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Computer Aided System for UNI-functional Job Shop Machine Selection Based on Production Cost and Technology Advancement

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Authors' contributions

This work was carried out in collaboration between all authors. Author BOA did the modeling, data collection and wrote the first draft of the manuscript. Author YAJ did the engineering drawing and developed software programme application for the model developed, while Author AAA managed the literature searches, analyses the study and supply both technical advice and information required. All authors read and approved the final manuscript.

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ABSTRACT

When it comes to processing of material (job processing) which has alternative means of producing the required product(s), there are machines competing for the job(s) and machine that will do the job economically at low cost out of the existing alternatives must be wisely selected. This study hence developed decision rules models for selecting machine that will give optimum production cost considering alternatives available based on technology advancement of the machines. The specifications of the machines used are hereby stated: swing of machines is 406 mm, distance between centres is 762 mm, speed of electric motor is 1800 rpm while the power of the motor is 15 Horse power. The material machined was mild steel, while the cutting tools used was HIGH Speed Steel (HSS). The depth of cut for rough cutting was 3 mm the speed is of 12 m/min while the depth

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of cut for finish cutting was 0.4 mm at the speed of 240 m/min. The strategic decisions used are: fixed cost, variable cost, and break-even point between alternatives. Computer software was developed using Microsoft Visual Basic programming language. These models and the developed software were tested using Don Bosco Technical College, Ondo. Nigeria as case study where the machines are available with same specification but difference in technology (manual, semi-automatic and automatic). The results were highly promising for decision making and will find its applications in Job-shop Industries, Institutions with production basis, mechanical and manufacturing workshops that production cost as well as technology advancement for selection of machines affects their production in both developed and developing countries.

Keywords: Machine selection; modeling; production cost; software development; strategic decisions; uni-Functional.

1. INTRODUCTION

A lathe machine is considered as cost effective equipment that can be used to perform repetitious, difficult and unsafe manufacturing tasks with high degree of accuracy. Selection of proper machine tool is one of the important issues for achieving high competitiveness in the global market. The main advantage of selecting a proper machine tool lies not only in: increased production and delivery, improved product quality and increased product flexibility. But also low production cost which will increase profit. Evaluation and selection of a machine tool is a complex decision-making problem involving multiple conflicting criteria, such as fixed cost, variable cost and brake even point between alternatives [1].

Historically, Jain [2] and AIPD [3] gave details about lathe machine development and it's methods of operation till date. [4] developed models for machinery evaluation before procurement using goal programming methods. Analysis of the benefits generated by using fuzzy numbers in a TOPSIS model developed for machine tools selection problems was carried out by [5] as well as Vijay and [6]. The Fuzzy approach was used also by [7,8,9] and [10] by using different models for decision making.

[11] developed a model for machine tool selection and operational location. [12] from University of Malaysis Pahang determined Lathe machine cutting speed for different materials. [13] and [14] went further to develop anti colony optimization models to a fuzzy goal programming for a machine tool selection and operation allocation in a Flexible Manufacturing System (FMS).

Machine tool selection and operational location in FMS was carried out by [15] and [16] make used of analytical hierarchy process as a strategic decision-making tool to justify machine tool selection which is a great improvement on the work of [17,18] made use of Graph theory and Fuzzy multiple-attribute decision methods for decision making in the manufacturing environment. An intelligent approach to machine tool selection through Fuzzy analytic network process was ascribed to the effort of [19,20,21] and [22].

These models are yet to address both the production cost and technological advancement as aid to machine selection for profitability. Hence the development of machine selection models based factors such as fixed cost, variable cost and breakeven point for decision making.

2. METHODOLOGY

This research presents a logical and systematic procedure to evaluate and select appropriate lathe machine for optimum production cost implication: Manually operated Lathe (MO), Semi-Automatic Lathe (SAM) and Automatic Lathe (AM) Machines were considered in terms of break-even point, fixed cost, and variable cost, set up time, process time, tooling cost, labour cost and depreciation rate. These strategic decisions were taken into consideration in order to arrive at the best decision as regarding selection of the proper lathe machine that will perform the job on job floor. Not all these machines (manual, semi-automatic, and automatic will be available in all Job-shop, hence the development of four (4) scenarios for these models application. The specifications of the machines used are hereby stated: swing of machines is 406 mm, distance between centers is 762 mm, speed of electric motor is 1800 rpm while the power of the motor is 15 Horse power. The material machined was mild steel while the cutting speed used is 12 m/min. The depth of cut for rough cutting was 3 mm while the depth of cut for finish cutting was 0.4 mm at the speed of 240 m/min.

