Prediction of Profit Lost to Underutilization during Useful Life of Manufacturing Systems

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Abstract
Rapluc-Comparator used for predicting and comparing future worth of profit that will be lost to underutilization during the useful life of production equipment and their replacement costs was developed in this study and used to evaluate the equipment replacement potentials of some manufacturing industries in Nigerian. Results obtained showed that 21.52% of the industries investigated (mainly small and medium scale firms) will lose profit worth more than their equipment replacement cost to underutilization at the end of their systems while 35.14% of them will lose profit worth over 50% of their equipment replacement cost. This revealed that capacity planning which amply accounts for both input availability and product demand before design and procurement of production facilities is inadequate in the small and medium scale manufacturing sector of this nation. Hence, the significant effect of unused capacity charges on selling price of products of small firms relative to those of the large ones in Nigeria and incessant liquidation of Nigerian small and medium manufacturing industries due to the inability of the firms to replace their production facilities as at when due because of huge profit lost to underutilization. Rapluc-Comparator is therefore recommended to owner/managers of industries for self-assessment of their potentials for continuous existence and robustness in stiff market competition.

Keywords: Capacity, manufacturing system, profit lost, replacement cost, underutilization

1.0 Introduction
Capacity utilization of manufacturing sector has been a crucial economic issue in developing countries over the years due to the leading position of this sector in promoting productivity, investment, import substitution, export expansion, employment and per capita income of any nation at a faster rate than any other sector (Ogwuma, 1995; Shebeb, 2002). In addition, manufacturing sector provides wider and more efficient linkage among different sectors (Ogwuma, 1995). Capacity utilization is a measure of the extent to which an enterprise or a nation uses its installed productive capacity (Hosen et al, 2011). Technically, capacity utilization is the average ratio of the actual output of a firm to the maximum that could be produced with her existing plant and equipment (Johansson, 1988) while for an economist, it measures the ratio of actual output to the level of output, beyond which the average cost of production begins to rise (Berndt and Morrison, 1981). However, Hosen et al (2011), revealed that even though the typical engineering idea of capacity differs from the economist’s definition because what is technically possible may not be economically desirable, time series analysis showed that both views stress the same fact (output versus input) over time. This view of Hosen et al (2011), is correct because with adequate capacity planning which account for optimal production level with respect to input availability and product demand before design and procurement of facilities in a firm, the differences between the available economic and engineering capacities is insignificant. Thus, irrespective of the perspective one is viewing it, capacity utilization remained the ratio of used capacity to the available one. The difference between the used and available capacities is referred as excess or underutilized capacity.

All entrepreneurs/companies desire hundred percent capacity utilization but records showed that none operates at this rate because of downtime due to equipment malfunctions and various other causes (James, 2002; Anwar and Moudud, 2004; Susan and Roger, 2004; Chijioke, 2010). A consistent rate of about 85 percent utilization of installed productive capacity is considered optimal in most industries. Records revealed average capacity utilization rate of United States firms as 79.5%, Japan 83–86%, European Union 82%, Australia 80%, Brazil 60–80%, India 70%, China perhaps 60%, Turkey 79.8%, Canada 87% while that of Nigeria is very low (30 – 40%) despite high demand of manufactured goods in this nation (Anwar and Moudud, 2004; Dauda, 2006; Akindele, 2014). Hence, a lot of wastes of meager production capacities available in this country. This ugly phenomenon is more pronounced in many indigenous owned/managed production firms in Nigeria. Thus, the ever increasing rate of liquidation of small and medium scale industries as well as many indigenous large scale production firms in this country despite several policy initiatives and resources government is injecting in this
sector to facilitate the process of industrialization in the country. Many attributed this national menace to lack of technological know-how, shortfall in utility and inadequate government policies (Ukoha, 2000; Oluronso, 2002; Dauda, 2006; Akindele, 2014). However, Chijioke (2010), revealed the inability of the liquidated firms to replace their production equipment/machineries after their useful life as the major cause of the high rate of their liquidation. This work stressed that Nigerian entrepreneurs are not sensitive to the adverse effect of huge profit they sacrifice daily to underutilized capacities on the stability and continuous existence of their firms in a stiff market competitive condition. Chijioke (2010), then recommended that this attitude must be controlled before other measures toward sustainable manufacturing sector will yield the desired result in this country. Therefore, it is economically necessary to develop a model that will be used in predicting and comparing the total profit that will be lost to unused capacity of any manufacturing system after its salvage period with its replacement cost at any given time and production rate. Comparison of these two parameters is necessary to enable operators of manufacturing systems know the ratio of the money required for their system replacement which will be lost due to excess or unused capacity. In other words the prediction and comparison of the two parameters is a tool for forecasting equipment replacement potentials of industries at any given production rate and time. Although, many model and approaches for capacity utilization measurement have been developed and used over the years by Rasche and Tatom (1977), Berndt and Morrison (1981), Corrado and Mattey (1997), Omer (1998), Kim (1999), Anwar and Moudud (2004), Ray and Kankanana (2005) and Hosen et al (2011) and many others, none of the tools developed/used in previous works quantified the losses associated with underutilized capacity of a system relative to its replacement cost. This is why atimes it is difficult to relate the losses to a tangible quantity which the investors in this sector will understand. Thus, the objective of this study is to develop a prediction tool that will used in evaluating the total profit that will be lost to underutilization during the useful life of manufacturing systems.

