up to 15 years of experience would result in increases costs by only 0.95%.

Third, the study measured the influence of the use of quality of maintenance material (e.g servicing oil, plugs etc.) on cost of repair. The result revealed that use of very poor quality maintenance material will increase the cost of repair/ pattern of depreciation by 5.57%, Use of super quality maintenance material will result in only 0.07% increases in costs.

Fourth, the study measured the influence of availability of spare parts on cost of repair/pattern of depreciation in percentage terms. The results were that non-availability of spare parts will increase the cost of repair/ pattern of depreciation by 5.21%, while complete availability will result in less than 1% increases.

Fifth, the study measured the influence of response time to repair on cost of repair. The result showed that very slow response time to maintenance will increase the cost of repair/ pattern of depreciation by 5.36%, while very quick response time to maintenance will result in only 0.02% increases.

Sixth, the study measured the influence of influence of intensity of use on costs of repair. The results revealed that high intensity of use beyond rated capacity will increase the cost of repair/ pattern of depreciation by up to 6%. Low intensity of use will result in only 0.16% increase in wear and tear.

Seventh, the study measured the influence of influence of operator's years of experience on cost of repair. The result revealed that use of inexperienced operators with less than one year experience will increase the cost of repair/ pattern of depreciation by up to 7.71%. Operators with years of experience above fifteen years usually result in only 0.36% increases in wear and tear costs

Eighth, the study measured the influence of frequency of power outage on the cost of repair. The result revealed that power outages above fifteen times weekly will increase higher cost of repair/ pattern of depreciation of 5.86%. Power outages below three times weekly will result in 2% increases.

Ninth, the study measured the percentage influence of voltage fluctuation on cost of repair. The result revealed that voltage levels above 300v or below 100v will increase the cost of repair/ pattern of depreciation by 5.64%, while normal voltage will result in only 0.02% increases.

Tenth, the study measured the percentage influence of country of manufacture of plant and machinery on cost of repair. The result revealed that plant and machinery manufactured in Taiwan and Korea will result in increase in wear and tear costs of up to 4.21%. Plant and machinery manufactured in Germany, the US and UK experience only 0.9% increases.

The next attempt was to articulate these factors into a multiple regression model. The attempt was to regress at (5% and 1% significant levels), the dependent variable Y (physical deterioration) on the X's (the independent variables) which are: age, number of times maintenance is carried out, response time to repair, use, experience of servicing personnel, power outage, manufactured country, voltage fluctuation, quality of maintenance material, availability of spare part and operator years of experience.

Multiple linear regression was used to model the influence of usage, design and maintenance factors on the pattern of physical deterioration of plant and machinery. The results of the multiple linear regression model for the seven industries is shown in Table 5. It can be seen there that in all cases, 100% or close to 100% of the dependent variable (physical deterioration) were explained by the independent variables. However, despite the high R^2, only about eight out of eleven independent variables were displayed by the SPSS (linear regression) program because of strong correlations (dependency) between variables that should be independent, a problem known as mulicolinearity. Further problems with the result was that most of the independent variable have p values above 0.05 and 0.10 which does not make them significant. The analysis was therefore re-done using double log regression. Table 5 presents the results of both the multiple linear regression and the log-log transformations.

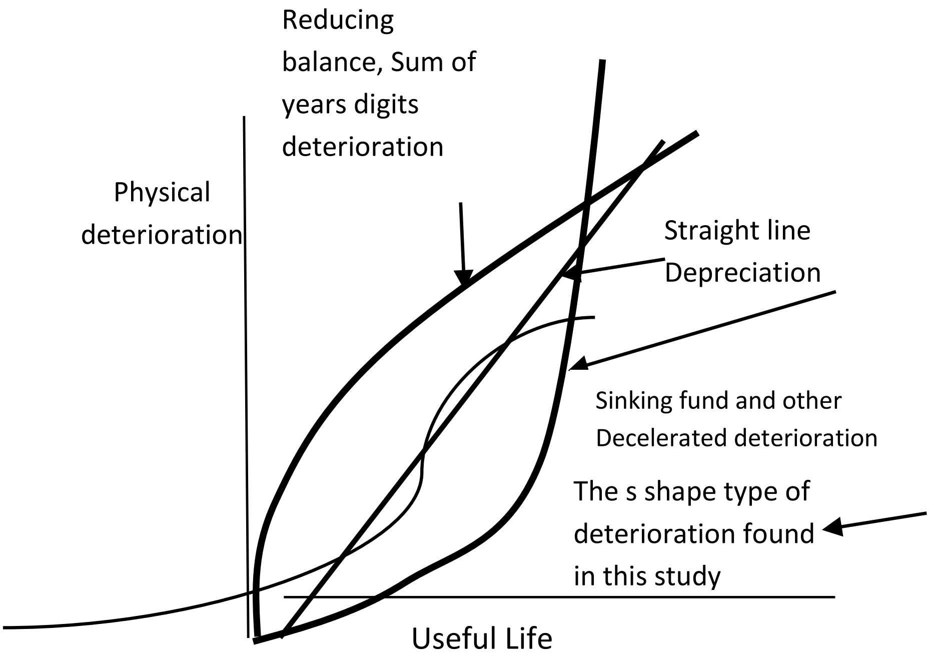
Table 5: The influence of usage, design and maintenance factors on the pattern of physical deterioration of plant and machinery