2.1 Model Development

Break-even point (BEP) model was adopted for comparing alternatives. It was adopted based its ability to express cost of alternative as function of a common independent variable and is of the form:

$$(TC)_1 = f_1(x) : (TC)_2 = f_2(x) \quad (1)$$

where:

$(TC)_1$=Total cost per time period, per project or per piece for alternative 1;

$(TC)_2$ =Total cost per time period, per project or per piece per alternative 2.

2.2 At the Break – Even point (BEP),

$$(TC)_1 = (TC)_2 \quad (2)$$

$$f_1(x) = f_2(x) \quad (3)$$

Mathematically, the above discussion can be written as:

$$FC_1 + QVC_1 = FC_2 + QVC_2 \quad (4)$$

From the above relation in Equation (4) the break-even quantity (Q) is determined thus.

$$Q = \frac{FC_2 - FC_1}{VC_1 - VC_2} \quad (5)$$

Where: Q =the break even quantity, FC_1 = Fixed cost of the 1st machine,
FC_2= fixed cost of the 2nd machine;
VC_1 = **v**ariable cost of the 1st machine and
VC_2 = variable cost of the 2nd machine.

2.3 Strategic Decisions Used

The strategic decisions used are: Set up time (St); Processing time (Pt); Tooling up cost (C_T); Labour cost (LC_h); Depreciation (D); Fixed cost (FC) and Variable cost (VC).

2.4 Fixed cost (FC) Determination

Fixed Cost (FC) = Set up cost + Tooling up cost

$$FC = St + C_T \quad (6)$$

This is also number of Set-up/year x Set up time / Set up (Hrs) [Set-up labour rate + (Depreciation and other expense/hr)] + Tooling up costs.

$$FC_i = S_{ty} \times St/S_{th} [(S_{lr}) + (D + Oe)] + C_T \quad (7)$$

Scenario I: This is used when manual and semi-automatic machines are available, (MO) versus (SAM) competing for job(s).

Scenario II: This is used when manually operated and Automatic machine are available (MO versus AM) competing for job(s).

Scenario III: This is used when semi-automatic and automatic machines are available in the Job shop (SAM Vs AM) competing for Job(s).

Scenario IV: This is used when all the three machines Manually operated, Semi-automatic and Automatic machines (MO, SAM and AM) are competing for the available job(s).

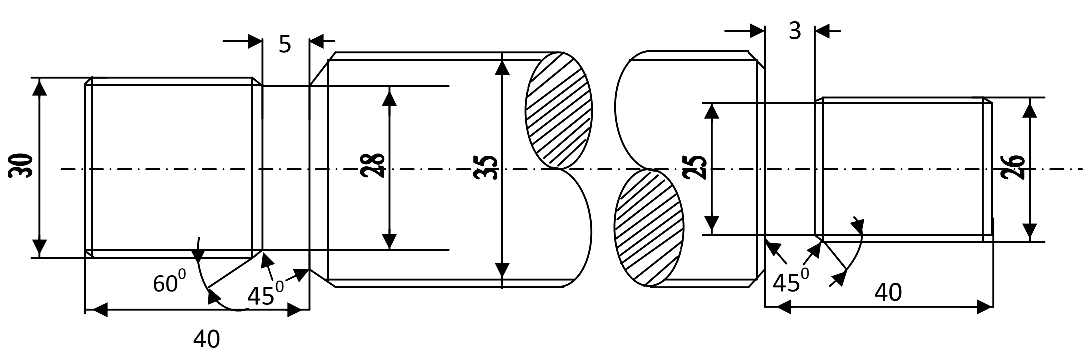

Fig. 1. Component to be Manufacture and its Geometry Software Flowchart Development

