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Computer Aided System for Industrial Productivity Performance Determination

B. O. Akinnuli[1] and Ridwan Emiola Asiru[1*]

[1]Department of Mechanical Engineering, Federal University of Technology, Akure, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

One obvious problem in determining productivity especially for small and medium scale companies is the lack of appropriate software to help determine their productivity. This work developed a computer aided system for industrial productivity performance determination for small and medium-scale industries. The industrial productivity assessment application was developed using C# in the visual studio Integrated development environment. The application featured an easy to use and modern graphical interface and PDF report generation functionality. The usage procedure basically involved getting the productivity input data via an administered questionnaire, feeding the input into the Material, Capital, Labour, Energy, Expenses and Output sections respectively and generating the productivity report. In order to evaluate the performance of the developed application, a suitable company "Psaltry International Ltd" was selected as a case study and the data from 2013 to 2019 were used as the test inputs. The input data were also analysed manually and the result were compared with the generated results from the productivity assessment application which duly showed that the result from the productivity application was accurate. Based on this it was recommended that small and medium scale industries should embrace the use of computer aid systems in the management of their productivity.

Keywords: Productivity; industrial productivity; software; small scale industry.

**Corresponding author: E-mail: ridwan.asiru@gmail.com;*

1. INTRODUCTION

One of the biggest concerns for any organization is to improve its productivity, representing the effective and efficient conversion of resources into marketable products and determining business profitability [1]. Consequently, considerable effort has been directed to understand the productivity concept with different approaches taken by researchers, resulting in a wide variety of productivity definitions [2-4].

Production is the process of manufacturing, fabricating or producing certain type of goods, semi-finished or finished, input being basic raw material or semi-finished products or sub-assemblies. A production process or a manufacturing process is the transformation of raw materials or components into finished products. The stages in a production process involve procurement, fabrication, assembly, testing, packaging and distribution.

Productivity can be expressed as the measure of the combined efficiency of employees, machines and equipment, raw material inputs, management performance, efficiency of the whole production system. Productivity can be computed and expressed as the ratio of average acceptable output per period by the total costs incurred through various resources (skill and unskilled labour, input material, power utilized, capital, energy used, total plant hrs worked, and other expenses) consumed in that period. It can be seen as a measure of efficiency of the integrated system comprising of resources like Money, Men, Materials, Machines (4 Ms of an industry) and time etc [5].

Productivity is defined in many ways because different measures of productivity serve different purposes. It is broadly defined as a terminology for the measurement of the effectiveness on employing the management skills, workers, materials, equipment, tools, and working space in order to produce a finished building, plant, structure, or other fixed facility at the lowest feasible cost Prokopenko [6] defines productivity as the relationship between results and the time it took to achieve them. He further noted that time is a universal factor and the lower the time taken to achieve a result, the more productive the system is. It can also be seen as more efficient and effective utilization of capital, land, energy, and information in conjunction with labour.

Development in the world of computing has made the computer a useful tool in solving engineering problems. The computer is able to assess data and process data faster than any other computation method and as such is a very valuable tool for the modern-day engineer. As such the development of computer aided system for industrial productivity assessment is a natural development.

This work intends to develop a software capable of determining total productivity of an industry and evaluate the performance of the software developed using an industry as case study.

2. LITERATURE REVIEW

2.1 Partial Productivity

Partial of factorial is the productivity of individual factors, which contributes to the overall productivity. In order to obviate the difficulty to the overall arising out of diversity of methods of measurement of units of input of different factors (Material, Labour, Overheads) it is convenient to adopt cost as a convenient measure of productivity.

Partial productivity is the ratio of output to partial input. It measures the productivity of each input and essentially determines the contribution of each factor in producing and generating output. The general formula for partial productivity is given below:

$$\textit{Partial Productivity} = \frac{Total\ Output}{Partial\ Input} \tag{1}$$

Different partial inputs can be Labour, Capital, Energy, machinery and materials, etc.