2.0 Model Development and Evaluation Procedure

The model of the profit lost to underutilization of a production system during its salvage period was derived from basic economic/mathematical concept which expresses profit, \( P_f \) as the difference between total sales, \( SP \) and production cost, \( CP \) (Equation 1).

\[
P_f = SP - CP \tag{1}
\]

Production cost is the total cost of materials, wages, depreciation and other production disbursements such as transportation cost, selling cost, maintenance cost etc. Therefore, profit per unit product, \( P_u \) constitutes the difference between the selling price per unit, \( S \) and production cost per unit (Equation 2);

\[
P_u = S - \frac{(M+\omega+D+O)}{A} \tag{2}
\]

Where \( M, W, D \) and \( O \) constitutes annual cost of raw materials, wages, depreciation and other disbursements respectively while \( A \) is the actual production rate of the system in any given year. Annual depreciation which measures the cost of deterioration in the value of a production system or the cost of having the system during any year under review was determined using straight depreciation method given by Onwualu et al (2002) as;

\[
D = \frac{(Z - F)}{N} \tag{3}
\]

Where \( Z, F \) and \( N \) are the initial cost, salvage value and salvage period of the system respectively. Initial cost constitutes total amount spent in the procurement, installation and commissioning of the production equipment/system. The total profit lost due to unused capacity of a manufacturing system in any year, \( P_L \) is the product of the profit per unit item sold and number of items that should have been produced but are not because the system is not fully utilized (underutilized capacity). Recall underutilized capacity of any system is the difference between its installed and actual production rate. Thus, the total profit lost to unused capacity of a manufacturing system in any given year is expressed mathematically as follows;

\[
P_L = P_u(C - A) \tag{4}
\]

Where \( C \) is the installed capacity of the systems per year, which is the number of products the system was installed to produce in a year. Hence, the future worth of the total profit lost, \( P \) to unused capacity at the end of the salvage period of any production equipment was determined from Equation (4) using compound interest approach;

\[
P = P_L(1 + i)^N \tag{5}
\]

Where \( i \) is the interest rate prevailing in the economy. Substituting Equations (2), (3) and (4) into Equation (5) gives the future worth of the profit per unit item sold and number of items that should have been produced but are not because the system is not fully utilized (underutilized capacity) during the salvage period of any production system as;

\[
P = \left( S - \frac{[(M+\omega+D) + p - Z]}{AN} \right) (C - A)(1 + i)^N \tag{6}
\]

Equation (6) is suitable for prediction when the annual production rate, selling price, cost of raw materials, wages, depreciation and other production disbursements remained constant over the salvage period of the manufacturing system. However, this is rarely possible in practice, in order to reduce the effect of variations in
the values of these parameters over the productive life span of the system, their mean values for a given test period \((k > 1\,\text{year})\) should be used for the prediction instead of production data of one year. Hence, accounting for the fluctuation in these production parameters from year to year gives the future worth of the profit that will be lost to underutilization of any production system as;

\[ P = \frac{1}{k} \sum_{k=1}^{N} \left( S - \frac{N[M + W + O]}{A[N + D]} + \frac{k - 2}{N} \right) (C - A)(1 + i)^N \]  

The future worth of the replacement cost, \(R\) of a production system at the end of its salvage period was deduced from capital recovery model of Onwualu et al (2002) as;

\[ R = Z(1 + i)^N - F \]  

Therefore, the percentage ratio, \(T\) of the profit lost to underutilization of a manufacturing system to its replacement cost was determined as;

\[ T = \frac{100[i + i]^N}{kZ[i + i]^N - kF} \sum_{k=1}^{N} \left( S - \frac{N[M + W + O]}{A[N + D]} + \frac{k - 2}{N} \right) (C - A) \]

In order to sidestep lengthy and error-prone manual computations in the use of these models (Equations 7, 8 and 9) and to make their application user friendly, an easy to comprehend object oriented C# dot net program, Rapluc Comparator was also developed for their implementation. This software was designed with an embedded installation setup that installs all its pre-requisite files including the .chm help files offline as a single install pack. System configuration required for this software includes Windows 2000 or higher; 512MB of RAM; 800MB of free disk space; 1024x768 screen resolution or higher and Microsoft.NET framework version 4.0 (64or 32 bits). Its installation involves double clicking on the CD/DVD drive icon on “My Computer” to open the software CD named “Rapluc Comparator” before a double click on the folder named “Rapluc Comparator setup” to run the setup file inside the folder following the prompts to install the software.

