Handout 2
Management of the Design Process

1.0 Introduction

There are 4 primary tasks involved in Project Management. These can be summarized as:

I. Planning

- Define objectives
- List tasks
- Estimate work and duration
- Determine interdependent tasks
- Schedule tasks
- Schedule resources

II. Directing – achieving objectives by the implementation of approved plans, i.e.,

- Assign tasks
- Review criteria for task completion

III. Controlling

- Review progress
- Report progress
- Replan
- Review completed work
- Resolve issues
- Close project

IV. Administer- developing and implementing personnel policies and operational procedures for project management

The next sections will discuss, the first three primary tasks in more detail. The fourth task is out of the scope of this course, but was presented above for completeness

2.0 Primary Tasks in Project Management
2.1 Planning and Scheduling

Various tools are available to assist in the planning of a project.

The Gantt Chart – Simple Bar Chart

The Gantt Chart is the most widely used method of project scheduling. It's advantages include:

- Direct correlation of tasks with duration of time
- Straight forward integration of sub-tasks having separate scheduling charts
- Time schedule is flexible, from daily to longer durations

Figure 2.1 displays the general layout of a Gantt chart. The horizontal axis represents the time frame. Examples of divisions within the time frame could be days, weeks, months or quarters. The vertical axis lists the tasks to be completed, typically in the order of initiation. Tasks that are to be begun at the beginning of the project are placed at the top, while those to be started later come towards the bottom.

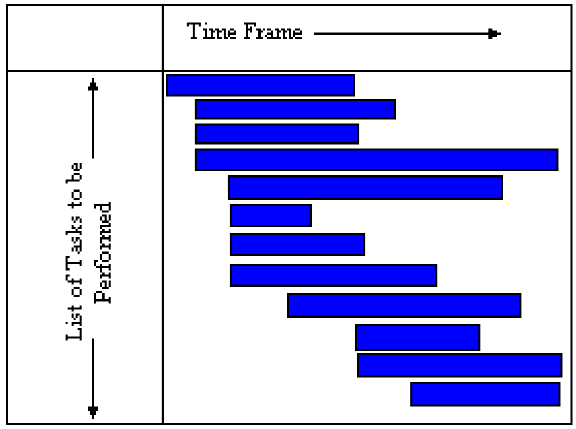
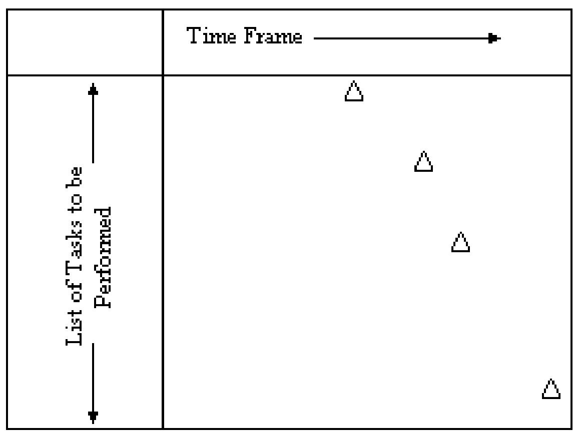


Figure 2.1 Structure of Gantt Charts

Milestone Chart

Similar to Gantt charts in structure, except only include symbols signifying the completion of a major task (refer to Figure 2.2. However, these two types of charts tend to be combined into one as illustrated in Figure 2.3. The combined chart would therefore illustrate duration as well as significant milestones.



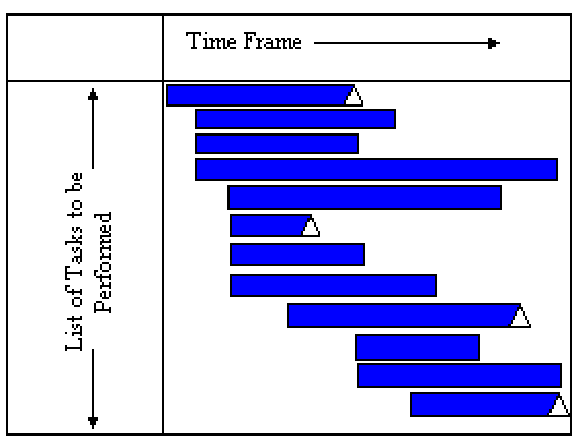


Figure 2.3 Combined Structure of Gantt and Milestone Chart

Arrow Diagram Method

Often referred to as the Critical Path Method, the ADM indicates the relationship between the tasks. They map out the path that is followed from the beginning to the end by using circles to represent events, and arrows to indicate the flow. With reference to Figure 2.4, the number above the arrows indicates time units for completion of the task. For example, the number 1 above the arrow between F and G means that it will take one time unit to complete task F. The time units are typically days, weeks, months or quarters.

From the arrow diagram, *the critical path* – the longest time to it takes to get from the beginning to the end of the project. The critical path therefore defines the shortest time required to complete the project. The other paths end up with float time, i.e., delays that can occur before you adversely affect the project by interfering with the start time of a succeeding activity. The path and float times for the ADM shown in Figure 2.4 are listed in Table 1 below.

