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Maintaining optimum balance between multiskilling and inventory in assembly line operations under dynamic demand

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Maintaining optimum balance between multiskilling and inventory in assembly line operations under dynamic demand

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Abstract

There is always demand variability in case of assembly line operations which can be absorbed either by multi-skilling of operators on the assembly line or by holding finished goods inventory. My thesis examines trade-offs between these two groups of policies by developing a simulation-based model. Model tries to capture different scenarios in terms of combination of inventory policies at different production rate which are evaluated for their cost implications; the idea is to enable decision makers to choose the best policy depending upon the situation specific parameters. A case study to illustrate the proposed model will be presented. A visual basic model to identify training needs in case of multiskilling will also be developed.
Acknowledgements

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LIST OF ABBREVIATIONS

A(n) = output during period n (units)

AI(n) = inventory available in period n (units)

BL(n) = backlog of demand during period n (units)

Davg = average demand (units/period)

D(n) = demand during period n (units)

DO(n) = desired dispatch quantity during period n (units)

EC = expected number of changeovers carried out (number/year)

EI = expected inventory level (units)

ES = expected shortages level (units)

ESL = expected service level (percentage)

I(n) = inventory at the end of period n (units)

NOC = number of changeovers

NOW(n) = number of workers required in period n

NPAI = number of inventory periods

NPBL = number of backlog periods

NPV = net present value

P_{w(n), MAX} = maximum production rate with workforce w(n) in period n

Q(n) = actual production output during period n (units)

RG = range of demand (units)

SS = safety stock (units)

T = number of simulated periods

TWE = total training requirement (worker-element)
Chapter 1  Introduction

In response to the market pressures for greater product variety coupled with smaller batch size and quicker delivery, intelligent flexible assembly systems are being adopted by many companies in developed countries. However, only large and well-established companies are positioned to benefit from them. In consequence, the penetration of advanced assembly technologies has been woefully slow. Use of dedicated manual assembly line is the most common assembly practice in many less developed industrial societies. One of the cost-effective strategies is to have flexible assembly line operations that ensure the matching of the production rate with the demand rate. The need for multi-skilling of a workforce becomes a major issue in the operations of flexible assembly besides team working. This flexibility provides many alternative means for operating the line by changing the number of workstations, and hence the number of workers, with the change in demand.

There are many benefits of having production rate equal to demand rate with a flexible workforce. These benefits include saving in storage and inventory carrying costs, reduced lead times, increased quality and increased flexibility. The cost involved in the flexible assembly line operations is in the form of training the workers for multi-skilling. Thus there is a need for economic analysis of the multi-skilled workforce for flexible assembly line operations.

In this study, economic trade-off between the cost of developing a multi-skilled workforce and cost of carrying inventory is examined. Four alternative policies having different combinations of multi-skilled workforce and inventory are examined. Their parameters are determined through simulation and visual basic program for giving the desired service level.
A summary of steps involved in the thesis is given below:

(1) Selecting a suitable model for line balancing.

(2) Developing a mathematical model for different inventory and multiskilling policies.

(3) Determining the parameters of the policies, using simulation.

(4) Executing the Visual Basic model for different production rates, to find station assignments and need for multi-skilling in different production scenarios.

(5) Comparing the economic performance of the alternative policies to select the best policy.
Chapter 2   Literature Review

In today’s competitive world with all the advanced forecasting tools, determining the actual customer demand is still very difficult. Aggregate planning helps to balance the conflicting objectives of maximizing customer service, minimizing inventory investments, maintaining a stable workforce, minimizing production cost and maximizing profits (Krajewski and Ritzman, 1992). This necessitates a trade-off among various cost factors. Higher service levels are possible by keeping high inventory, but this would result in high production cost. On the other hand, low inventories may result in shortages and poor service level.

Multi-skilled workforce is another strategy with the help of which it is possible to achieve high service level with low inventories. Thus it is possible to achieve high service levels at lower production cost provided the cost related to multi-skilling is less than the saving due to reduced inventories.

My thesis uses a visual basic model to determine the need of multi-skilling of workers and, if justified, the extent to which multi-skilling be done, since it requires time and cost in training. Operators requiring multi-skilling in an assembly line under probabilistic demand conditions are identified by solving the line balancing problem at different production rates. A real life case of assembly operations of an engine plant is studied to illustrate the model.

The concept of cross training, cross utilization, multi-skilling and multifunctional workforce has received significant attention in a variety of operating environments. This is largely due to the
human resource and operations management related benefits that may accrue from a well
designed cross utilization programme (Brusco et al., 1998). From a human resource standpoint,
these benefits include alleviation of boredom, reduction of stress and enhancement of employee
morale. From an operations management perspective, cross utilization creates substantial staffing
and scheduling flexibility, enabling operations managers to match available labor to time,
varying demand and supplies more effectively (Schonberger, 1982).

Several researchers studied the flexibility aspects of the workforce in service and manufacturing
systems. Downey and Leonard (1992), Ritzman et al. (1984) and Schonberger (1993) showed
that worker flexibility is one of the best ways to achieve reliable customer service and alleviate
capacity bottlenecks. Cross training also allows workers to broaden their skills and enhance their
value to the employer. Multi-skilled workforce increases the output while decreasing idle time on
the production line (Dahlen et al., 1995).

Brusco (1998) examined the effects of various degrees of cross training on the efficiency of labor
and machines in the overall shop performance. The results indicated that the relative
performance of the dispatching rules remains the same as the degree of worker cross training
changes, and the initial introduction of worker cross training has the most significant
improvement and the subsequent benefits follow the law of diminishing returns.

Ebeling and Lee (1994) investigated cost benefit analysis of the cross training to reduce the
impact of absenteeism. They established two rules for the maximum effectiveness of cross
training. First, train more workers for those jobs which require low cost and short duration. Second, train high attendance workers for more jobs than low attendance workers.

