subassembly made on a feeder line and consumed at the assembly line rate. A pseudo bills is a grouping of items that are not actually made but simplify master scheduling and bill maintenance.

3.1.3. Three Types of Bill of Material

There are 3 types of BOM (Plossl, 1987):

Engineering BOM

Engineering BOM contains all items which required building a product and defining the engineering specification for each item. This type of BOM usually completed by assembly drawing, which show how items joining to make final product. Engineering BOM does not show how product and subassembly processed. It aims to plan item availability. A bill of material can define products as they are designed.

Manufacturing BOM

Manufacturing BOM is Engineering BOM which completed by processing step for a product. It aims to make and schedule the final product. A bill of material can define products as they are built.

Planning BOM

Planning BOM is the advanced of Manufacturing BOM. It aims to make easy and increase the accuracy of planning process, simplify customer order entry, and create maintenance system and efficient and flexible data storage.

3.1.4. The Important Uses of Bill of Material

There are some important uses of BOM (Tersine, 1994):

1. Define the product and distinguish it from other products
2. Facilitate the forecasting of optional product features
3. Permit the master schedule to be stated in terms of the fewest possible end items
4. Allow easy order entry from customers
5. Provide the basis for product costing
6. Facilitate material procurement
7. Aid manufacturing planning and final assembly scheduling
8. Permit efficient file storage and maintenance

3.2. Routing File

The routing consists of a series of operations required to make the item (Arnold, 1998). For each product, this file contains a step-by-step set of instructions describing how the product is made. It gives details of the following:

- The operations required to make the product and the sequence in which those operations are performed
- A brief description of each operation
- Equipment, tools, and accessories needed for each operation

- Setup time, the standard time required for setting up the equipment for each operation
- Run times, the standard time to process one unit through each operation
- Lead times for each operation

3.3. Production Scheduling

Scheduling is an important tool for manufacturing and engineering, where it can have a major impact on the productivity of a process. In manufacturing, the purpose of scheduling is to minimize the production time and costs, by telling a production facility what to make, when, with which staff, and on which equipment. Production scheduling aims to maximize the efficiency of the operation and reduce costs (Wikipedia, 2008).

Morton and Pentico (1993) state, " Scheduling is the process of organizing, choosing, and timing resource usage to carry out all the activities necessary to produce the desired outputs at the desired times, while satisfying a large number of time and relationship constraints among the activities and the resources."

3.3.1. Scheduling Terminology

1. Jobs: Jobs are activities to be done. It consisted of one or many operations.

2. Operation: Smallest activity unit in scheduling.

3. Machine: processing part of the jobs

Machines are grouped in several classes (Sipper and Bulfin, 1997):

- Single machine: there is only one machine and all jobs must be processed on it.
- Parallel machine: several machines that can do the same process on jobs.
- Flow shops: each job must be processed by each machine exactly once. All jobs have the same routing, i.e., they must visit the machines in the same order. A job cannot begin processing on the second machine until it has completed processing on the first.
- Job shops: each job may have a unique routing.
- Open shops: job shops in which jobs have no specified routing

3.3.2. Operation Overlapping

In operation overlapping, the next operation is allowed to begin before the entire lot is completed on the previous operation. This reduces the total manufacturing lead times because the second operation starts before the first operation finishes all the parts in the order.

Operation overlapping is a method of expediting an order, but there are some costs involved (Arnold, 1998).

3.3.3. Lot Splitting

Lot splitting is commonly used in practice to break large orders into smaller transfer lots in an attempt to move parts more quickly through the production process (Umble & Srikanth, 1995). Lot splitting allows for simultaneous processing of a batch of products on more than one work center, resulting in reduced flow time (Jacobs & Bragg, 1988). Lot splitting is a technique for accelerating the flow of work by splitting job lots into sublots.

Lot splitting (APICS, 2002) dividing a lot into two or more sublots and simultaneously processing each sublot on identical (or very similar) facilities as separate lots, usually to compress lead time or to expedite a small quantity

3.4. Gantt Chart

A Gantt chart is a popular type of bar chart that illustrates a project schedule. A Gantt chart is a graphical representation of the duration of tasks against the progression of time. A Gantt chart is a useful tool for planning and scheduling projects. The Gantt chart is a scheduling chart based on time versus other methods such as production, weight, volume, quantity, etc.

The graphical job description consists of a collection of blocks, each of which is identified by a code. The length of the block is equal to the processing time of the associated operation, using the scale of the Gantt chart (Baker, 1974).

The purpose of the chart is to graphically display the state of each resource (usually a machine) at all times. The *x* axis represents time and the *y* axis consists of a horizontal bar for each machine. When a job is to be processed on a machine, a rectangle is placed on the horizontal bar, which begins at the job's start time and ends at its completion time. Gantt Charts also can be constructed placing jobs, instead of machines, on the *y* axis (Sipper and Bulfin, 1997).