2.2 Labour Productivity

Labour is one of the factors of production as such, the Labour productivity is essentially a very common index amongst the partial productivity. This index describes the major role of labour in manufacturing products or services [7]. The productivity of labour indicates better efficiency and how useful the labour relates to the output produced.

While partial productivities have over time become widely adopted in industries, it does not truly demonstrate the performance variation. This is due to fact that there is a trade-off between the different manufacturing sources [8].

Consequently, an increase in one of the factors of production might lead to reduction in another factor and this will not be captured when calculating with partial productivities since it is the overall output that is compared with a specific input [8].

Salehi, Shirouyehzad and Dabestani [8] noted that there are four methods for calculating the labour inputs: Working time (Man hour), cost for paid labour, the number of labours engaged in target working time and the number of direct labourers. Hara and Hibiki [9] thus considered the "per hour" valuation as the most important measurement of labour productivity and proposed the following

$$Labour\ productivity = \frac{Real\ value\ added}{Labour\ input} = \frac{Real\ value\ added}{employment \times hours\ worked} \quad (2)$$

The labour input in most organisation is often a mix between skilled and unskilled labour as such the labour input (LI) adopted in the development of the software will be

$$\text{Labour input (LI)} = \frac{L_{ush} \times W_s}{D_{sl}} + \frac{L_{ush} \times W_{us}}{D_{usl}} \quad (3)$$

Where: L_{sh} denotes the skilled labour hours; W_s denotes the average wage rate, D_{sl} denotes the deflator for skilled labour, L_{ush} denotes unskilled labour hours, W_{us} represent the wage of unskilled labour and D_{usl} is deflator for unskilled labour.

2.3 Material productivity

Material productivity is essentially the ratio of output to materials input. Productivity is typically represented as the ratio between the output of a production process and its inputs (OECD 2007). Material productivity is a single-factor productivity indicator and measures the effectiveness by which output has been created from each unit of material [10,11] and can be expressed the following way

$$MP_{t,i} = \frac{Y_{t,i}}{M_{t,i}} \quad (4)$$

Where Y represents output, M material input or material use (Mt, i>0), t the time dimension, and i the level dimension (country, firm).

The concept of material productivity has been increasingly standardised, used in the academic literature [12,13] and taken up in a number of statistical offices in industrial countries such as across the EU and Japan [14].

Material consist of direct material and indirect material, Direct material are those which go into the manufacturing of the product, while indirect material represent other consumables such as fuel, chemicals in heat treatment, cutting tools, coolant etc. Material productivity is measured in terms of goods produced [15].

The total material input in production is often expressed as a function of the quantity of raw materials used and the price per unit of raw material. The deflator accounts for changes in price from the base year to the target year when calculating the productivity over a period of time. The material input will be expressed as a

$$\text{Material input (MI)} = \frac{R_m \times P_{pt}}{D_m} \quad (5)$$

Where R_m is raw material in Tonnes, Ppt is price per unit, D_m is material deflator

2.4 Capital Productivity

Capital productivity is the ratio of output (goods or services) to the input of physical capital. Improving physical capital (known as capital deepening) typically yields an increase in output. The capital input to manufacturing organisation can be roughly estimated as a product of the cost of running the plant per hour and the total number of hours worked. This is shown below:

$$Capital\ Input(CI) = \frac{T_{pms} \times P_{hr}}{D_p} \quad (6)$$

Where: Tp_{hw} is total plant hours works, P_{hr} is the plant hour rate, Dp is plant hour rate deflator (the change in the plant hour rate is factored in via the plant hour rate deflator).