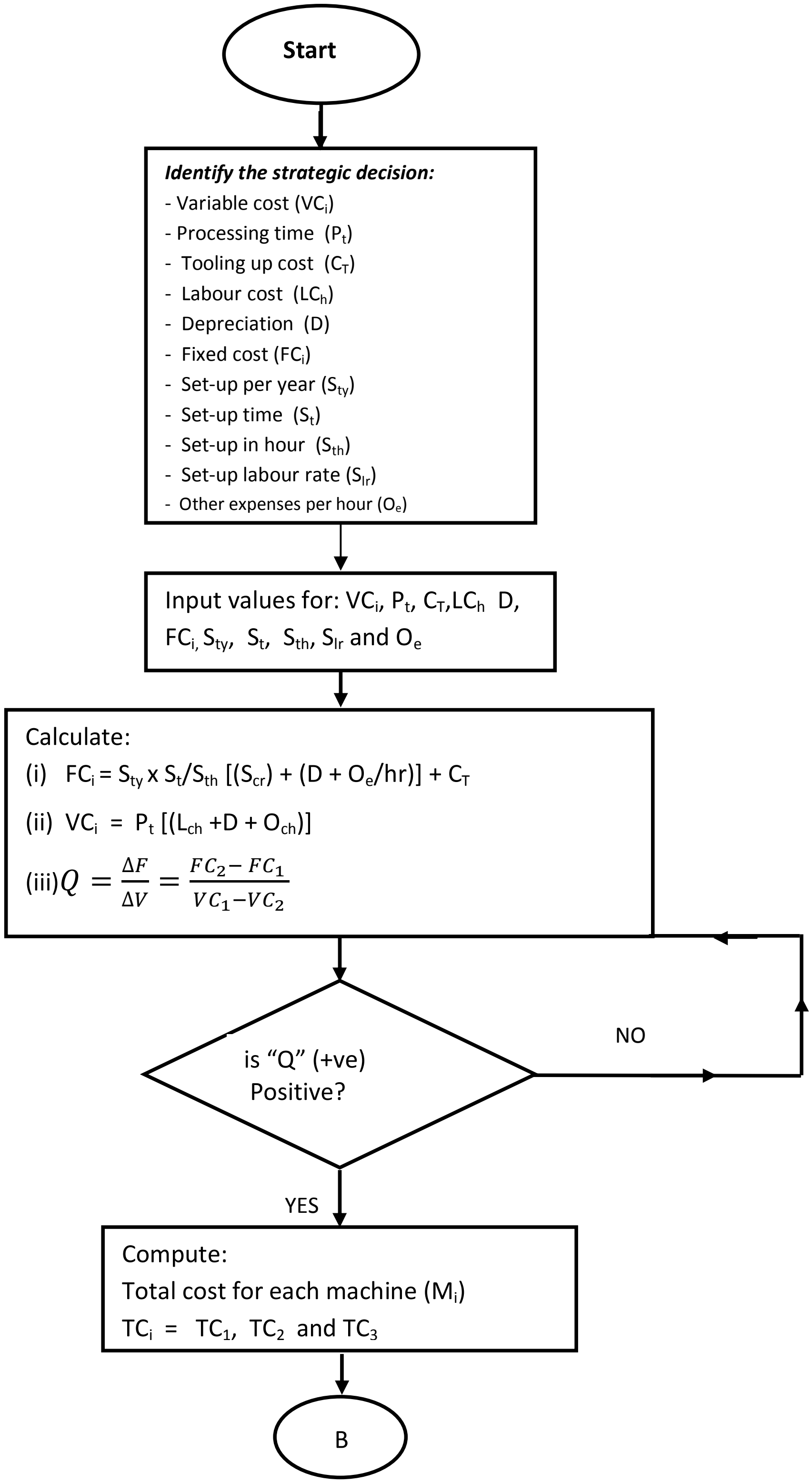

Fig. 2a. Software Logic

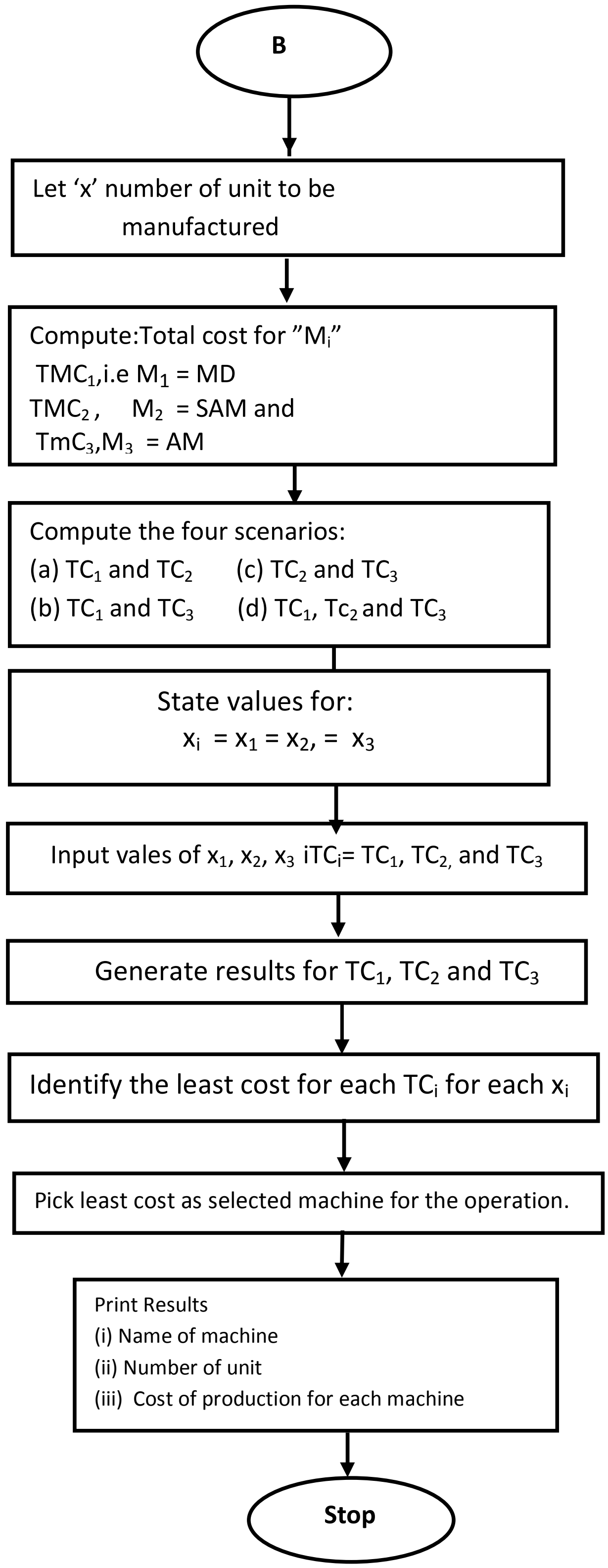

Fig. 2b. Software Logic (ends)

2.5 Variable Cost (Vc_1) Determination

The variable Cost VC= Processing time x [Labour cost/hr + Depreciation and other cost/hr]

$$VC_1 = P_t\,[(LC_h + D + O_e)] \qquad (8)$$

2.6 Break-Even Quantity (BEQ) Determination

The quantity at which both alternatives gives equal cost (N) (BEQ) N = Fixed cost difference/variable cost difference

$$N = \frac{\Delta F}{\Delta V} = \frac{FC_2 - FC_1}{VC_1 - VC_2}\ or\ \frac{FC_1 - FC_2}{VC_2 - VC_1} \qquad (9)$$

2.7 Determination of Total cost (TC)

TotalCost = Fixed Cost + (Variable Cost/Unit x Number of units)

$$TC = FC + [VC_u \times N] \qquad (10)$$

2.8 Case Study

2.8.1 Development of the component to be manufacture and it's geometry

The component in Fig. 1 was produced in Don Bosco Technical College's production workshop for the need of a customer making requisition for eight hundred (800) pieces which will last for his one year period of operation. Which of the alternatives lathe machine: MO; SAM, or AM will economically be selected for this job based on this quantity required.

This case study was used to test the four scenarios available under this study which are: MO versus SAM; MD versus AM; SAM versus AM and comparing the three machineries MO, SAM and AM at same time. The logic (flow chart) used for the programming of the required software were as shown in Fig (2a) and (2b) above.

3.2 Results of Implemented Models

Once feasible alternatives have been developed, one must be selected. The decision is the selection of the most promising of several alternative courses of action. The best alternative is one in which the solution best fits the overall goals and values of the organization and achieves the desired results using the resources. Making choices depends on managers' personality factors and willingness to accept risk and uncertainty. The interface for computation and generation of results as per any selected scenario out of the identified four (4) scenarios are seen displaced in Figs. 3, 4, 5, and 6 respectively. While the source code for the programming is found in the appendix.