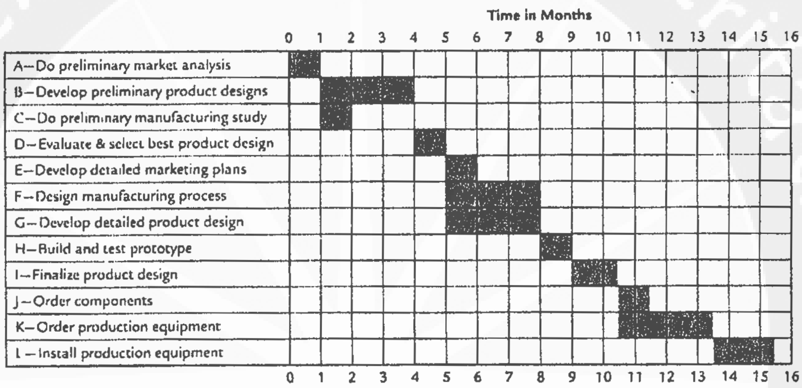

Figure 3.2. Gantt Chart Example

The disadvantages of Gantt Charts (Plossl, 1987):

1. planning and scheduling are shown together
2. they are too simple to detect critical slippages
3. they don't show dependencies well
4. they are difficult to keep up to date

3.5. Hypothesis Test

A statistical hypothesis is simply a claim about a population that can be put to a test by drawing a random sample (Wonnacot, 1984). A hypothesis is not necessary true, it can be either right or wrong, which sample data is used to decide (Siegel, 2000). Hypothesis Test is used for : construct and test a valid statistical hypothesis, conduct comparative statistical tests(t-tests), relate alpha and beta risk to sample size, conceptually understand analysis of variance (ANOVA), interpret the results of various statistical tests (T-tests, f-tests, chi-square tests), compute confidence intervals to assess degree of improvements.

3.5.1. Definition of Terms

- Null hypothesis (H_0): Statement of no change or difference. This statement is tested directly, and we either reject H_0 or we do not reject H_0. Null hypothesis can be stated by: $H_0 = \mu_1 = \mu_2 = \mu_3 = \ldots = \mu_k$

- Alternative hypothesis (H_1): The statement that must be true if H_0 is rejected. The alternative hypothesis can be stated by: $H_1 = H_a$

- Degree of freedom is a way of counting the information in an experiment. In other words, they relate to sample size. More specifically, d.f. = n-1.

3.5.2. Analysis of Variance (ANOVA)

Analysis of Variance (ANOVA), or one-factor analysis of variance, is a procedure to test the hypothesis that several populations have the same mean (Watson et al, 1986).

Total variation (SST) is addition of variation among-groups (SSA) and variation within-groups (SSW).

Variation within-groups show error level and *variation among-group* shows variation of difference between one group to another groups. n is symbol for number of populations which should be analyzed. Total variation is shown by sum of squares total (SST) by formula:

$$SST = \sum_{j=1}^{c} \sum_{i=1}^{n} \left(Xij - \overline{\overline{X}} \right)^2 \qquad (3.1)$$

Where:

n = number of populations

c = number of sample (or columns)

Xij = *j*th observation from the *i*th treatment

$\overline{\overline{X}}$ = grand mean

Grand mean is mean of all *nc* observations.

Sum of squares among-group is the addition of square difference between mean from all groups with grand mean, then it was multiplied to total number of populations. Variation among group can be calculated by:

$$SSA = \sum_{j=1}^{c} nj \left(\overline{X}j - \overline{\overline{X}} \right)^2 \qquad (3.2)$$

Where:

n = number of populations

c = number of sample (or columns)

$\overline{Xj}$ = sample mean

$\overline{\overline{X}}$ = grand mean

Sum of squares within-groups (SSW) is calculated by count the difference between mean from each population and mean of all observations in sample from the *ith* treatment, then adds the squares of difference for all populations.

$$SSW = \sum_{j=1}^{c} \sum_{i=1}^{nj} \left(Xij - \overline{Xj}\right)^2 \qquad (3.3)$$

Where:

n = number of populations

c = number of sample (or columns)

Xij = *jth* observation from the *ith* treatment

$\overline{Xj}$ = mean of *jth* observation

Table of ANOVA Single Factor is shown in Table 3.1.

Table 3.1. Analysis of Variance for the One-Way ANOVA

Source of variation	**Sum of squares**	**Degrees of freedom**	**Mean square**	**Computed f**
Among groups	$SSA = \sum_{j=1}^{c} nj \left(\overline{X}j - \overline{\overline{X}}\right)^2$	**c-1**	$MSA = \frac{SSA}{c-1}$	$F = \frac{MSA}{MSW}$
Within groups	$SSW = \sum_{j=1}^{c} \sum_{i=1}^{nj} \left(Xij - \overline{Xj}\right)^2$	**n-c**	$MSW = \frac{SSW}{n-c}$	
Total	$SST = SSA + SSW$	**n-1**		

3.5.3. F-test and p-value

The analysis of variance uses an F-test based on Fstatistic, a ratio of two variances measures, to perform each hypothesis test (Siegel, 2000). F probability distributions can be used to test the hypothesis that two populations have equal variances (Watson et al, 1993). F distributions form a family of distributions dependent on two parameters or two degrees of freedom, v_1 and v_2. The first of the two degrees of freedom, v_1 is associated with the numerator of the F ratio, and the second, v_2, is associated with the denominator. F statistic for a one way ANOVA is the ratio of variability measures for the two sources of variation: MSA and MSW.

$$F = \frac{MSA}{MSW} \qquad (3.4)$$

A p-value is the probability that the test statistic employed in the hypothesis test would assume a value as extreme as or more extreme than the observed value of the test statistic if the null hypothesis is true (Watson et al, 1993). Criteria for rejecting or not rejecting a null hypothesis by using p-value:

If p-value $< \alpha$, then reject H_0

If p-value $\geq \alpha$, then do not reject H_0

In general, any hypothesis that lies outside the confidence interval may be judged implausible-that is, can be rejected. A confidence interval may be regarded as just the set of acceptable hypotheses. If a 95%

confidence interval is being used, it would be natural to speak of the hypothesis as being tested at a 95% confidence interval. In conforming to tradition, however, we usually speak of testing at an error level of 5%. With 5% chance of error, we can reject the hypothesis of no difference (H_0). The value inside at 95% confidence level are called acceptable hypotheses (at the 5% error level), while the values outside are called rejected hypotheses (Wonnacot, 1984).