2.5 Energy Productivity

Energy productivity (EP) of an industry is measured by relating the energy consumption of an industry (input) to its output. Although with advent in technology, different innovative energy sources have been adopted by manufacturing industries and other organisations around the globe, oil and electricity still remains a major source of energy for production. Energy input can be related as shown below

$$Energy\ Input(EI) = \frac{O_l \times P_{pl}}{D_o} + \frac{O_e}{D_{oe}} + \frac{E \times E_r}{D_e} \quad (7)$$

Where O_l is litres of oil used; P_{pl} is price per litre of oil used; D_e is energy deflator; O_e is other energy used; D_{oe} is deflator of other energy used; E is electricity unit used, E_r is rate per kWh, $D_e$is energy deflator.

2.6 Input Deflator

In statistics, a deflator is a value that allows data to be measured over time in terms of some base period, usually through a price index, in order to distinguish between changes in the money value of a gross national product (GNP) that come from a change in prices, and changes from a change in physical output. It is the measure of the price level for some quantity. A deflator serves as a price index in which the effects of inflation are nulled. It is the difference between real and nominal GDP

2.7 Total Input

Therefore total input for the current period (TIP) $_i$ is a function of the sum the different partial input as shown below

$$(TI)_i = \sum[LI, MI, CI, EI, OE]_i \quad (8)$$

$$(TI)_i = Li + Mi + CIi + EIi + OEi \quad (9)$$

Where L_i is Labour Input; M_i is Material Input; C_i is Capital input; E_i is Energy Input; OE is Other Energy Input

2.8 Total Output

The total plant output for a period of time is function of the finished goods and the work in progress.

$$[TOP]_i = \frac{(F_{gp})_i \times (P_{pu})_i}{Df_n} + \frac{(W_{ip} \times \%C_P \times P_{pu})}{Df_{oe}} + \frac{D_{vs}}{D_{dS}} \quad (10)$$

Where:
F_{gp} is the mass of finished goods produced in tonnes, P_{pu} is price per unit hour (*i*),
D_{fn} is the deflator, factor (i), W_{ip} is work in progress, C_p is percentage completed;
D_{foe} is deflator for other expenses, D_{vs} is dividend from security (i), D_{ds} is deflator for dividend form security.

2.9 Total Productivity Measurement or Overall productivity

The total productivity is thus a ratio of the different productivities

Total productivity measure (TPM) = $\frac{[TOP]i}{[TIP]i}$

Where, $[TOP]_i$ is total output for any year i and $[TIP]_i$ is total input of any year;

