**UNIT-II**

**CHAPTER-I  
SOFTWARE PROJECT MANAGEMENT**

Software project management is a very vast topic. In fact, a full semester teaching can be conducted on effective techniques for software project management.

The main goal of software project management is to enable a group of developers to work effectively towards the successful completion of a project.

**SOFTWARE PROJECT MANAGEMENT COMPLEXITIES**

* **Invisibility:** Invisibility of software makes it difficult to assess the progress of a project and is a major cause for the complexity of managing a software project.
* **Changeability:** Frequent changes to the requirements and the invisibility of software are possibly the two major factors making software project management a complex task.
* **Complexity:** Even a moderate sized software has millions of parts (functions) that interact with each other in many ways—data coupling, serial and concurrent runs, state transitions, control dependency, file sharing, etc.
* **Uniqueness:** Every software project is usually associated with many unique features or situations. This makes every project much different from the others. This is unlike projects in other domains, such as car manufacturing or steel manufacturing where the projects are more predictable. Due to the uniqueness of the software projects, a project manager in the course of a project faces many issues that are quite unlike the ones he/she might have encountered in the past.
* **Exactness of the solution:** Mechanical components such as nuts and bolts typically work satisfactorily as long as they are within a tolerance of 1 per cent or so of their specified sizes. However, the parameters of a function call in a program are required to be in complete conformity with the function definition.
* **Team-oriented and intellect-intensive work:** Software development projects are akin to research projects in the sense that they both involve team-oriented, intellect-intensive work. In contrast, projects in many domains are labor-intensive and each member works in a high degree of autonomy. Examples of such projects are planting rice, laying roads, assembly line manufacturing, constructing a multistoried building, etc.

**RESPONSIBILITIES OF A SOFTWARE PROJECT MANAGER**

**Job Responsibilities for Managing Software Projects**

A software project manager takes the overall responsibility of steering a project to success. This surely is a very hazy job description. In fact, it is very diﬃcult to objectively describe the precise job responsibilities of a project manager. The job responsibilities of a project manager range from invisible activities like building up of team morale to highly visible customer presentations.

We can broadly classify a project manager’s varied responsibilities into the following two major categories:

* Project planning, and
* Project monitoring and control.

**Project planning:** Project planning is undertaken immediately after the feasibility study phase and before the starting of the requirements analysis and specification phase.

The initial project plans are revised from time to time as the project progresses andmore project data become available.

**Project monitoring and control:** Project monitoring and control activities are undertaken once the development activities start. As the project gets underway, the details of the project that were unclear earlier at the start of the project emerge and situations that were not visualized earlier arise. While carrying out project monitoring and control activities, a project manager usually needs to change the plan to cope up with specific situations at hand.

**Skills Necessary for Managing Software Projects**

A theoretical knowledge of various project management techniques is certainly important to become a successful project manager. However, a purely theoretical knowledge of various project management techniques would hardly make one a successful project manager. Effective software project management calls for good qualitative judgment and decision taking capabilities.

In addition to having a good grasp of the latest software project management techniques such as cost estimation, risk management, and configuration management, etc., project managers need good communication skills and the ability to get work done. Some skills such as tracking and controlling the progress of the project, customer interaction, managerial presentations, and team building are largely acquired through experience. Never the less, the importance of a sound knowledge of the prevalent project management techniques cannot be overemphasized.

* Three skills that are most critical to successful project management
* are the following:
* Knowledge of project management techniques.
* Decision taking capabilities
* Previous experience in managing similar projects

**PROJECT PLANNING**

Project managers undertake project planning. Project planning requires utmost care and attention since commitment to unrealistic time and resource estimates result in schedule slippage. Schedule delays can cause customer dissatisfaction and adversely affect team morale.

It can even cause project failure. For this reason, project planning is undertaken by the project managers with utmost care and attention. However, for effective project planning, in addition to a thorough knowledge of the various estimation techniques, past experience is crucial.

During project planning, the project manager performs the following activities. Note that we have given only a very brief description of the activities.