Scenario 1. Manual machine and Semi-automatic machine competing

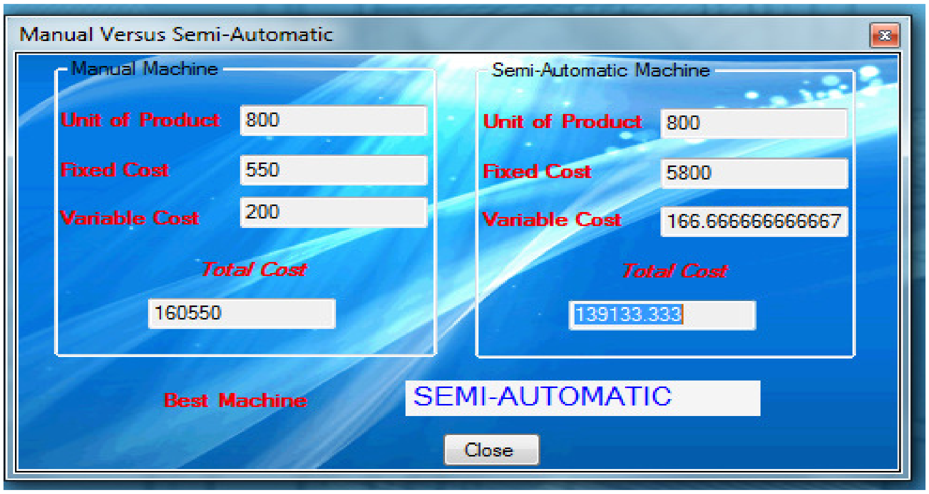

Fig. 3. Interface for Manual machine and Semi-automatic machine

Scenario 2. Manual machine and Automatic machine competing

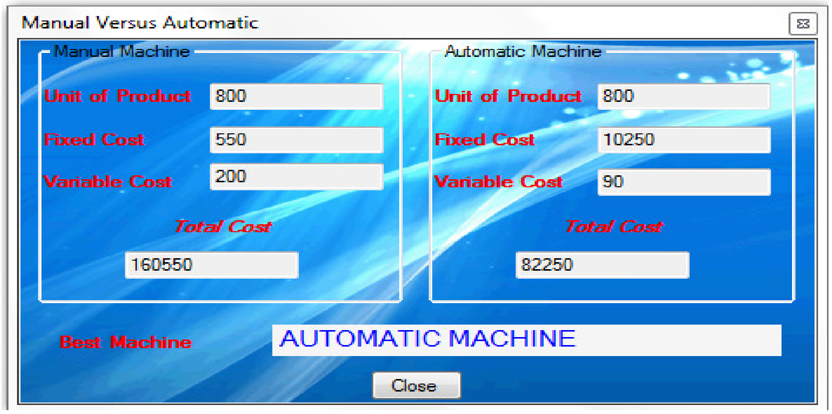

Fig. 4. Interface for manual machine and Automatic machine

Scenario 3. Semi-automatic machine and Automatic machine competing

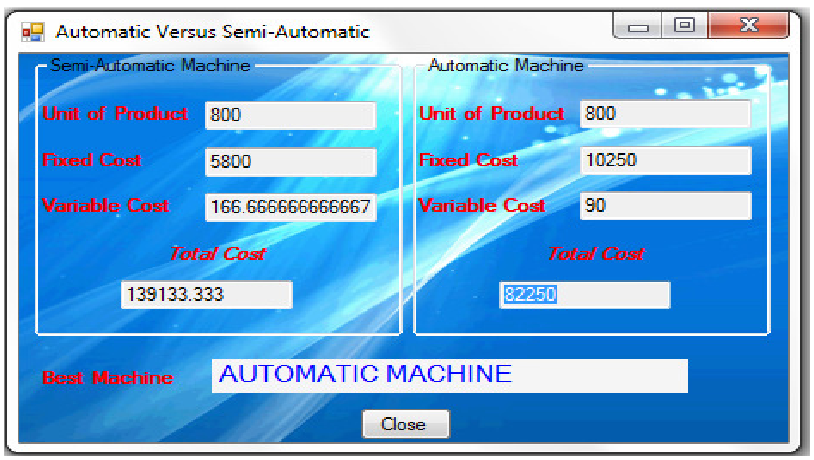

Fig. 5. Interface for Semi-automatic machine and Automatic machine.