Labour productivity $[LP]_i$ = $\frac{[TOP]i}{[LI]i}$

Capital productivity $[CP]_i$ = $\frac{[TOP]i}{[CI]i}$

Material Productivity $[MP]_i$ = $\frac{[TOP]i}{[MI]i}$

Energy Productivity $[EP]_i$ = $\frac{[TOP]i}{MEIi}$

Other expenses productivity $[OEP]_i$ = $\frac{[TOP]i}{[OEI]i}$

3. MATERIALS AND METHODS

3.1 Development of Software

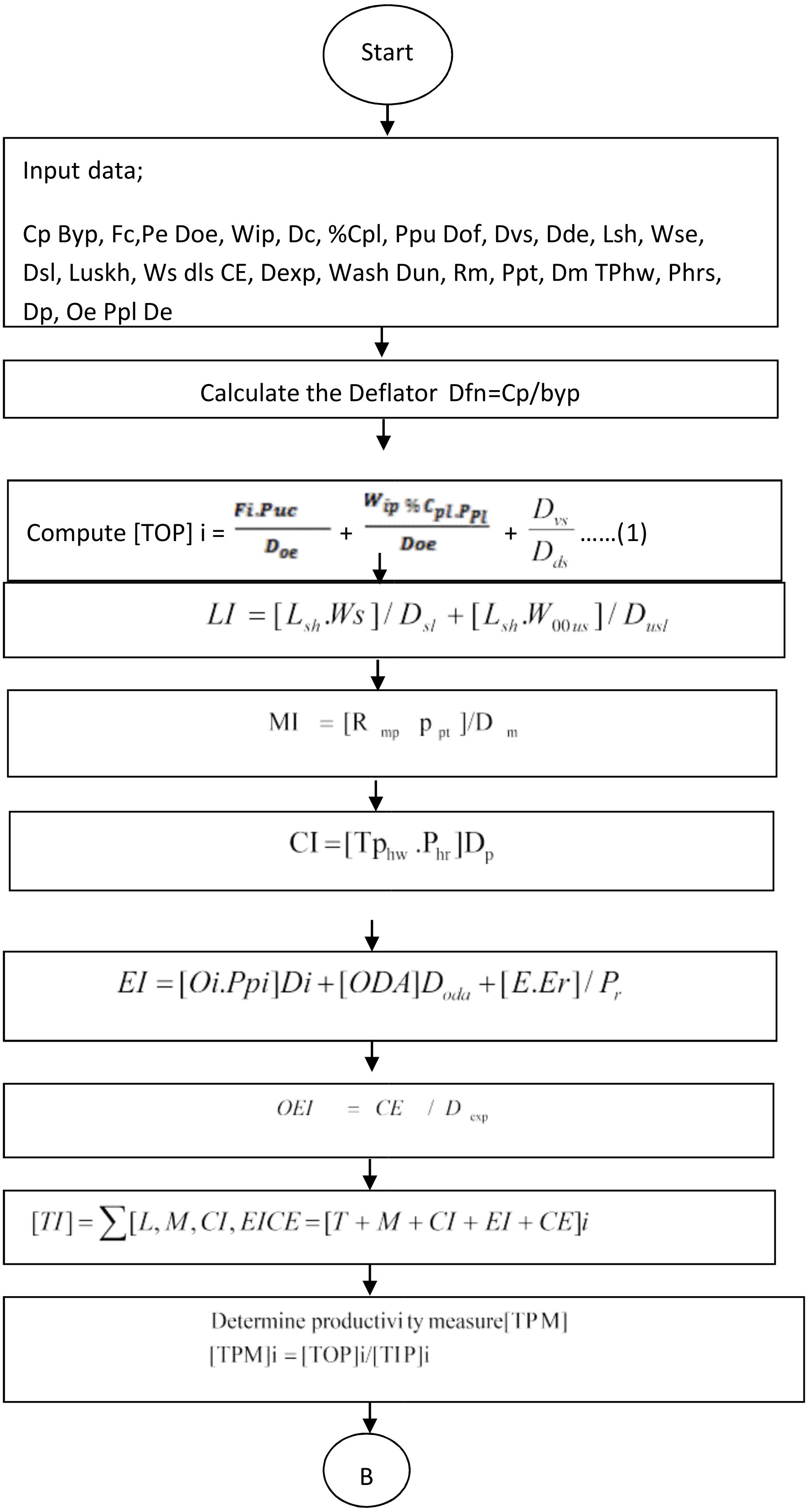
The software was developed using the C# programming language. The software was done using the visual studio integrated environment (IDE). The inputs to the software was collected as text input via the input field in the graphical user interface GUI of the developed software. The basic required inputs parameters are skilled labour (hrs), unskilled labour (hrs), materials, total plant hrs worked, energy used, other expenses, finished goods produced, work in progress, percentage of completion, price per unit, dividend from security, deflator for dividend.

The final output was an installable executable file (.exe) and the expected output will be the productivity ratio and index table. The flow chart below shows the different input stages and expected output for the developed software.

3.2 Case Study

In order to generate accurate data for testing and performance analysis of the software, a suitable case – study was selected. An ideal case study is an organization with well documented records of inputs and outputs spanning a couple of years.

Psaltry International Company Limited (PIL) is an agro-allied company located in Ado-Awaye in Oke-Ogun area of Oyo state. Its focus is the production of Starch and High Quality Cassava Flour. The company has a production combined capacity of about 35,000 MT of various cassava based products including starch, sorbitol, flour and glucose. At present, it has over 8000 hectares of land which it outsources to farmers for its out-grower scheme.