Industry	Multiple Regression Equation	Log-log transformation
Feed mill industry	Y = 54.40 + 2.30x1 – 10.720x2 +107.553x4 – 53.20X5 – 30.123X6-31.558X7-2.859X8-5.050X11 (R^2 = 1.0)	lnY = 3.355 +0.418lnx1 - 0.550lnx2 +0.720lnX5 - 2.441lnx6 - 0.516lnx7 + 0.546lnx9 + 0.032lnx11 (R^2 = 1.0)
Chemical and Pharmaceutical industry	Y= 30.40 + 3.550X1 – 5.979X2 + 100.14X4 – 56.235X5 – 21.096X6 – 36.993X7 + 3.909X8 – 0.168X11 (R^2 = 0.999)	lnY = 3.355 +0.418lnX1 – 0.550lnX2 +0.720lnX5 – 2.441lnX6 – 0.516lnX7 + 0.546lnX9 + 0.032lnX11 (R^2 = 100%)
water purification industry	Y = 30.40 + 3.550X1 -0.336X2 +23.471X4 + 8.013X5 -21.390X6 – 21.911X7 + 4.775X8 – 7.704X11 (R^2 = 100%)	lnY = 2.582 +0. 680lnX1 – 0.524lnX2 + 2.145x5- 2.624lnX6 + 0.070lnX7 + 0,094lnX9 – 1.090lnX11 (R^2 = 100%)
Food industry	Y = 32.70 + 3.40X1 – 10.90X2 + 32.556x4 – 62.982X5 + 23.356X6 – 14.918X7 +11.581X8 – 0.360X11 (R^2=1)	lnY = 2.679 +0. 645lnX1 – 0.096lnX2 + 1.162lnX5 - 0.598lnX6 – 1.427lnX7 – 0.632lnX9 - 0.369lnX11 R^2 = 1
Domestic and industrial plastic	Y = 50.40 + 2.550X1 – 23.122X2 + 117.509X4 -108.155X5 – 26.763X6 – 3.960X7 – 3.574X11 (R^2=1)	lnY = 3.216 +0. 468lnX1 – 1.441lnX2 + 1.003x5– 3.101lnX6 + 0.194lnX7 + 0.904lnX9 - 0.20lnX11 (R^2=1)
paper and pulp industry	Y = 59.30 + 2.10X1 – 16.143X2 + 168.246X4-37.002X5 – 72.833X6 + 48.424X7 – 11.747X8 – 6.757X11 ((R^2 = 0.999)	lnY = 3.355 +0. 418lnX1 – 0.550lnX2 + 0.720lnX5 - 2.441lnX6 – 0.516lnX7 + 0.546X9 +0.032lnX11 (R^2=1)
Metal industry	Y = 52.70 + 2.40X1 – 20.854X2 + 188.832X4 -66.947X5 – 62.619X6 - 42.409X7- 14.932X8 - 2.665x11 (R^2 = 0.999)	lnY = 3.291 +0.441lnX1 – 1.216lnX2 +0.954X5 – 3.272lnX6 + 0.107lnX7 + 0.947X9 + 0.438lnX11 ((R^2 = 0.999)

Summary and Recommendations

The findings are largely a confirmation of conceptual expectations. The study has found that:

Physical deterioration of plant and machinery has been found to be initially flat in early years before assuming a convex upsweep pattern (for both plant and machinery). This means that physical deterioration do not follow the patterns suggested by traditional models like straight line model, sum of years digit etc.



Moreover, the pattern of depreciation varies from Industry to Industry. The attempt in the paper has been to distinguish between modelling for different industries. Any generalization that still exists should be treated as a limitation of the paper.

and age, usage, high power outage and voltage fluctuation increase physical deterioration of plants while frequency maintenance, availability of spare parts and highly experienced servicing personnel can decrease physical deterioration of plants.

The study also recommends the replacement of popularly used inaccurate physical deterioration models with the patterns of depreciation and regression models propounded by this study in the interests of accuracy. The physical deterioration models designed in this study can be combined with the models designed for functional and economic obsolescence to obtain a holistic model of depreciation for use in depreciated replacement cost valuation of plant and machinery in the following manner.

Depreciation = physical deterioration + functional obsolescence + economic obsolescence

= $(a + b_1X_1 + b_2X_2 + b_3X_3 + \ldots + bnXn)$ + {(Reproduction cost – replacement cost) + (YP x excess operating cost over operating cost of modern assets)} + (Inutility % x Replacement cost).

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