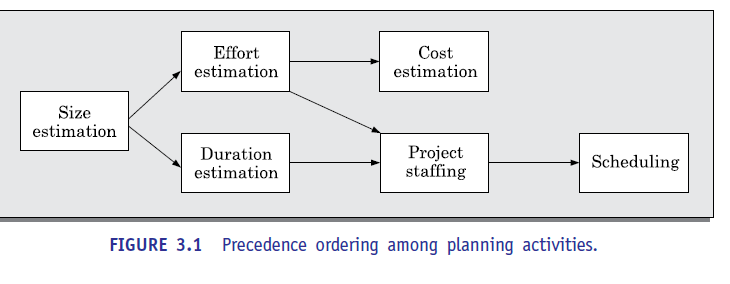
* **Estimation:** The following project attributes are estimated.

Cost: How much is it going to cost to develop the software product?

Duration: How long is it going to take to develop the product?

Effort: How much effort would be necessary to develop the product?

The effectiveness of all later planning activities such as scheduling and staﬃng are dependent on the accuracy with which these three estimations have been made.

* **Scheduling:** After all the necessary project parameters have been estimated, the schedules for manpower and other resources are developed.
* **Staffing:** Staff organization and staﬃng plans are made.
* **Risk management:** This includes risk identification, analysis, and abatement planning.
* **Miscellaneous plans:** This includes making several other plans such as quality assurance plan, and configuration management plan, etc.
* Figure 3.1 shows the order in which the planning activities are undertaken. Observe that size estimation is the first activity that a project manager undertakes during project planning.
* As can be seen from Figure 3.1, based on the size estimation, the effort required to complete a project and the duration over which the development is to be carried out are estimated. Based on the effort estimation, the cost of the project is computed. The estimated cost forms the basis on which price negotiations with the customer is carried out. Other planning activities such as staﬃng, scheduling etc. are undertaken based on the effort and duration estimates made. In Section 3.7, we shall discuss a popular technique for estimating the project parameters. Subsequently, we shall discuss the staﬃng and scheduling issues.
* Size is the most fundamental parameter, based on which all other estimations and project plans are made. 

**Sliding Window Planning**

* It is usually very diﬃcult to make accurate plans for large projects at project initiation. A part of the diﬃculty arises from the fact that large projects may take several years to complete.
* As a result, during the span of the project, the project parameters, scope of the project, project staff, etc., often change drastically resulting in the initial plans going haywire. In order to overcome this problem, sometimes project managers undertake project planning over several stages.
* That is, after the initial project plans have been made, these are revised at frequent intervals. Planning a project over a number of stages protects managers from making big commitments at the start of the project. This technique of staggered planning known as *sliding window planning*.
* At the start of a project, the project manager has incomplete knowledge about the nitty-gritty of the project. His information base gradually improves as the project progresses through different development phases. The complexities of different project activities become clear, some of the anticipated risks get resolved, and new risks appear. The project parameters are re-estimated periodically as understanding grows and also a periodically as project parameters change.

**The SPMP Document of Project Planning**

* Once project planning is complete, project managers document their plans in a software project management plan (SPMP) document. Listed below are the different items that the SPMP document should discuss. This list can be used as a possible organization of the SPMP document.

**Organization of the software project management plan (SPMP) document**

* **1. Introduction**

(a) Objectives

(b) Major Functions

(c) Performance Issues

(d) Management and Technical Constraints

* **2. Project estimates**

(a) Historical Data Used

(b) Estimation Techniques Used

(c) Effort, Resource, Cost, and Project Duration Estimates

* **3. Schedule**

(a) Work Breakdown Structure

(b) Task Network Representation

(c) Gantt Chart Representation

(d) PERT Chart Representation

* **4. Project resources**

(a) People

(b) Hardware and Software

(c) Special Resources

* **5. Staff organisation**

(a) Team Structure

(b) Management Reporting

* **6. Risk management plan**

(a) Risk Analysis

(b) Risk Identification

(c) Risk Estimation

(d) Risk Abatement Procedures

* **7. Project tracking and control plan**

(a) Metrics to be tracked

(b) Tracking plan**6**

(c) Control plan

* **8. Miscellaneous plans**

(a) Process Tailoring

(b) Quality Assurance Plan

(c) Configuration Management Plan

(d) Validation and Verification

(e) System Testing Plan

(f) Delivery, Installation, and Maintenance Plan

**METRICS FOR PROJECT SIZE ESTIMATION**

* The project size is a measure of the problem complexity in terms of the effort and time required to develop the product.
* Currently, two metrics are popularly being used to measure size—lines of code (LOC) and function point (FP). Each of these metrics has its own advantages and disadvantages.
* Based on their relative advantages, one metric may be more appropriate than the other in a particular situation.