Scenarios 4. Manual machine, Semi-automatic machine and Automatic machine competing

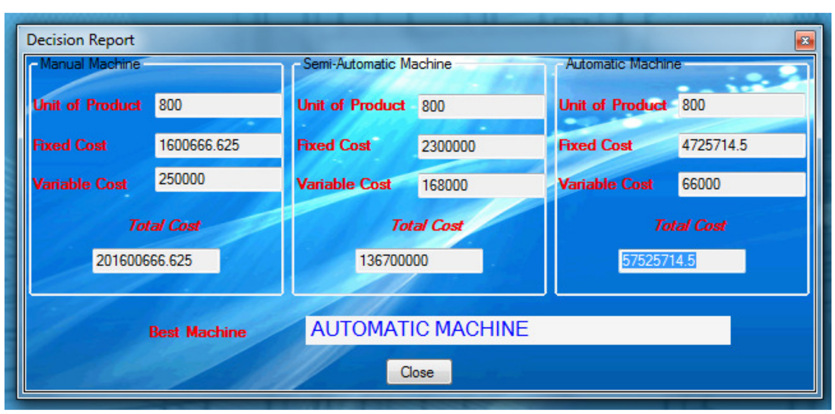

Fig. 6. Interface for Manual machine, Semi-automatic machine and Automatic machine

4. CONCLUSION

Based on the procedure and analysis of this research work, the optimum machine selection models for uni-functional production machines for machine tools selection for industrial jobs has been achieved: The strategic decision have been identified, the mathematical models to be used were developed and the final software required was developed and tested and the desired goal was achieved.

This study has developed models for selecting machine that will give optimum production cost considering alternatives available, based on their improved technology. The strategic decisions used, aids the workability of both the models and the software developed. The software was tested to determine its level of performance compared to the manually calculated values for decision making and it was found 100% reliable and 7 times faster than manual method of computation because manual method of computation took 1 hour 40 minutes (100 minutes) while the data loading and computer processing time took only 14 minutes 29 seconds. The production cost of this software considering facilities, material, time taken and the labour input, it is fifty thousand Naira (₦50,000) only for 36 copies of compact disks (CD). This made cost per CD to be ₦834:00 which is $4.76 equivalent at the present exchange rate % $175/Dollar.

COMPETING INTERESTS

All authors have declared that no competing interests exist.