Corrective maintenance policies of worker flexibility and machine redundancy are studied by Sheu and Krajewski (1994). Their simulation results show that worker flexibility and machine redundancy reduce inventory costs and improve delivery performance. The economic analysis indicated that the selection of the maintenance policy is a function of the cost of capital, expected machine life of the redundant equipment and annual cost of worker flexibility. They used mathematical programming in conjunction with simulation to investigate the effects of cross utilization policy in a postal setting. Riley and Lockwood (1997) studied the training needs for functional flexibility in the hotel industry. Their results indicate that the need for functional flexibility via cross training is dependent on the technology involved and the market volatility. In a high tech environment, flexibility is obtained in a planned manner through training, whereas contingency management may gradually stabilize itself through institutionalizing coping strategies in conditions where product and labor market have short term volatility.

The previous research attempts at studying multi-skilling in the manufacturing environment have focused on the aspects of worker absenteeism (Downey and Leonard, 1992; Plenert, 1997), while in service systems, these have been triggered due to demand variability (Ebeling and Lee, 1994; Riley and Lockwood, 1997). In my thesis an attempt has been made to study the aspects of multi-skilling in the manufacturing environment under demand variability.
Chapter 3  Selecting a suitable model for line balancing

Assembly Line

An assembly line is a special case of the product layout. Adopting a product layout makes sense when the batch size of a given product or part is large relative to the number of different products or parts produced. Assembly lines refer to progressive assembly operations linked by some material handling device. Virtually any product that has multiple parts and is produced in large volume is produced on assembly lines to some degree.

Main Characteristics are:

- Continuous system --> variety low, volume high
- Standard products
- High volume
- Special-purpose machines, dedicated to specific task(s)
- Low skill workers
- Continuous flow (forced) --> from one station to next
- Low WIP
- Low unit production cost

Main Ideas are:

- Break the entire process down into small, but easy to master work stations
- Group tasks together into a work station
- Link work together by material handling systems (moving belts, conveyor lines, etc.)
- Two major concerns: Technological constraints and efficiency
Assembly Line Balancing

Is primarily a scheduling issue, but has implications for layout planning and configuration (workstation formation).

The assembly line balancing problem is one of assigning all tasks to a series of workstations so that each workstation has no more work than can be done in the cycle time, and so that the unassigned time (i.e. idle time) is minimized across all workstations.

The assembly line balancing problem is complicated by the relationship among tasks imposed by product design and process technologies --> precedence relationship (specifies the order in which tasks must be performed).

Terms and Symbols:

- Task (simplest element that can be used to balance the line)
- Task time (ti)
- Number of workstations (N)
- Theoretical number of workstations N
- Total Work Content (TWC), i.e. the time value is added (Σ t)
- Cycle Time (C), i.e. the time allowed at each workstation to finish all the assigned tasks i.e. time between two consecutive finished products rolling of the assembly line, i.e. the speed of the line
- Idle Time (I), i.e. the actual time discrepancy between C and Σ t at a particular workstation
- Efficiency (E), i.e. the proportion of time Σ t value is added to the cycle time
(C) times the number of workstations (N)

- Balance Delay (BD), i.e. the proportion of time that no value is added \((1 - E = BD)\)
- Productivity \((P)\) is the time \((T)\) observed divided by \((C)\)

Theoretical Number of Workstations:

\[
Max E = \frac{\sum t_x}{C * \hat{N}} = 100\% \\
\text{rearrange:} \\
\hat{N} = \frac{\sum t_x}{C}
\]

Assembly Systems and Line Balancing

- Assembly involves the joining together of two or more separate parts to form a new entity, called a subassembly, an assembly or some similar name.

- Three major categories of processes used to accomplish the assembly of the components:
  1. Mechanical fastening
  2. Joining methods
  3. Adhesive bounding

Model Variations

It is highly desirable to assign appropriate amount of work to the stations to equalize the process or assembly times at the workstations.

This brings the line balancing problem and the three different types of lines.

2. **Batch-model Line**: Used for the production of two or more models with similar sequence of processing or assembly operations.

3. **Mixed-model Line**: Several models are intermixed on the line and are processed simultaneously.

These cases may be applied to both manual flow lines and automated flow lines.

Type 2 and 3 are easier to apply to manual flow-lines.

The problem of line balancing becomes more complicated when going from type 1 to type 3.

**The Line Balancing Problem**

It is to arrange the individual processing and assembly tasks at the workstations so that the total time required at each station is approximately the same.

If workstation times are unequal, the slowest station determines the overall production rate of the line.

**Methods of Line Balancing**

They are heuristic approaches - based on logic and common sense rather than on mathematical proof. They do not guarantee an optimal solution, but result in good solutions which approach the true optimum.

1. **Largest-candidate rule:**

   **PROCEDURE**

   **Step 1**: List all elements in descending order.

   **Step 2**: Start from the top and select an element that satisfies the precedence requirements and does not cause the sum of the values at the station to exceed the cycle time.
Step 3: Continue to apply Step 2 until no further elements can be added without exceeding.

Step 4: Repeat steps 2 and 3 for the other stations until all the elements have been assigned.

The practical realities of the line balancing problem may not permit the realization of the most desirable number of stations.

2. Kilbridge and Wester’s method:

PROCEDURE

Step 1: Construct the precedence diagram so that the nodes with identical precedence are arranged vertically in columns.

Step 2: List the elements in order of their columns. If an element can be located in more than one column, list all the columns by the element to show the transferability of the element.

Step 3: To assign elements to workstations, start with the column I elements. Continue to the assignment procedure in order of column number until the cycle time is reached. Go on until all elements are allocated.

In general, this method provides a superior line balancing solution when compared with the largest-candidate rule.

3. Ranked positional weights method:

PROCEDURE
**Step 1:** Calculate the ranked positional weight value (RPW) for each element by summing the element’s Te together with the Te values for all the elements that follow it in the arrow chain of the precedence diagram.

**Step 2:** List the elements in descending order of their RPW.

**Step 3:** Assign elements to stations according to RPW, avoiding precedence constraint and time-cycle violations.

**4. COMSOAL - A Computerized Line Balancing Method**

**PROCEDURE**

**Step 1:** Construct list a, showing all work elements in one column and the total number of elements that immediately precede each element in an adjacent column.

**Step 2:** Construct list B, showing all elements from list A that have no immediate predecessors.

**Step 3:** Select at random one of the elements from list B, which must not cause the cycle time Tc to be exceeded.

**Step 4:** Eliminate the element selected in step 3 from lists A and B and update both lists, if necessary. There may be changes in the number of immediate predecessors for certain elements in list A; and there may now be some new elements having no immediate predecessors that should be added to list B.