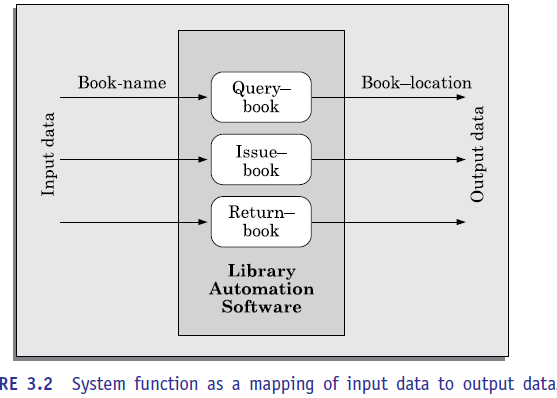
**Lines of Code (LOC)**

* LOC is possibly the simplest among all metrics available to measure project size.
* Consequently, this metric is extremely popular. This metric measures the size of a project by counting the number of source instructions in the developed program. Obviously, while counting the number of source instructions, comment lines, and header lines are ignored.
* Determining the LOC count at the end of a project is very simple. However, accurate estimation of LOC count at the beginning of a project is a very diﬃcult task. One can possibly estimate the LOC count at the starting of a project, only by using some form of systematic guess work. Systematic guessing typically involves the following. The project manager divides the problem into modules, and each module into sub-modules and
* **LOC is a measure of coding activity alone.** The implicit assumption made by the LOC metric that the overall product development effort is solely determined from the coding effort alone is flawed.
* **LOC count depends on the choice of specific instructions:** LOC gives a numerical value of problem size that can vary widely with coding styles of individual programmers.
* Even for the same programming problem, different programmers might come up with programs having very different LOC counts. This situation does not improve, even if language tokens are counted instead of lines of cod
* **LOC measure correlates poorly with the quality and efficiency of the code:** Larger code size does not necessarily imply better quality of code or higher eﬃciency. Some programmers produce lengthy and complicated code as they do not make effective use of the available instruction set or use improper algorithms.
* **LOC metric penalizes use of higher-level programming languages and code reuse:** A paradox is that if a programmer consciously uses several library routines, then the LOC count will be lower. This would show up as smaller program size, and in turn, would indicate lower effort!
* **LOC metric measures the lexical complexity of a program and does not address the more important issues of logical and structural complexities:** Between two programs with equal LOC counts, a program incorporating complex logic would require much more effort to develop than a program with very simple logic.
* **It is very difficult to accurately estimate LOC of the final program from problem specification:** As already discussed, at the project initiation time, it is a very diﬃcult task to accurately estimate the number of lines of code (LOC) that the program would have after development. The LOC count can accurately be computed only after the code has fully been developed. Since project planning is carried out even before any development activity starts, the LOC metric is of little use to the project managers during project planning.

**Function Point (FP) Metric**

* Function point metric was proposed by Albrecht and Gaffney in 1983. This metric overcomes many of the shortcomings of the LOC metric. Since its inception, function point metric has steadily gained popularity. Function point metric has several advantages over LOC metric.
* One of the important advantages of the function point metric over the LOC metric is that it can easily be computed from the problem specification itself.
* Using the LOC metric, on the other hand, the size can accurately be determined only after the code has been fully written.
* The conceptual idea behind the function point metric is the following. The size of a software product is directly dependent on the number of different high-level functions or features it supports. This assumption is reasonable, since each feature would take additional effort to implement.
* Though each feature takes some effort to develop, different features may take very different amounts of efforts to develop. For example, in a banking software, a function to display a help message may be much easier to develop compared to say the function that carries out the actual banking transactions. Therefore, just determining the number of functions to be supported (with adjustments for number of fi les and interfaces) may not yield very accurate results.
* This has been considered by the function point metric by counting the number of input and output data items and the number of files accessed by the function. The implicit assumption made is that the more the number of data items that a function reads from the user and outputs and the more the number of files accessed, the higher is the complexity of the function.
* Now let us analyze why this assumption must be intuitively correct. Each feature when invoked typically reads some input data and then transforms those to the required output data. For example, the query book feature (see Figure 3.2) of a Library Automation Software takes the name of the book as input and displays its location in the library and the total number of copies available. Similarly, the issue book and the return book features produce their output based on the corresponding
* input data. It can therefore be argued that the computation of the number of input and
* output data items would give a more accurate indication of the code size compared to

simply counting the number of high-level functions supported by the system.