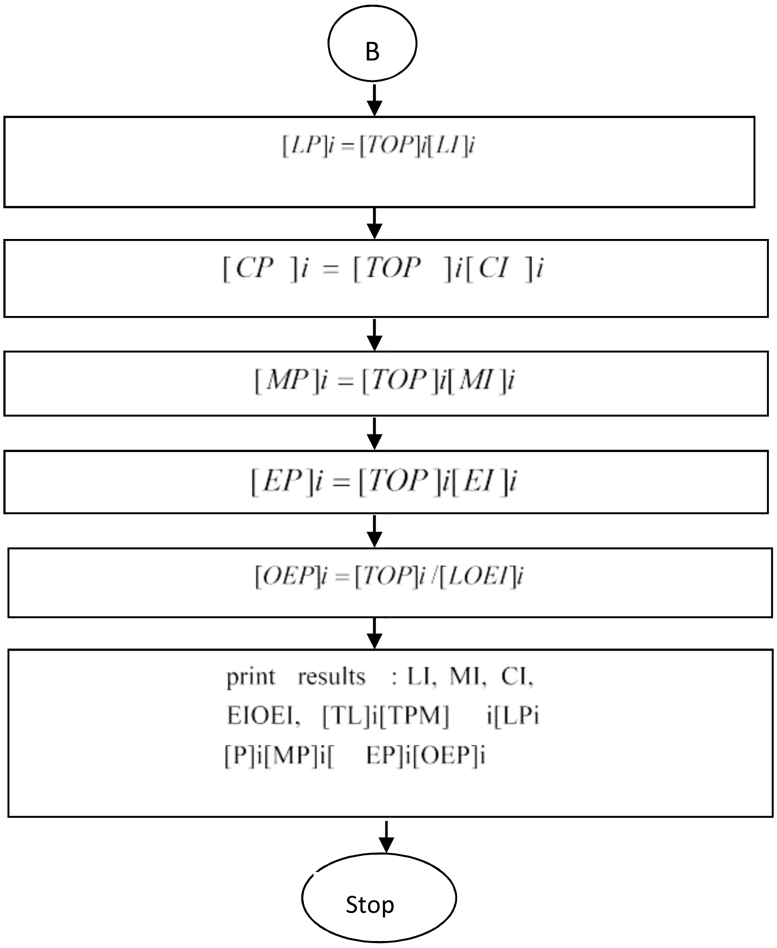


Fig. 1. Software Logic

3.3 Questionnaire Design

The questionnaire was designed to essentially collect quantitative information on the different inputs outlined for the software. The questionnaire was divided into 3 main sections; A, B and C respectively. Section A was designed to collect relevant information relating to the organisation while section B, and C were designed to collect the organisation's output data and the different inputs parameters respectively.

3.4 Performance Evaluation

In order to test the performance of the developed software, a suitable questionnaire was developed and administered to a test company. The questions where structured to obtain the required quantitative information for the various partial productivity inputs. The inputs where inserted into the required fields on the software and further used to test the accuracy of the software against the values obtained from manual calculations

4. RESULTS AND DISCUSSION

The models of productivity measures were used to develop the productivity application software. The software for productivity models application was created in C# programming using the Visual Studio IDE and compiled into an executable file (.exe). The final executable file is compatible with both 64-bit and 32-bit system architecture.

The software was developed with a relatively simple and easy to use graphical user interface (GUI). On start of the application, the user is presented with a security interface for either registration or login. A successful login operation consequently gives the user access to the main application interface to either create a new organization/company's record or update existing ones as shown in Fig. 2 below. Fig. 3 shows the flowchart of the operation of the software.