**Step 5:** Select one of the elements from list B which is feasible for cycle time.

**Step 6:** Repeat steps 4 and 5 until all elements have been allocated to stations within the Tc constraint.
Step 7: Retain the current solution and repeat steps 1 through 6 to attempt to determine an improved solution. If an improved solution is obtained, it should be retained.

I have selected *Single Model Assembly line* balanced using *Ranked Positional Weight* method for the case study to determine optimum balance between inventory and multiskilling under dynamic production scenarios.
Chapter 4  Developing a mathematical model for different inventory policies.

Four alternative policies examined in this study for selecting the most economic policy are based on two major strategic variables – inventory based and multi-skilling based strategies to absorb demand variability. The variation of each of these variables is considered over a continuum from low to high. Although a number of policies could be investigated, in this study, the four policies involving the combination of these two variables at the extreme point of the continuum are considered.

Policy 1 investigates the case where the inventory levels are high and uncontrolled but no multi-skilling is attempted. Policy 2 attempts to curb the inventory levels without introducing multiskilling. Policy 3 simulates the case of zero inventory (similar to a JIT system) facilitated by a multi-skilled workforce capable of responding to demand uncertainties. Policy 4 is a variant of policy 3, allowing full utilization of the workforce with a slight increase in inventory levels. These four policies are further discussed as follows.

Policies based on inventory consideration

Policy 1 - Constant workforce and production rate policy.

In this manufacturing policy, the production rate is set at the average demand rate and this requires a constant number of workers. When the actual demand rate is less than this production rate, the excess production is held as inventory. On the other hand, when the actual demand rate is more than the production rate, the additional demand is fulfilled from inventory. In case sufficient inventory is not available, the unfulfilled demand is backlogged, leading to a
reduction in service level. This policy is termed as constant workforce and constant production rate policy (CWPR-policy).

Desired dispatch quantity in a period is equal to the demand in that period and the backlog, if any, of the previous period:

\[ DO(n) = D(n) + BL(n-1) \]  \hspace{1cm} (1)

The desired dispatch quantity is adjusted for previous period inventory, if any, to determine the desired production output for the assembly line operations:

\[ A(n) = D(n) + BL(n-1) - I(n-1) \]  \hspace{1cm} (2)

Since the conveyor speed is constant and equal to average demand rate, the actual production output is constant in all the periods and is equal to average demand:

\[ Q(n) = D_{\text{avg}} \]  \hspace{1cm} (3)

The available inventory for shipment in a period is equal to the actual production in that period plus the inventory of the previous period:

\[ AI(n) = Q(n) + I(n-1) \]  \hspace{1cm} (4)

The periods in which the desired dispatch quantity is less than the available inventory for shipment, there are no shortages and backlog. Whereas, if the desired dispatch quantity is more
than available inventory, the system is not able to meet the demand and some of the demand remains unfulfilled as backlog. Thus the system operates with inventory and backlog.

**Performance measures of CWPR-policy.** In CWPR-policy, the manpower required is constant, therefore no additional training and changeovers are required:

\[
\text{NOW}(n) = \text{Constant} \quad (5) \\
TWE = 0 \quad (6) \\
NOC = 0 \quad (7)
\]

The expected value of backlog and inventory is given by equations (8) and (9) respectively:

\[
ES = \frac{1}{N} \sum_{n=1}^{NPBL} [\text{Dispatch quantity (n)} - \text{Available inventory (n)}] 
\]

\[
ES = \frac{1}{N} \sum_{n=1}^{NPBL} \text{DO(n) – AI(n)} 
\]

NPBL is the number of periods for which backlog occurred

\[
ES = \frac{1}{N} \sum_{n=1}^{NPAI} [\text{Available inventory (n)} - \text{Dispatch quantity (n)}] 
\]
NPAI is the number of periods for which available inventory is more than dispatch quantity.

Expected service level is given by equation (11):

\[
ESL = 1 - \frac{NPBL}{T}
\]  

(11)

**Policy 2 - Constant workforce policy.**

In this manufacturing policy also a constant number of workers are deployed but production rate is allowed to be lower than the maximum possible production rate to limit the accumulation of inventory up to safety stock. This policy is termed as constant workforce policy (CWpolicy).

Desired dispatch quantity is given by equation (12):

\[
DO(n) = D(n) + BL(n-1)
\]  

(12)

The desired production quantity in period t is given by equation (13):

\[
A(n) = D(n) + BL(n - 1) + SS - I(n - 1)
\]  

(13)

However, it may not be possible to produce this quantity in some of the periods because of the constraints imposed by maximum production rate. If Pmax is the maximum production rate with the given workforce, the actual production output is given by equation (14):

\[
Q(n) = \text{Min} \left[ A(n), P_{max} \right]
\]  

(14)

The available inventory for shipment is calculated as follows:
\[ AI(n) = Q(n) + I(n-1) \tag{15} \]

This system also operates with inventory and backlog.

*Performance measures of CW-policy.* The performance measures of the CW-policy are the same as in the case of CWPR-policy.

**Policies based on multiskilling consideration**

**Policy 3 - Zero inventory policy.**

The policy termed as zero inventory policy (ZI-policy) has production rate exactly equal to the demand rate. This results in zero inventory and 100 per cent service level. This requires the change in speed of the assembly line and the number of workstations. The number of workers in the assembly line is increased for higher demand rate and decreased for lower demand rate respectively. With the change in the number of workstations, the work content at each workstation also changes. At each workstation some new elements are added and some other existing elements are given to other workstations. This change of work content necessitates the need of additional training to the workers. In this policy, desired dispatch quantity, desired production rate, actual production output and available inventory for shipment are all equal to the demand rate in that period:

\[ DO(n) = D(n) \tag{16} \]

\[ A(n) = D(n) \tag{17} \]
\[ Q(n) = D(n) \quad (18) \]
\[ AI(n) = Q(n) \quad (19) \]

Performance measures of ZI-policy. The expected value of the number of workers (NOW) required and the number of changeovers (NOC) is determined through simulation:

\[ NOW(n) \propto D(n) \quad (20) \]

\[ NOW = f(D^{avg}, RG) \quad (21) \]

\[ NOC = f(D^{avg}, RG) \quad (22) \]

The total additional training requirement is a function of average demand and range of demand and is established from the results of line balancing:

\[ TWE = f(D^{avg}, RG) \quad (23) \]

The expected value of backlog and inventory is zero and service level is 100 per cent.
Policy 4 - Maximum manpower utilization policy.