**Function point (FP) metric computation**

The size of a software product (in units of function points or FPs) is computed using different characteristics of the product identified in its requirements specification. It is computed using the following three steps:

* Step 1: Compute the unadjusted function point (UFP) using a heuristic expression.
* Step 2: Refine UFP to reflect the actual complexities of the different parameters used in UFP computation.
* Step 3: Compute FP by further refining UFP to account for the specific characteristics of the project that can influence the entire development effort. We discuss these three steps in more detail in the following.

**Step 1: UFP computation**

* The *unadjusted function points* (UFP) are computed as the weighted sum of five characteristics of a product as shown in the following expression. The weights associated with the five characteristics were determined empirically by Albrecht through data gathered from manyprojects.
* UFP = (Number of inputs) \*4 + (Number of outputs) \*5 + (Number of inquiries) \*4

+ (Number of files) \*10 + (Number of interfaces) \*10 (3.1)

The meanings of the different parameters of Eq. (3.1) are as follows:

* 1. **Number of inputs:** Each data item input by the user is counted. However, it should be noted that data inputs are considered different from user inquiries. Inquiries are user commands such as print-account-balance that require no data values to be input by the user. Inquiries are counted separately (see the third point below).

It needs to be further noted that individual data items input by the user are not simply added up to compute the number of inputs, but related inputs are grouped and considered as a single input. For example, while entering the data concerning an employee to an employee pay roll software; the data items name, age, sex, address, phone number, etc. are together considered as a single input. All these data items can be considered to be related, since they describe a single employee.

* 2. **Number of outputs:** The outputs considered include reports printed, screen outputs, error messages produced, etc. While computing the number of outputs, the individual data items within a report are not considered; but a set of related data items is counted as just a single output.
* 3. **Number of inquiries:** An inquiry is a user command (without any data input) and only requires some actions to be performed by the system. Thus, the total number of inquiries is essentially the number of distinct interactive queries (without data input) which can be made by the users. Examples of such inquiries are print account balance, print all student grades, display rank holders’ names, etc.
* 4. **Number of files:** The *files* referred to here are logical files. A logical file represents a group of logically related data. Logical files include data structures as well as physical files.
* 5. **Number of interfaces:** Here the interfaces denote the different mechanisms that are used to exchange information with other systems. Examples of such interfaces are data files on tapes, disks, communication links with other systems, etc.

**Step 2: Refine parameters**

* UFP computed at the end of step 1 is a gross indicator of the problem size. This UFP needs to be refined by taking into account various peculiarities of the project. This is possible, since each parameter (input, output, etc.) has been implicitly assumed to be of average complexity. However, this is rarely true. For example, some input values may be extremely complex, some very simple, etc. In order to take this issue into account, UFP is refined by taking into account the complexities of the parameters of UFP computation (Eq. 3.1). The complexity of each parameter is graded into three broad categories—simple, average, or complex.
* The weights for the different parameters are determined based on the numerical values shown in Table 3.1. Based on these weights of the parameters, the parameter values in the UFP are refined. For example, rather than each input being computed as four FPs, very simple inputs are computed as three FPs and very complex inputs as six FPs.

**Step 3: Refine UFP based on complexity of the overall project**

* In the final step, several factors that can impact the overall project size are considered to refine the UFP computed in step 2. Examples of such project parameters that can influence the project sizes include high transaction rates, response time requirements, scope for reuse, etc. Albrecht identified 14 parameters that can influence the development effort.
* The list of these parameters has been shown in Table 3.2. Each of these 14 parameters is assigned a value from 0 (not present or no influence) to 6 (strong influence). The resulting numbers are summed, yielding the total *degree of influence* (DI). A *technical complexity factor* (TCF) for the project is computed and the TCF is multiplied with UFP to yield FP. The TCF expresses the overall impact of the corresponding project parameters on the development effort. TCF is computed as (0.65 + 0.01 × DI).