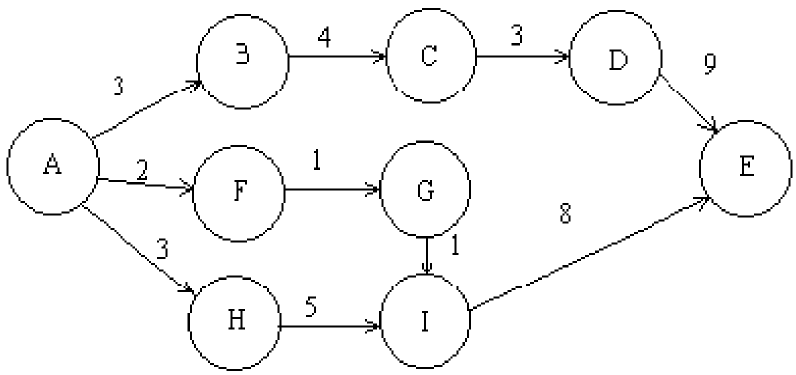


Figure 2.4 Structure of an Arrow Diagram

Table 1. Path and Float times for ADM shown in Figure 2.3

PATH	TIME	FLOAT
AFG	4	4
AH	8	-
ABCDE	19 (Critical Path)	-
AFGIE	12	7
AHIE	16	3

Objective Tree Method

Defining the objectives of a project presents the team with a clear idea of what has to be accomplished. This allows the teams to arrive at a comprehensive agreement on the goals of the project. Further, it provides the baseline from which to work when project's goals need to be altered during the duration of the project.

The objective tree diagram can be generated following the following three general steps:

- Identify and list the design objectives from the design problem statement and from group discussions
- Organize objectives into groups of higher and lower objectives, grouping them according to importance (hierarchical levels).
- Draw a diagramatic tree of the objectives showing the hierarchical relationships and interconnections

Figure 2.5 shows the objective tree diagram for the design of a device to carry disabled individuals up a flight of stairs. In addition to incorporating all the design objectives into the diagram, the design constraints can be included as well.

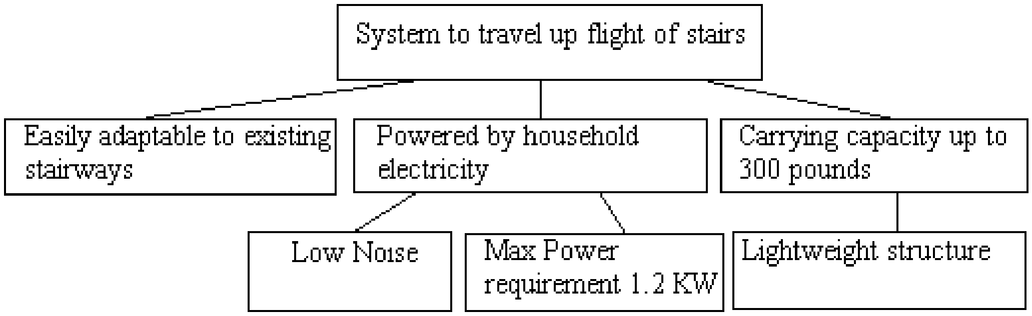


Figure 2.5 Example of Objective Tree Diagram for the design of a device to carry disabled people up a flight of stairs.

2.2 Decision Making

In any design process, one is constantly making decisions on all aspects of the project, including project objectives, cost and materials. Several tools exist in order to assist in the decision making process. These include *decision matrices* and *decision trees*.

Decision Matrices

Can vary in complexity from extremely simple to very complex. In the simplest case, it consists of a matrix (rows and columns) that allow one to evaluate alternatives relative to various design factors and weights as illustrated in Figure 2.6.

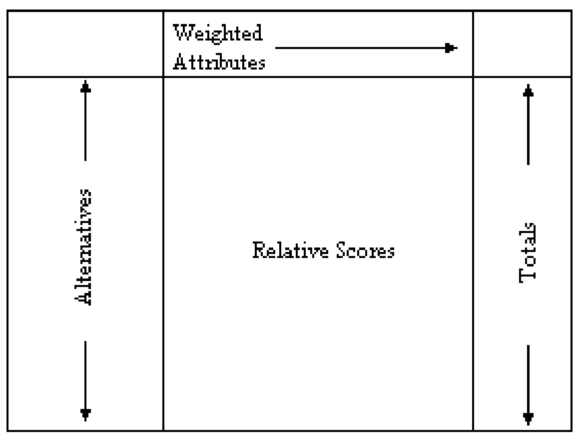


Figure 2.6 Structure of a Basic Decision Matrix

The following basic steps can therefore be followed in the creation of a decision matrix

1. List all the alternatives, each in a separate row
2. Going across the columns, list all the criteria by which these alternatives will be evaluated. As all criteria may not be of the same importance, assign weights to each criterion.
3. Assign/calculate scores for each alternative based on each decision criterion. As each property would typically be expressed in different units, normalization is performed. The resulting scaled parameter values would now all be within a single range (typically between 0-1, 0-10 or 0-100). For parameters that need to be maximized, scaling is carried out by dividing each value by the largest one, i.e.,

   s= value of material property/largest value of material property

   For parameters that need to be minimized (e.g. cost, density) scaling is carried out by dividing the smallest value by each value, i.e.,

   s= lowest value of material property/value of material property

These values are then multiplied by 1, 10 or 100 to obtain the approriate ranges.