This policy is a variant of policy 3, where modification is done to increase the line efficiency and reduce the average number of workers required. In each period, the number of workers required is identified on the basis of demand rate and available inventory. Instead of producing at the demand level, the production rate is set at the maximum output possible with the specified number of workers.

The excess production is held as inventory to be used for meeting the demand of the next period. This policy is termed as maximum manpower utilization policy (MMU-policy). In this policy also, backlogs are not allowed and the manufacturing system operates at 100 per cent service level.

Desired dispatch quantity is given by equation (24) as there is no backlog:

\[ DO(n) = D(n) \]  \hspace{1cm} (24)

The desired production output for the assembly line operations is given by equation (25):

\[ A(n) = D(n) - I(n - 1) \]  \hspace{1cm} (25)

Let \( W(t) \) be the number of workstations required at the production rate \( A(n) \) and \( P_{w(n)} \) Max be the maximum production possible with \( W(n) \) number of workstations. The actual production output is given by equation (26):

\[ Q(n) = P_{w(n)} \text{ Max} \]  \hspace{1cm} (26)
The available inventory for shipment is calculated as follows:

\[
AI(n) = Q(n) + I(n - 1)
\]  

(27)

In this way the system operates without any loss of production due to the different level of demand at the cost of holding small amount of inventory.

**Performance measure of MMU-policy.** The expected number of workers required, number of changeovers and total additional training requirements are determined as in the case of zero inventory policy using equations (20-23). The expected value of backlog is zero and service level is 100 per cent. The expected value of inventory is calculated by simulating the system for T periods and is given by equation (28):

\[
EI = \sum_{n=1}^{N} \frac{I(n)}{T}
\]

(28)

These four policies are simulated under different demand scenarios.
Chapter 5  THE CASE STUDY

The following case study of an automobile company illustrates the application of the procedure outlined in Figure 1 to a real life situation. The assembly operations of this company are a part of the large production system. The output (sub-assembly) of this assembly line is fed to the final assembly operations. The production rate of the final assembly is planned on a daily basis, therefore the demand of the sub-assembly varies from day to day. It is assumed that the demand follows a uniform distribution. The company is working on a two-shift basis of 7.5 hours each. There are 260 working days in a year.

![Flowchart of proposed model](image-url)

**Figure 1**
A Flowchart of proposed model
At present, the company is using the traditional approach of running the line at constant speed and constant production rate. Safety stock is used to respond to the demand variations. The present approach results in frequent backlogs, leading to dissatisfied customers and high inventories, resulting in high operational cost. The company wishes to enhance customer service and reduce production cost by synchronizing the production rate with demand. The change in production rate can be achieved through change in the number of workstations and the number of workers on the assembly line. The change in the number of workers on the assembly line does not require hiring and firing of workers as the change in manpower is accommodated by deployment in other operational areas.

The assembly operation has 30 work elements, the technological precedence requirement and the elemental times are given in Table I. The information regarding demand characteristics and cost parameters are given in Table II.
<table>
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<th>Elemental time (s)</th>
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<td>20</td>
<td>8.84</td>
<td>17,19</td>
</tr>
<tr>
<td>21</td>
<td>6.32</td>
<td>20</td>
</tr>
<tr>
<td>22</td>
<td>4.6</td>
<td>-</td>
</tr>
<tr>
<td>23</td>
<td>4.6</td>
<td>-</td>
</tr>
<tr>
<td>24</td>
<td>10.34</td>
<td>-</td>
</tr>
<tr>
<td>25</td>
<td>6.54</td>
<td>24</td>
</tr>
<tr>
<td>26</td>
<td>6.9</td>
<td>-</td>
</tr>
<tr>
<td>27</td>
<td>26.8</td>
<td>-</td>
</tr>
<tr>
<td>28</td>
<td>3.44</td>
<td>21,22</td>
</tr>
<tr>
<td>29</td>
<td>11.72</td>
<td>25,28</td>
</tr>
<tr>
<td>30</td>
<td>3.36</td>
<td>23,29</td>
</tr>
</tbody>
</table>

**Table I**
Element times and precedence relationship
Average Demand 55 units/hour  
Range of Demand 20 units/hour  
Nature of Distribution Uniform  
Product Cost $50 per unit  
Inventory carrying cost $10 per unit per year  
Shortage cost $100 per unit short per year  
Changeover cost $200 per changeover  
Worker wages $1000 per month per worker  
Training cost $500 per worker-element  

**Table II**  
Demand characteristics and cost parameters

Five demand scenarios denoted as A, B, C, D and E and given in Table III are studied to find the best policy to operate the assembly line.

<table>
<thead>
<tr>
<th>Demand Scenario</th>
<th>Average Demand (units/hour)</th>
<th>Range of demand (units/hour) ±</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>60</td>
<td>15</td>
</tr>
<tr>
<td>C</td>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td>D</td>
<td>65</td>
<td>7</td>
</tr>
<tr>
<td>E</td>
<td>65</td>
<td>15</td>
</tr>
</tbody>
</table>

**Table III**  
Demand scenario under consideration

**Training needs under different demand scenarios**

To determine the training needs under different demand scenarios, a computer program to perform the line balancing and calculate multiskilling using Visual Basic is developed. The assembly line data (elemental time and precedence relationship) were processed using this program for different production rates/cycle times. This gives the assignment of work elements to workstations at different production rates, which is analyzed to identify the elements where
the workstation is changed with the change in production rates. The elements for which the workstation is changed for a given demand range are the candidates for which workers need to be trained to develop additional skills. Each element and workstation is thus analyzed to determine the additional training requirements.