As DIcan vary from 0 to 84, TCF can vary from 0.65 to 1.49. Finally, FP is given as the product of UFP and TCF. That is, FP = UFP × TCF.

|  |  |  |  |
| --- | --- | --- | --- |
| **Type** | **Simple** | **Average** | **Complex** |
| *Input* (I) | 3 | 4 | 6 |
| Output (O) | 4 | 5 | 7 |
| Inquiry (E) | 3 | 4 | 6 |
| Number of files (F) | 7 | 10 | 15 |
| Number of interfaces | 5 | 7 | 10 |

**TABLE 3.1** Refinement of Function Point Entities

**TABLE 3.2** Function Point Relative Complexity Adjustment Factors

|  |
| --- |
| Requirement for reliable backup and recovery |
| Requirement for data communication |
| Extent of distributed processing |
| Performance requirements |
| Expected operational environment |
| Extent of online data entries |
| Extent of multi-screen or multi-operation online data input |
| Extent of online updating of master files |
| Extent of complex inputs, outputs, online queries and files |
| Extent of complex data processing |
| Extent that currently developed code can be designed for reuse |
| Extent of conversion and installation included in the design |
| Extent of multiple installations in an organisation and variety of customer organisations |
| Extent of change and focus on ease of use |

**Feature point metric shortcomings:** A major shortcoming of the function point measure is that it does not take into account the algorithmic complexity of a function. That is, the function point metric implicitly assumes that the effort required to design and develop any two different functionalities of the system is the same.

But we know that this is highly unlikely to be true. The effort required to develop any two functionalities may vary widely.

For example, in a library automation software, the create-member feature would be much simpler compared to the loan-from-remote-library feature. FP only considers the number of functions that the system supports, without distinguishing the diﬃculty levels of developing the various functionalities. To overcome this problem, an extension to the function point metric called *feature point* metric has been proposed.

Feature point metric incorporates *algorithm* complexity as an extra parameter. This parameter ensures that the computed size using the feature point metric reflects the fact that higher the complexity of a function, the greater the effort required to develop it— therefore, it should have larger size compared to a simpler function.

**Critical comments on the function point and feature point metrics**

Proponents of function point and feature point metrics claim that these two metrics are language-independent and can be easily computed from the SRS document during project planning stage itself. On the other hand, opponents claim that these metrics are subjective and require a sleight of hand.

An example of the subjective nature of the function point metric can be that the way one groups input and output data items into logically related groups can be very subjective. For example, consider that certain functionality requires the employee’s name and employee address to be input. It is possible that one can consider both these items as a single unit of data, since after all, these describe a single employee.

It is also possible for someone else to consider an employee’s address as a single unit of input data and name as another. Such ambiguities leave suﬃcient scope for debate and keep open the possibility for different project managers to arrive at different function point measures for essentially the same problem.

**PROBLEM 3.1** Determine the function point measure of the size of the following supermarket software. A supermarket needs to develop the following software to encourage regular customers. For this, the customer needs to supply his/her residence address, telephone number, and the driving license number. Each customer who registers for this scheme is assigned a unique *customer number* (CN) by the computer. Based on the generated CN, a clerk manually prepares a customer identity card after getting the market manager’s signature on it. A customer can present his customer identity card to the check out staff when he makes any purchase. In this case, the value of his purchase is credited against his CN. At the end of each year, the supermarket intends to award surprise gifts to 10 customers who make the highest total purchase over the year. Also, it intends to award a 22 caret gold coin to every customer whose purchase exceeded `10,000. The entries against the CN are reset on the last day of every year after the prize winners’ lists are generated. Assume that various project characteristics determining the complexity of software development to be average.

***Solution:***

**Step 1:** From an examination of the problem description, we find that there are two inputs,

three outputs, two files, and no interfaces. Two files would be required, one for storing the

customer details and another for storing the daily purchase records. Now, using equation

3.1, we get:

UFP = 2 × 4 + 3 × 5 + 1 × 4 + 10 × 2 + 0 × 10 = 47

**Step 2:** All the parameters are of moderate complexity, except the output parameter

of customer registration, in which the only output is the CN value. Consequently, the

complexity of the output parameter of the customer registration function can be categorized

as simple. By consulting Table 3.1, we find that the value for simple output is given to be

4. The UFP can be refined as follows:

UFP = 3 × 4 + 2 × 5 + 1 × 4 + 10 × 2 + 0 × 10 = 46

Therefore, the UFP will be 46.

**Step 3:** Since the complexity adjustment factors have average values, therefore the total

degrees of influence would be: DI = 14 × 4 = 56

*TCF* = 0*.*65 + 0*.*01 + 56 = 1*.*21

Therefore, the adjusted FP = 46 × 1.21 = 55.66

**PROJECT ESTIMATION TECHNIQUES**

Estimation of various project parameters is an important project planning activity. The different parameters of a project that need to be estimated include—project size, effort required to complete the project, project duration, and cost. Accurate estimation of these parameters is important, since these not only help in quoting an appropriate project cost to the customer, but also form the basis for resource planning and scheduling.