Fig. 2. Graphical Interface of developed software

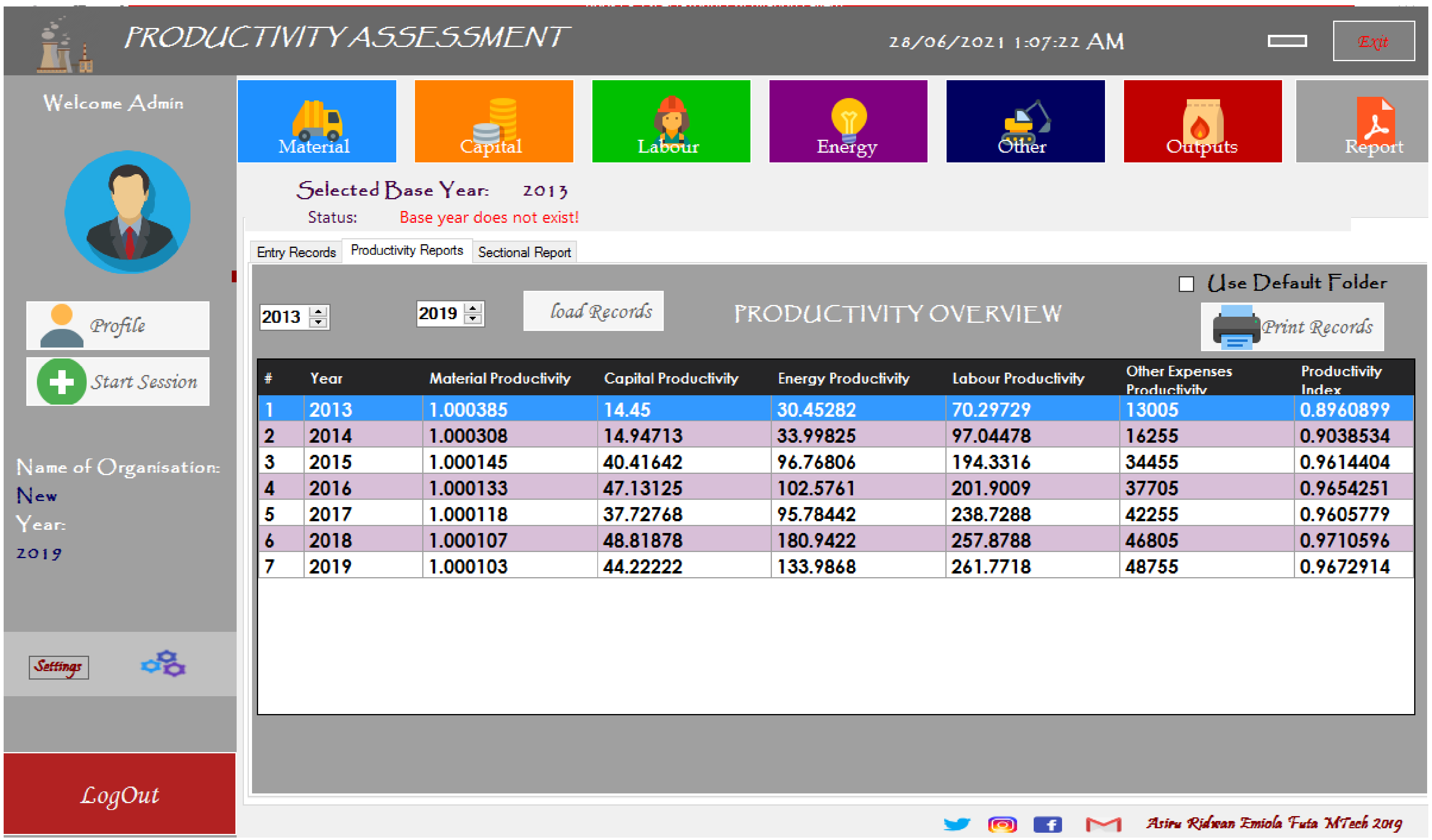


Fig. 4. Partial Productivity and Overall Productivity of Psaltry International Ltd