Table IV shows the assignment of work elements to different workstations for different production rates (varying from 40-80 units/hour). It also shows the additional training requirements, expressed in worker-elements, to operate the assembly line at different production rates. (The concept of worker-elements is employed to gauge the degree of multi-skilling required in the similar sense as man-hours are used to measure the labor content of a job.)
As can be seen from Table IV, elements 1 is always carried out at workstation 1 for the entire range of production rate. Thus there is no need of additional training for these elements. Element 2 is carried out at workstation 1 for a production rate ranging from 40-72 units/hour and at

<table>
<thead>
<tr>
<th>Work Station to which this element is assigned at different ranges of production (units/hour)</th>
<th>Additional no. of work element for which training required under different demand scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate (Units/hr)</td>
<td>EN / CT (Sec)</td>
</tr>
<tr>
<td>-----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>50-70</td>
<td>45-75</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>21</td>
<td>4</td>
</tr>
<tr>
<td>22</td>
<td>4</td>
</tr>
<tr>
<td>23</td>
<td>4</td>
</tr>
<tr>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>26</td>
<td>4</td>
</tr>
<tr>
<td>27</td>
<td>4</td>
</tr>
<tr>
<td>28</td>
<td>4</td>
</tr>
<tr>
<td>29</td>
<td>4</td>
</tr>
<tr>
<td>30</td>
<td>4</td>
</tr>
</tbody>
</table>

Table IV
Assignment of work elements to workstation at different range of production rates and additional training requirements under different demand scenario.
workstation 2 for a production rate ranging from 75-80 units/hour. Thus the operator at workstation 2 needs to be trained for doing element 2 as well.

Similarly the table shows the need for multiskilling at each station for different production rate. As the range of proposed production rate increases so does the need for multiskilling, as we can see from table IV, production rate of 40-80 units/hr results in the maximum number of work elements i.e. 70 for which additional training is required.
Chapter 6  Simulation to determine the parameters of the policies

Simulation using arena is carried out to determine the different comparable parameters of the 4 different inventory policies discussed in earlier chapter. Demand is assumed to follow a uniform distribution and the simulation is run for two-shift basis of 7.5 hours each considering there are 260 working days in a year.

Simulation is run for each of the four inventory policy under five different demand scenarios as shown in table V, so a total of $4 \times 5 = 20$ simulation is run.

Table V
Simulation Scenarios under consideration
Different Inventory Policy to be simulated:

1. **Constant workforce and production rate policy:**
   - Number of workers required in a period is constant
   - Additional training requirement = 0
   - Number of changeovers = 0

**Performance Measures:**
- Expected Inventory (Simulation)
- Expected Shortfall (Simulation)

---

**Scenario A – Policy 1 (Constant workforce and production rate policy) Replications:1**

**Replication 1**
- **Start Time:** 0.00
- **Stop Time:** 260.00
- **Time Units:** Days

**Counter**

<table>
<thead>
<tr>
<th>Count</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>End Inventory</td>
<td>30,176.00</td>
</tr>
<tr>
<td>Shortage</td>
<td>812.00</td>
</tr>
</tbody>
</table>

Table VI

Simulation Model and output for Scenario A – Inventory Policy 1
2. Constant workforce policy:

- Number of workers required in a period is constant
- Inventory accumulation is limited to safety stock level or Desired Demand

**Performance Measures:**

- Expected Inventory (Simulation)
- Expected Shortfall (Simulation)

<table>
<thead>
<tr>
<th>Entity Arrival</th>
<th>Assign Demand Production</th>
<th>Assign Beginning Inv. Desired Production</th>
<th>Assign End Inv. Required Qty Backlog</th>
<th>Assign Actual Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decide Required Qty &gt;= Available Inv.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decide True</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dispose</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End Inventory</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Scenario A – Policy 2 (Constant workforce policy)**  Replications: 1

**Replication 1**

Start Time: 0.00  Stop Time: 260.00  Time Units: Days

<table>
<thead>
<tr>
<th>Counter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>End Inventory</td>
<td>4,022.00</td>
</tr>
<tr>
<td>Shortage</td>
<td>856.00</td>
</tr>
</tbody>
</table>

Table VII

Simulation Model and output for Scenario A – Inventory Policy 2
3. Zero Inventory policy:

- Expected Inventory = 0
- Expected Shortfall = 0
- Expected Service level = 100%

Performance Measures:

- Expected Number of workers required (Simulation)
- Total additional training requirement (Visual Basic Program)

### Table VIII
Simulation Model and output for Scenario A – Inventory Policy 3

<table>
<thead>
<tr>
<th>Replication</th>
<th>Start Time</th>
<th>Stop Time</th>
<th>Replications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication 1</td>
<td>0.00</td>
<td>260.00</td>
<td>1</td>
</tr>
</tbody>
</table>

**Tally**

<table>
<thead>
<tr>
<th>Expression</th>
<th>Average</th>
<th>Half Width</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record Number of Worker</td>
<td><strong>8.1183</strong></td>
<td><strong>0.011174655</strong></td>
<td><strong>7.5008</strong></td>
<td><strong>8.7483</strong></td>
</tr>
</tbody>
</table>

**Counter**

<table>
<thead>
<tr>
<th>Count</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>End Inv</td>
<td>0</td>
</tr>
<tr>
<td>Record Avg Changeover</td>
<td>0</td>
</tr>
<tr>
<td>Shortage</td>
<td>0</td>
</tr>
</tbody>
</table>

---

Entity Arrival → Assign Demand → Production → Record Number → Changeover

End Inv → Shortage → Dispose
4. Maximum manpower utilization policy:

- Production rate set to maximum possible with the specified number of workers
- Backlogs are not allowed
- Manufacturing system operates at 100%

**Performance Measures:**

- Expected Inventory (Simulation)
- Expected Number of workers required (Simulation)
- Expected Number of changeover (Simulation)
- Total additional training requirement (Visual Basic Program)
### Scenario A – Policy 4 (Maximum manpower utilization policy) Replications: 1

**Replication 1**

Start Time: 0.00  
Stop Time: 260.00  
Time Units: Days

<table>
<thead>
<tr>
<th>Expression</th>
<th>Average</th>
<th>Half Width</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record Number of Worker</td>
<td>7.2188</td>
<td>0.027812565</td>
<td>5.5578</td>
<td>8.8877</td>
</tr>
<tr>
<td>Counter</td>
<td></td>
<td>Value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Record Avg Changeover</td>
<td>702.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Record Inventory</td>
<td>1,823.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table IX**

Simulation Model and output for Scenario A – Inventory Policy 4
Chapter 7 Comparing the economic performance of the alternative policies

Once we run the simulation model for different inventory policy under dynamic demand scenarios we can acquire the comparison parameters of the different policies, also running the Visual Basic program we can find the multiskilling required under different scenario.