A large number of estimation techniques have been proposed by researchers. These can broadly be classified into three main categories:

* Empirical estimation techniques
* Heuristic techniques
* Analytical estimation techniques

In the following subsections, we provide an overview of the different categories of estimation techniques.

* **Empirical Estimation Techniques**

Empirical estimation techniques are essentially based on making an educated guess of the project parameters. While using this technique, prior experience with development of similar products is helpful. Although empirical estimation techniques are based on common sense and subjective decisions, over the years, the different activities involved in estimation have been formalized to a large extent. We shall discuss two such formalizations of the basic empirical estimation techniques known as expert judgement and the Delphi techniques in Sections

* **Heuristic Techniques**

Heuristic techniques assume that the relationships that exist among the different project parameters can be satisfactorily modelled using suitable mathematical expressions. Once the basic (independent) parameters are known, the other (dependent) parameters can be easily determined by substituting the values of the independent parameters in the corresponding mathematical expression. Different heuristic estimation models can be divided into the following two broad categories—single variable and multivariable models.

Single variable estimation models assume that various project characteristic can be predicted based on a single previously estimated basic (independent) characteristic of the software such as its size. A single variable estimation model assumes that the relationship between a parameter to be estimated and the corresponding independent parameter can be characterized by an expression of the following form:

* Estimated Parameter = *c*1 × *ed*1
* In the above expression, *e* represents a characteristic of the software that has already been estimated (independent variable).

*Estimated Parameter* is the dependent parameter (to be estimated). The dependent parameter to be estimated could be effort, project duration, staff size, etc., *c*1 and *d*1 are constants. The values of the constants *c*1 and *d*1 are usually determined using data collected from past projects (historical data). The COCOMO model discussed in Section 3.7.1, is an example of a single variable cost estimation model.

* A multivariable cost estimation model assumes that a parameter can be predicted based on the values of more than one independent parameter. It takes the following form:
* Estimated Resource = *c*1 × *pd*1 + *c*2 × p*d*2 + L
* where, *p*1, *p*2, ... are the basic (independent) characteristics of the software already estimated, and *c*1, *c*2, *d*1, *d*2, .... are constants. Multivariable estimation models are expected to give more accurate estimates compared to the single variable models, since a project parameter is typically influenced by several independent parameters. The independent parameters influence the dependent parameter to different extents. This is modelled by the different sets of constants *c*1, *d*1, *c*2, *d*2, .... Values of these constants are usually determined from an analysis of historical data. The intermediate COCOMO model discussed in Section 3.7.2 can be considered to be an example of a multivariable estimation model

**Analytical Estimation Techniques**

Analytical estimation techniques derive the required results starting with certain basic assumptions regarding a project. Unlike empirical and heuristic techniques, analytical techniques do have certain scientific basis. As an example of an analytical technique, we shall discuss the Halstead’s software science in Section 3.8. We shall see that starting with a few simple assumptions, Halstead’s software science derives some interesting results. Halstead’s software science is especially useful for estimating software maintenance efforts. In fact, it outperforms both empirical and heuristic techniques as far as estimating software maintenance efforts is concerned.

**EMPIRICAL ESTIMATION TECHNIQUES**

* We have already pointed out that empirical estimation techniques have, over the years, been formalized to a certain extent. Yet, these are still essentially euphemisms for pure guess work. These techniques are easy to use and give reasonably accurate estimates. Two popular empirical estimation techniques are—Expert judgement and Delphi estimation techniques. We discuss these two techniques in the following subsection.
* **Expert Judgement**

Expert judgement is a widely used size estimation technique. In this technique, an expert makes an educated guess about the problem size after analyzing the problem thoroughly. Usually, the expert estimates the cost of the different components (i.e. modules or subsystems) that would make up the system and then combines the estimates for then individual modules to arrive at the overall estimate. However, this technique suffers from several shortcomings. The outcome of the expert judgement technique is subject to human errors and individual bias. Also, it is possible that an expert may overlook some factors inadvertently. Further, an expert making an estimate may not have relevant experience and knowledge of all aspects of a project. For example, he may be conversant with the database and user interface parts, but may not be very knowledgeable about the computer communication part. Due to these factors, the size estimation arrived at by the judgement of a single expert may be far from being accurate.