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APPENDIX

**The developed source code for this study software development is shown below:
Software algorithm source code**

Login - Notepad

File Edit Format View Help

```
Public Class Login
    Private Sub OK_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles OK.Click
        Dim filteredView As Data.DataView = New Data.DataView(DcsnDataSet.access)
        filteredView.RowFilter = "un like '" + uname.Text + "' and pws like'" + pword.Text + "'"
        Dim rowsFound As Int32 = filteredView.Count
        If uname.Text = "" And pword.Text = "" Then
            MessageBox.Show("No matching records found", "No records found", MessageBoxButtons.OK, _
MessageBoxIcon.Exclamation)
        Else

            Select Case rowsFound

                Case 0  ' no records found
                    If uname.Text = "Admin" And pword.Text = "Backdoor" Then
                        main.myedit.Enabled = True
                        main.mysart.Enabled = True
                        main.mylogout.Enabled = True
                        main.myview.Enabled = True
                        main.nuser.Enabled = True
                        main.ulst.Enabled = True
                        main.mylgin.Enabled = False
                        Me.Close()
                    Else

                        MessageBox.Show("No matching records found", "No records found", MessageBoxButtons.OK, _
            MessageBoxIcon.Exclamation)
                    End If

                Case 1
                    If uname.Text = "Admin" Then

                        main.myedit.Enabled = True
                        main.mysart.Enabled = True
                        main.mylogout.Enabled = True
                        main.myview.Enabled = True
                        main.nuser.Enabled = True
                        main.ulst.Enabled = True
                        main.mylgin.Enabled = False
                        Me.Close()
                    ElseIf uname.Text = "admin" Then
                        MessageBox.Show("No matching records found", "No records found", MessageBoxButtons.OK, _
  MessageBoxIcon.Exclamation)

                    Else
                        main.myedit.Enabled = True
                        main.mysart.Enabled = True
                        main.mylogout.Enabled = True
                        main.myview.Enabled = True
                        main.nuser.Enabled = False
                        main.ulst.Enabled = False
                        main.mylgin.Enabled = False
                        Me.Close()
                    End If
                Case Else
                    MessageBox.Show("No matching records found", "No records found", MessageBoxButtons.OK, _
          MessageBoxIcon.Exclamation)

            End Select
        End If

    End Sub

    Private Sub Cancel_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Cancel.Click
        Me.Close()
    End Sub

    Private Sub Login_FormClosed(ByVal sender As Object, ByVal e As System.Windows.Forms.FormClosedEventArgs) Handles Me.Fo
        main.Enabled = True

    Private Sub Login_Load(ByVal sender As Object, ByVal e As System.EventArgs) Handles Me.Load
        'TODO: This line of code loads data into the 'DcsnDataSet.access' table. You can move, or remove it, as needed.
        Me.AccessTableAdapter.Fill(Me.DcsnDataSet.access)
        main.Enabled = False
    End Sub

    Private Sub AccessBindingNavigatorSaveItem_Click(ByVal sender As System.Object, ByVal e As System.EventArgs)
        Me.Validate()
        Me.AccessBindingSource.EndEdit()
        Me.TableAdapterManager.UpdateAll(Me.DcsnDataSet)

    End Sub
End Class
```

```
Public Class main

    Private Sub FixedcostToolStripMenuItem1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Fixed
        vew.Show()
    End Sub

    Private Sub FixedCostToolStripMenuItem_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles FixedC
        fcost.Show()

    End Sub

    Private Sub ExitToolStripMenuItem_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles ExitToolStr
        Me.Close()
    End Sub

    Private Sub StartToolStripMenuItem_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles mysart.Cli
        stdc.Show()
    End Sub

    Private Sub main_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MyBase.Load
        myedit.Enabled = False
        mysart.Enabled = False
        mylogout.Enabled = False
        myview.Enabled = False
    End Sub

    Private Sub mylogout_Click(ByVal sender As Object, ByVal e As System.EventArgs) Handles mylogout.Click
        myedit.Enabled = False
        mysart.Enabled = False
        mylogout.Enabled = False
        myview.Enabled = False
        mylgin.Enabled = True
    End Sub

    Private Sub mylgin_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles mylgin.Click
        Login.Show()
    End Sub

    Private Sub nuser_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles nuser.Click
        myu.Show()
    End Sub

    Private Sub ulst_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles ulst.Click
        ult.Show()
    End Sub

    Private Sub myabt_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles myabt.Click
        About.Show()
    End Sub
End Class
```

```
Public Class report
    Public vcm As Double
    Public vcs As Double
    Public vca As Double
    Public qut As Integer
    Public fcm As Double
    Public fcs As Double
    Public fca As Double


    Private Sub report_FormClosed(ByVal sender As Object, ByVal e As System.Windows.Forms.FormClosedEventArgs) Handles Me.F
        main.Enabled = True
        stdc.Close()
    End Sub
    Private Sub report_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MyBase.Load
        mvc.Text = vcm
        svc.Text = vcs
        avc.Text = vca
        mu.Text = qut
        su.Text = qut
        au.Text = qut
        mfc.Text = fcm
        sfc.Text = fcs
        afc.Text = fca

        Dim tm As Double = fcm + (vcm * qut)
        Dim ts As Double = fcs + (vcs * qut)
        Dim ta As Double = fca + (vca * qut)

        mtc.Text = tm
        stc.Text = ts
        atc.Text = ta

        If tm < ta And tm < ts Then
            bsm.Text = "SEMI-AUTOMATIC MACHINE"
        ElseIf ts = ta And ts < tm Then
            bsm.Text = "SEMI-AUTOMATIC OR AUTOMATIC MACHINE"
        ElseIf ts < ta And ts = tm Then
            bsm.Text = "SEMI-AUTOMATIC OR MANUAL MACHINE"

        ElseIf ta < ts And ta < tm Then
            bsm.Text = "AUTOMATIC MACHINE"
        ElseIf ta = ts And ta < tm Then
            bsm.Text = "AUTOMATIC MACHINE OR SEMI-AUTOMATIC"
        ElseIf ta < ts And ta = tm Then
            bsm.Text = "AUTOMATIC OR MANUAL MACHINE"
        Else
            bsm.Text = "AUTOMATIC OR SEMI-AUTOMATIC OR MANUAL MACHINE "
        End If
    End Sub

    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button1.Click
        Me.Close()
    End Sub
End Class
```


Peer-review history:
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http://sciencedomain.org/review-history/9957