4. Obtain totals for each alternative from the formula:

$$Total = \sum_{i=1}^{n} w_i s_i$$

where n is the number of criteria, w_i, the weight assigned to each criterion and s_i, the scale value for each criterion. Further,

$$\sum_{i=1}^{n} w_i = 1$$

Remember that use of these tools should not be a substitute for good engineering judgement, especially since a great deal of subjectivity is employed in determining the weights and some of the scores.

The Concept Selection Technique

A variation of the decision matrix, known as The Concept Selection Technique, has been developed by Pugh (1981). It was developed to allow designers to carry out the process of concept selection in a progressive and orderly fashion, thereby reducing the likelihood of selecting the wrong concept. The concept selection technique is an iterative process as described by the following steps:

1. Develop all concepts to the same level of detail and create a concept evaluation matrix. For example, Figure 2.7 illustrates the concept evaluation matrix for several concepts for the placement of an electric motor on an electric bike. The matrix axes display each concept versus the criteria to be used to evaluate each design. The criteria are derived from the problem statement.
2. One of the concepts is chosen as the reference or datum to which all the others will be compared.
3. Each concept/criteria combination is then evaluated versus the datum, where:

- \+ Improves on the datum
- **-** Is worse than the datum
- S Is similar to the datum, i.e., one cannot conclusively tell either way

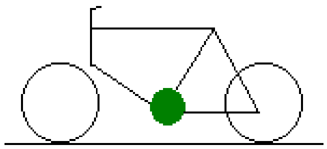
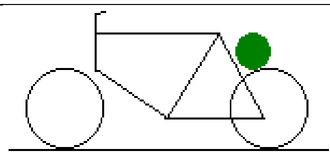
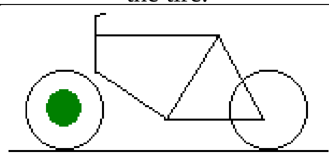
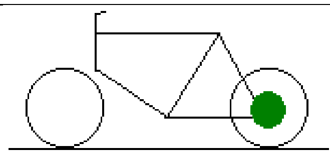
4. Look at the scores of +, **-** and S's for each concept. Re-examine those concepts whose scores seem to be unusually high. If they still remain that way, these are most likely your strong concepts.
5. Change your datum and re-evaluate all the concepts. A pattern of one or more strong concepts should begin to emerge. If this does not occur then this could mean that your criteria are too ambiguous or that one or more concepts are subsets of each other.
6. If one or more concepts remain strong, let them be the datum and redo the matrix. If they still remain strong, then they will be your likely candidate(s) to move onto the detailed design stage. Note that as you uncover weak areas of different concepts, improvements should be made, where possible, to them. In the process new concepts may be developed. If improvements cannot be made to them through modifications, then the concepts are indeed weak and should be abandoned.

Electric Bicycle Design – An Example

Figure 2.7 shows an example of three matrices (merged into one to save space) for the selection of an electric bicycle concept from four candidates. The main issue being addressed at this stage is the location of the electric motor that will power the bicycle. In each schematic, the electric motor is represented by the green circle.

For the first evaluation, concept #1 was taken as the datum. Each of the other concepts were then given a +,**-** or S evaluation. From the first cut, concept #1 and #2 appeared to be the strongest candidates. A second evaluation was performed with concept #2 as the datum. The result was the same, with concept #1 and #2 still ahead of the pack. Finally, one last evaluation was performed where neither concept #1 or #2 were the datum. The result was still the same. Note that on concept#1 fared slightly better than #2. But due to the small difference, both should be investigated further.

Figure 2.7 Concept Selection Technique. Electric Bicycle Example.

CRITERIA / CONCEPTS	Rider Stability	Use of Standard Parts	Complexity: Transmission	Manufacturing Cost	Maintenance Cost	Sum +ve's	Sum –ve's
 # 1 Motor integrated with pedal mechanism	D	A	T	U	M	-	-
	+	S	S	-	+	2	1
	+	+	+	+	S	3	0
 #2 Motor assembly drives rear wheel via the tire.	-	S	S	+	-	1	2
	D	A	T	U	M		
	+	+	+	+	-	4	1
 #3 Front Wheel Direct Drive	-	-	-	-	S	0	4
	-	-	-	-	+	1	4
	D	A	T	U	M		
 #4 Rear wheel direct drive	S	-	-	-	S	0	3
	+	-	-	-	+	2	3
	+	S	S	S	S	1	0

References

Pugh, S. "Concept Selection-A Method that Works", Proceedings of the International Conference on Engineering Design, Rome 1981.

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Ertas A. and J. Jones, The Engineering Design Process, John Wiley and Sons, New York, 1996