Entering all the variables in the Cost Calculation module of the VB program we can calculate the total relevant cost of each combination of Scenario – Policy. Table X shows the total relevant cost of different policies under scenario A.

### Scenario A (50-70)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Policy 1 CWPR</th>
<th>Policy 2 CWP</th>
<th>Policy 3 ZIP</th>
<th>Policy 4 MMU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional Training Requirements</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Inventory (units)</td>
<td>30,176</td>
<td>4022</td>
<td>0</td>
<td>1859</td>
</tr>
<tr>
<td>Shortage (units)</td>
<td>812</td>
<td>856</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Service level (%)</td>
<td>85</td>
<td>84.7</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Avg. No. Changeovers</td>
<td>0</td>
<td>0</td>
<td>394</td>
<td>410</td>
</tr>
<tr>
<td>Max. no of workers/period</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Training cost ($)</td>
<td>301760</td>
<td>40220</td>
<td>0</td>
<td>18590</td>
</tr>
<tr>
<td>Inventory carrying cost ($)</td>
<td>81200</td>
<td>85600</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Shortage cost ($)</td>
<td>0</td>
<td>0</td>
<td>78800</td>
<td>82000</td>
</tr>
<tr>
<td>changeover cost ($)</td>
<td>0</td>
<td>0</td>
<td>4160000</td>
<td>4160000</td>
</tr>
<tr>
<td>Worker Wages ($)</td>
<td>3640000</td>
<td>3640000</td>
<td>4160000</td>
<td>4160000</td>
</tr>
<tr>
<td>Total relevant cost ($)</td>
<td>4022960</td>
<td>3765820</td>
<td>4253800</td>
<td>4275590</td>
</tr>
</tbody>
</table>

Table X

Analysis of policies for demand scenario A

Similarly we can find out the total relevant cost for all the scenario – policy combination and table XI shows the compiled total relevant cost of all the possible combination
Table XI

Total relevant cost of Policies under different demand scenario

<table>
<thead>
<tr>
<th>Demand Scenario</th>
<th>Code</th>
<th>Mean</th>
<th>Range</th>
<th>Policy 1 (CWPR)</th>
<th>Policy 2 (CWP)</th>
<th>Policy 3 (ZIP)</th>
<th>Policy 4 (MMU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>60</td>
<td>10</td>
<td></td>
<td>4022960</td>
<td>3765820</td>
<td>4253800</td>
<td>4275590</td>
</tr>
<tr>
<td>B</td>
<td>60</td>
<td>15</td>
<td></td>
<td>5256280</td>
<td>4855720</td>
<td>4784800</td>
<td>4919230</td>
</tr>
<tr>
<td>C</td>
<td>60</td>
<td>20</td>
<td></td>
<td>5449530</td>
<td>4916670</td>
<td>4775600</td>
<td>4980310</td>
</tr>
<tr>
<td>D</td>
<td>65</td>
<td>7</td>
<td></td>
<td>4427270</td>
<td>4258480</td>
<td>4297500</td>
<td>4435310</td>
</tr>
<tr>
<td>E</td>
<td>65</td>
<td>15</td>
<td></td>
<td>5256280</td>
<td>4855720</td>
<td>4784300</td>
<td>4864130</td>
</tr>
</tbody>
</table>

As seen from the table XI Inventory Policy 2 i.e. Constant work force policy when run under demand scenario A i.e. 40-80 units/hour yields the most economical production scenario. Also we find that Constant workforce and production rate policy when run at demand scenario C results to be the most expensive.

But inventory policy 3 (i.e. Just – In – Time ) is the most consistent under all the demand scenario, though its difficult to achieve ideal JIT conditions but once achieved it will help manufacturer to handle any level of demand at the most optimum cost compared to other inventory policies which might be economical in one demand scenario but expensive in another demand scenario.

Using this model the planning department can find out which inventory policy to follow and what amount of multi-skilling will be required for the next operational period which may include the next quarter or year, based on the forecast of demand and the actual plant capacity.
Chapter 8  Conclusions

In a competitive environment, the flexible assembly line operations can help in achieving 100 per cent service level along with low level of inventories. A simulation study was conducted to determine the performance characteristics of the different policies of assembly line operations under variable demand conditions.

In some of the cases, the hybrid policy of changing production rates along with small inventories to increase the line efficiency proved to be the best. In other cases, constant workforce policy was found to be more economical, but this policy gives a low level of service, which may not be desirable in the era of intense competition.

The multi-skilling of workers offers benefits far greater than merely facilitating the change in the production rate as explored in this study. It also provides benefits such as reduction in overtime costs, greater employee versatility, leading to job enlargement, increased worker awareness and participation in the manufacturing process and flexibility in operations.

Undoubtedly, a well planned, cost effective cross training programme is an important requirement for developing an efficient manufacturing system. The line balancing case study undertaken in this paper provides a systematic approach to identify the training needs of operators for a line operating at variable demands.
Future work in this area can include exploring a combination of more complex assembly line environment consisting of multi-model assembly line or U-Assembly line, which will require complex line balancing and multi-skilling calculation then what is presented in this thesis.
Bibliography


Appendix A: Visual Basic Snap Shots

Program Main Screen

Screen to enter Elemental Times
Screen to Calculate Station Assignments

Screen shows the station assignment for the given scenario
Screen to calculate multi-skilling required

Screen shows the cost associated with each scenario
Appendix B: Visual Basic Program

'Program: To calculate station assignment, multiskilling and cost
'Programmer: Jitesh kapadia
'Date: 15 Oct, 2003
'Description: Form Start, which flashes up while the program is loaded

Private Sub Form_Load()
    frmstart.Move 0, 0, Screen.Width, Screen.Height
    Show 'displays this form while frmMain loads!
    For pause = 1 To 50
        Refresh 'displays labels and images properly
        Next
    Load frmMain
    Unload Me
    frmMain.Show
End Sub