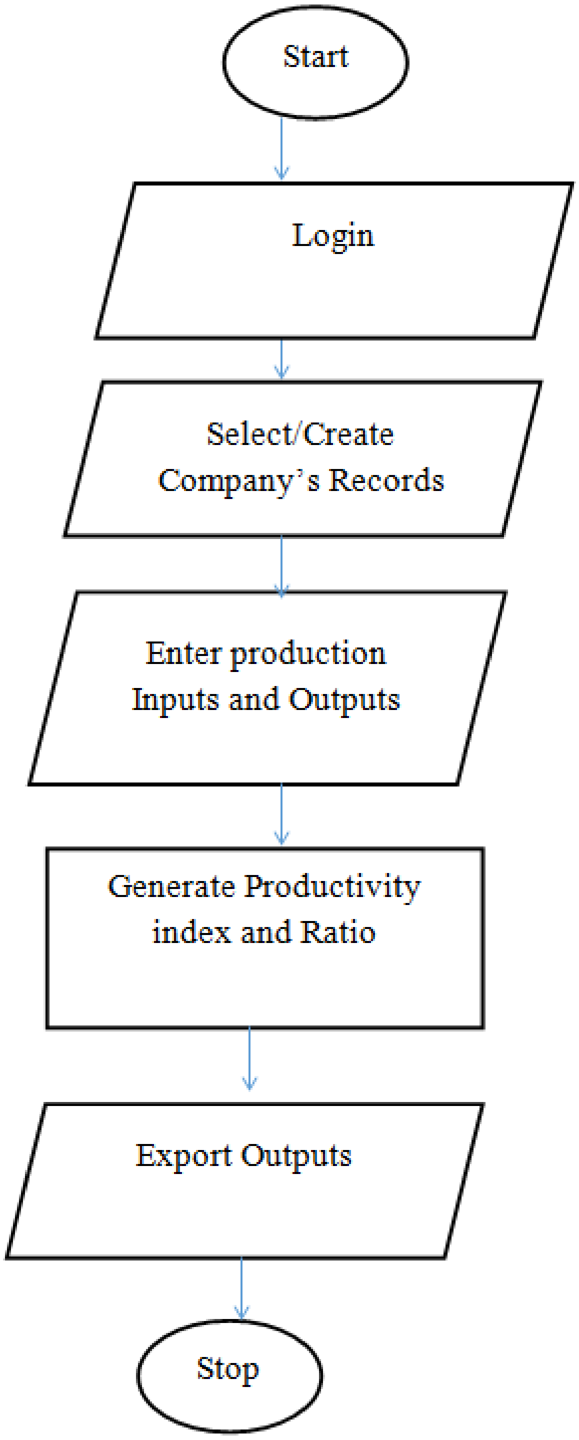


Fig. 3. Flow chart on operation procedure

4.1 Performance of the Software Developed using an Industry as Case Study

To test the accuracy of the software, Psaltry International Limited was selected as the case study. Questionnaires were administered at the company and data gotten from the administered questionnaire were used logged in into the various inputs category of the software. Fig. 4 shows the output of software showing the material productivity, capital productivity, labour productivity, energy productivity, other expense productivity and the productivity index of the company.

5. CONCLUSION AND RECOMMENDATION

The proposed industrial productivity assessment application was successfully developed using C# in the visual studio Integrated development environment. The application featured an easy to use and modern graphical interface and PDF report generation functionality. The usage procedure basically involved getting the productivity input data via an administered questionnaire, feeding the input into the Material, Capital, and Labour, Energy, Expenses and Output sections respectively and generating the productivity report.

The productivity application allows the user create accounts for different companies and generate their corresponding report as well as select any valid year as the base year against which the inputs of other years are to be compared.

Small and medium scale industries are advised to embrace the use of computer aided system in order to evaluate the productivity of their workers as well as improve their overall productivity as it is economical to use the application for the determination of small and medium scale industries.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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