Launching of Rapluc Comparator after its installation requires a double click on its HelpNDoc 3 shortcut icon on the desktop (Fig. 1) or click the same on the window start menu to feature the command window of the software (Fig. 2). The command window serves as the main program interface by which operations are performed using its main menu and tool bar. The main menu (Fig. 3) has three major options- “FILE”, “VIEW” and “HELP”. A click on the “FILE” menu displays five different sub-options, “New”, “Existing”, “Export to Excel”, “Print” and “Exit”. A click on “New” opens a window (Fig. 2) for creating a new test record; type in your data in the appropriate text boxes as per each test period or year before a click on “save” to save the inputs and thereafter click on “calculate” to generate the predicted values of \(P\), \(R\) and \(T\) which will be displayed under the “Result” section of the window (Fig. 4). The “Existing” option is used to display the tests sidebar if it is not visible. The side bar shows the list of all the previous tests saved in this program. The “Export to Excel” option allows for exportation of table of data (inputs and predictions) from this application to Microsoft Excel while “Print” is used for printing of works performed directly. “Exit” closes the application. The “VIEW” menu is used to display and hide the Toolbar, Parameter definition and Tests sidebar. The “Toolbar” gives quick access to useful functions like New, Existing, Save, Export, Print, Show all data, Data Summary and Help. “Show all data” button shows the parameters values during all experimental periods for all tests recorded with the predicted values of \(P\), \(R\) and \(T\) while “Data Summary” button shows a table of data for all saved tests (Fig. 5). The “HELP” menu shows two options; “About” and “Help”. The “Help” shows the help file while “About” displays information about the software.

The production data used in the assessment of profit lost to underutilization with this software were obtained using questionnaire approach complemented with physical verification of the data through field visits to thirty-seven manufacturing firms in Nigeria between May and December, 2013. The questionnaire was structured so as to assess all the parameters of the models while the interest rate used in this study is the prevailing mean interest rate of 14.9% in Nigeria during this period.

Fig. 1: Rapluc Comparators HelpNDoc 3 shortcut on the desktop
Fig. 2: Command window of Rapluc Comparator

Fig. 3: Main menu and Toolbar options of the Rapluc Comparator

Fig. 4: Predictions of P, R and T for BEST BITE Company
3.0 Result and Discussion

The Rapluc-Comparator predictions of the profit lost to underutilization, replacement cost and the comparative ratio of these two parameters made from the production data of the thirty-seven Nigerian manufacturing companies investigated are shown in Table 1. This table shows that 21.52% of the industries will lose profit worth more than their equipment replacement cost to underutilization at the end of their systems’ useful life while 35.14% of them will lose profit worth over 50% of their equipment replacement cost. This revealed that capacity planning which amply accounts for both input availability and product demand before design/procurement of production equipment is lacking in the small and medium scale manufacturing sector of this nation. Hence, the high cost of goods from these sectors relative to large scale sector resulting from shifting the cost of unused capacity to consumers, thereby placing the firms in a tight corner in a prevailing competitive economy. The results also revealed high rate of liquidation of manufacturing industries in this nation as a result of the inability of the firms to replace their production facilities as and when due because of huge profit lost to underutilization during the useful life of their facilities.

Table 1: Comparative Analysis of the Profit Lost to Underutilization and Replacement Costs of Production Systems
4.0 Conclusion and Recommendation

Models and their implementation software, Rapluc-Comparator used for evaluating profit that will be lost to underutilization during the useful life of a production system were developed in this study. Analysis of some Nigerian manufacturing industries using this software revealed low capacity utilization rate as one of the major causes of high cost of products of small and medium scale manufacturing firms as well as incessant liquidation of many indigenously owned/managed industries in this country. This is because entrepreneurs at this level are not sensitive to the negative effect of huge profit they sacrifice daily to underutilized capacities on the stability of their firms in a stiff market competition. Rapluc-Comparator is therefore recommended to operators of industries for self-assessment of their potentials for continuous existence and robustness in stiff market competition.

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