'Program: To calculate station assignment, multiskilling and cost
'Programmer: Jitesh kapadia
'Date: 15 Oct, 2003
'Description: Form Main, Main page of the program

Private Sub cmdCost_Click()
    frmCost.Show
    frmSA.Hide
    frmMain.Hide
    frmTR.Hide
    frmET.Hide
End Sub

Private Sub cmdEnterET_Click()
    frmSA.Hide
    frmMain.Hide
    frmTR.Hide
    frmET.Show
    frmETC.Hide
    frmCost.Hide
End Sub
Private Sub cmdExit_Click()

End
End Sub

Private Sub cmdWSA_Click()
frmSA.Hide
frmMain.Hide
frmTR.Show
frmET.Hide
frmCost.Hide
End Sub

'Program: To calculate station assignment, multiskilling and cost
'Programmer: Jitesh kapadia
'Date: 15 Oct, 2003
'Description: Form Elemental Time, allows entering the element times for calculating station assignment

Private Sub cmdCalculate_Click()

frmSA.Hide
frmMain.Hide
frmTR.Hide
frmET.Hide
frmETC.Show
frmCost.Hide
End Sub

Private Sub cmdClear_Click()

txtEN1.Text = ""
txtEN2.Text = ""
txtEN3.Text = ""
txtEN4.Text = ""
txtEN5.Text = ""
txtEN6.Text = ""
txtEN7.Text = ""
txtEN8.Text = ""
txtEN9.Text = ""
txtEN10.Text = ""

Private Sub cmdCalculate_Click()
    frmSA.Show
    frmMain.Hide
    frmTR.Hide
    frmET.Hide
    frmETC.Hide

    Dim i As Integer
    Dim intsum As Integer

    For i = 0 To 9

        If Val(txtET1.Text) < Val(txtCT.Text) Then

            intsum = Val(txtET1.Text)
            txtET1.Text = ""
            frmSA.lbl(i).Caption = frmETC.txtEN1.Text
            txtEN1.Text = ""

            If intsum + Val(txtET2.Text) < Val(txtCT.Text) Then

                intsum = intsum + Val(txtET2.Text)
                txtET2.Text = ""

        End If
    Next i
End Sub
frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN2.Text
txtEN2.Text = ""

If intsum + Val(txtET3.Text) < Val(txtCT.Text) Then
    intsum = intsum + Val(txtET3.Text)
    txtET3.Text = ""
    frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN3.Text
    txtEN3.Text = ""
    If intsum + Val(txtET4.Text) < Val(txtCT.Text) Then
        intsum = intsum + Val(txtET4.Text)
        txtET4.Text = ""
        frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN4.Text
        txtEN4.Text = ""
        If intsum + Val(txtET5.Text) < Val(txtCT.Text) Then
            intsum = intsum + Val(txtET5.Text)
            txtET5.Text = ""
            frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN5.Text
            txtEN5.Text = ""
            If intsum + Val(txtET6.Text) < Val(txtCT.Text) Then
                intsum = intsum + Val(txtET6.Text)
                txtET6.Text = ""
                frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN6.Text
                txtEN6.Text = ""
                If intsum + Val(txtET7.Text) < Val(txtCT.Text) Then
                    intsum = intsum + Val(txtET7.Text)
                    txtET7.Text = ""
                    frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN7.Text
                    txtEN7.Text = ""
                    If intsum + Val(txtET8.Text) < Val(txtCT.Text) Then
                        intsum = intsum + Val(txtET8.Text)
                        txtET8.Text = ""
                        frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN8.Text
                        txtEN8.Text = ""
If intsum + Val(txtET9.Text) < Val(txtCT.Text) Then

    intsum = intsum + Val(txtET9.Text)
    txtET9.Text = ""
    txtEN9.Text = ""

If intsum + Val(txtET10.Text) < Val(txtCT.Text) Then

    intsum = intsum + Val(txtET10.Text)
    txtET10.Text = ""
    frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN10.Text
    txtEN10.Text = ""

If intsum + Val(txtET11.Text) < Val(txtCT.Text) Then

    intsum = intsum + Val(txtET11.Text)
    txtET11.Text = ""
    frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN11.Text
    txtEN11.Text = ""

If intsum + Val(txtET12.Text) < Val(txtCT.Text) Then

    intsum = intsum + Val(txtET12.Text)
    txtET12.Text = ""
    frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN12.Text
    txtEN12.Text = ""

If intsum + Val(txtET13.Text) < Val(txtCT.Text) Then

    intsum = intsum + Val(txtET13.Text)
    txtET13.Text = ""
    frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN13.Text
    txtEN13.Text = ""

If intsum + Val(txtET14.Text) < Val(txtCT.Text) Then

    intsum = intsum + Val(txtET14.Text)
    txtET14.Text = ""
    txtEN14.Text = ""

If intsum + Val(txtET15.Text) < Val(txtCT.Text) Then

    intsum = intsum + Val(txtET15.Text)
txtET15.Text = ""
frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN15.Text
txtEN15.Text = ""

If intsum + Val(txtET16.Text) < Val(txtCT.Text) Then
intsum = intsum + Val(txtET16.Text)
txtET16.Text = ""
txtEN16.Text = ""

If intsum + Val(txtET17.Text) < Val(txtCT.Text) Then
intsum = intsum + Val(txtET17.Text)
txtET17.Text = ""
frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN17.Text
txtEN17.Text = ""

If intsum + Val(txtET18.Text) < Val(txtCT.Text) Then
intsum = intsum + Val(txtET18.Text)
txtET18.Text = ""
frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN18.Text
txtEN18.Text = ""

If intsum + Val(txtET19.Text) < Val(txtCT.Text) Then
intsum = intsum + Val(txtET19.Text)
txtET19.Text = ""
txtEN19.Text = ""

If intsum + Val(txtET20.Text) < Val(txtCT.Text) Then
intsum = intsum + Val(txtET20.Text)
txtET20.Text = ""
frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN20.Text
txtEN20.Text = ""

If intsum + Val(txtET21.Text) < Val(txtCT.Text) Then
intsum = intsum + Val(txtET21.Text)
txtET21.Text = ""
frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN21.Text
txtEN21.Text = ""
If intsum + Val(txtET22.Text) < Val(txtCT.Text) Then

    intsum = intsum + Val(txtET22.Text)
    txtET22.Text = ""
    frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEn22.Text
    txtEn22.Text = ""

If intsum + Val(txtET23.Text) < Val(txtCT.Text) Then

    intsum = intsum + Val(txtET23.Text)
    txtET23.Text = ""
    frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN23.Text
    txtEN23.Text = ""

If intsum + Val(txtET24.Text) < Val(txtCT.Text) Then

    intsum = intsum + Val(txtET24.Text)
    txtET24.Text = ""
    frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN24.Text
    txtEN24.Text = ""

If intsum + Val(txtET25.Text) < Val(txtCT.Text) Then

    intsum = intsum + Val(txtET25.Text)
    txtET25.Text = ""
    frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN25.Text
    txtEN25.Text = ""

If intsum + Val(txtET26.Text) < Val(txtCT.Text) Then

    intsum = intsum + Val(txtET26.Text)
    txtET26.Text = ""
    txtEN26.Text = ""

If intsum + Val(txtET27.Text) < Val(txtCT.Text) Then

    intsum = intsum + Val(txtET27.Text)
    txtET27.Text = ""
    frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN27.Text
    txtEN27.Text = ""

If intsum + Val(txtET28.Text) < Val(txtCT.Text) Then

    intsum = intsum + Val(txtET28.Text)
    txtET28.Text = ""
frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN28.Text
txtEN28.Text = ""

If intsum + Val(txtET29.Text) < Val(txtCT.Text) Then
intsum = intsum + Val(txtET29.Text)
txtET29.Text = ""
frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN29.Text
txtEN29.Text = ""

If intsum + Val(txtET30.Text) < Val(txtCT.Text) Then
intsum = intsum + Val(txtET30.Text)
txtET30.Text = ""
frmSA.lbl(i).Caption = frmSA.lbl(i).Caption & vbCrLf & frmETC.txtEN30.Text
txtEN30.Text = ""
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
    End If
End If
Private Sub cmdClear_Click()
frmETC.Move 0, 0, Screen.Width, Screen.Height
txtCT.Text = ""
txtEN1.Text = ""
txtEN2.Text = ""
txtEN3.Text = ""
txtEN4.Text = ""
txtEN5.Text = ""
txtEN6.Text = ""
txtEN7.Text = ""
txtEN8.Text = ""
txtEN9.Text = ""
txtEN10.Text = ""
txtEN11.Text = ""
txtEN12.Text = ""
txtEN13.Text = ""
txtEN14.Text = ""
txtEN15.Text = ""
txtEN16.Text = ""
txtEN17.Text = ""
txtEN18.Text = ""
txtEN19.Text = ""
txtEN20.Text = ""
txtEN21.Text = ""
txtEN22.Text = ""
txtEN23.Text = ""
txtEN24.Text = ""
txtEN25.Text = ""
txtEN26.Text = ""
txtEN27.Text = ""
txtEN28.Text = ""
txtEN29.Text = ""
txtEN30.Text = ""
End Sub
End Sub

Private Sub cmdExit_Click()
    frmMain.Show
End Sub

Private Sub Command1_Click()

End Sub

Private Sub cmdLoad_Click()

txtEN1.Text = frmET.txtEN1.Text
txtEN2.Text = frmET.txtEN2.Text
Private Sub cmdExit_Click()
    frmSA.Hide
    frmMain.Show
    frmTR.Hide
    frmET.Hide
End Sub

Private Sub cmdCalculate_Click()
    Dim i As Integer
    Dim sum As Integer
End Sub
sum = 0

For i = 0 To 29
    If Val(txt1(i).Text) <> Val(txt2(i).Text) And Val(txt1(i).Text) <> 0 And Val(txt2(i).Text) <> 0
        Then
            sum = sum + 1
        End If
    Next i

For i = 0 To 29
    If Val(txt1(i).Text) <> Val(txt3(i).Text) And Val(txt1(i).Text) <> 0 And Val(txt3(i).Text) <> 0
        And Val(txt2(i).Text) <> Val(txt3(i).Text)
        Then
            sum = sum + 1
        End If
    Next i

For i = 0 To 29
    If Val(txt1(i).Text) <> Val(txt4(i).Text) And Val(txt1(i).Text) <> 0 And Val(txt4(i).Text) <> 0
        Then
            sum = sum + 1
        End If
    Next i

For i = 0 To 29
    If Val(txt1(i).Text) <> Val(txt5(i).Text) And Val(txt1(i).Text) <> 0 And Val(txt5(i).Text) <> 0
        Val(txt4(i).Text) <> Val(txt5(i).Text)
        Then
            sum = sum + 1
        End If
    Next i
End If
Next i

tXTATE.Text = sum

End Sub

Private Sub Text1_Change()

End Sub

Private Sub cmdClear_Click()
For i = 0 To 29
txt1(i) = ""
txt2(i) = ""
txt3(i) = ""
txt4(i) = ""
txt5(i) = ""
Next i

tXTATE.Text = ""
End Sub

'Program: To calculate station assignment, multiskilling and cost
'Programmer: Jitesh kapadia
'Date: 15 Oct, 2003
'Description: Form Cost, which calculates cost for different production scenarios

Option Explicit

Dim i As Integer
Dim total As Currency

Private Sub cmdCalculate_Click()

For i = 0 To 3
    total = 0

    total = Val(txt1(i).Text) * 500
    total = total + Val(txt2(i).Text) * 10
total = total + Val(txt3(i).Text) * 100
total = total + Val(txt4(i).Text) * 200
total = total + Val(txt5(i).Text) * 1000 * 260 * 2

txt6(i).Text = FormatCurrency(total)

Next i
End Sub

Private Sub cmdClear_Click()
For i = 0 To 3
    txt1(i).Text = ""
    txt2(i).Text = ""
    txt3(i).Text = ""
    txt4(i).Text = ""
    txt5(i).Text = ""
    txt6(i).Text = ""
Next i
End Sub

Private Sub cmdExit_Click()
    frmMain.Show
    Me.Hide
End Sub