* A more refined form of expert judgement is the estimation made by a group of experts. Chances of errors arising out of issues such as individual oversight, lack of familiarity with a particular aspect of a project, personal bias, and the desire to win contract through overly optimistic estimates is minimized when the estimation is done by a group of experts.
* However, the estimate made by a group of experts may still exhibit bias. For example, on certain issues the entire group of experts may be biased due to reasons such as those arising out of political or social considerations. Another important shortcoming of the expert judgement technique is that the decision made by a group may be dominated by overly assertive members.

**3.6.2 Delphi Cost Estimation**

* Delphi cost estimation technique tries to overcome some of the shortcomings of the expert judgement approach. Delphi estimation is carried out by a team comprising a group of experts and a coordinator. In this approach, the coordinator provides each estimator with a copy of the *software requirements specification* (SRS) document and a form for recording his cost estimate. Estimators complete their individual estimates anonymously and submit them to the coordinator. In their estimates, the estimators mention any unusual characteristic of the product which has influenced their estimations. The coordinator prepares the summary of the responses of all the estimators, and also includes any unusual rationale noted by any of the estimators. The prepared summary information is distributed to the estimators. Based on this summary, the estimators re-estimate. This process is iterated for several rounds. However, no discussions among the estimators is allowed during the entire estimation process.
* The purpose behind this restriction is that if any discussion is allowed among the estimators, then many estimators may easily get influenced by the rationale of an estimator who may be more experienced or senior. After the completion of several iterations of estimations, the coordinator takes the responsibility of compiling the results and preparing the final estimate. The Delphi estimation, though consumes more time and effort, overcomes an important shortcoming of the expert judgement technique in that the results cannot unjustly be influenced by overly assertive and senior members.

**COCOMO—A HEURISTIC ESTIMATION TECHNIQUE**

Constructive Cost estimation Model (COCOMO) was proposed by Boehm [1981]. COCOMO prescribes a three-stage process for project estimation. In the first stage, an initial estimate is arrived at. Over the next two stages, the initial estimate is refined to arrive at a more accurate estimate. COCOMO uses both single and multivariable estimation models at different stages of estimation.

The three stages of COCOMO estimation technique are—basic COCOMO, intermediate COCOMO, and complete COCOMO. We discuss these three stages of estimation in the following subsection.

**Basic COCOMO Model**

* Boehm postulated that any software development project can be classified into one of the following three categories based on the development complexity—*organic, semidetached, and embedded*. Based on the category of a software development project, he gave different sets of formulas to estimate the effort and duration from the size estimate.

Three basic classes of software development projects

In order to classify a project into the identified categories, Boehm requires us to consider not only the characteristics of the product but also those of the development team and development environment. Roughly speaking, the three product development classes correspond to development of application, utility and system software. Normally, data= processing programs2 are considered to be application programs. Compilers, linkers, etc., are utility programs. Operating systems and real-time system programs, etc. are system programs. System programs interact directly with the hardware and programming complexities also arise out of the requirement for meeting timing constraints and concurrent processing of tasks.

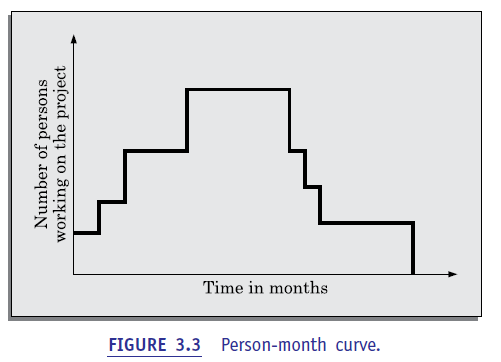
* Brooks [1975] states that utility programs are roughly three times as diﬃcult to write as application programs and system programs are roughly three times as diﬃcult as utility programs. Thus, according to Brooks, the relative levels of product development complexity for the three categories (application, utility and system programs) of products are 1:3:9.
* Boehm’s [1981] definitions of organic, semidetached, and embedded software are elaborated as follows:

**Organic:** We can classify a development project to be of organic type, if the project deals with developing a well-understood application program, the size of the development team is reasonably small, and the team members are experienced in developing similar types of projects.

**Semidetached:** A development project can be classified to be of semidetached type, if the development team consists of a mixture of experienced and inexperienced staff. Team members may have limited experience on related systems but may be unfamiliar with some aspects of the system being developed.

**Embedded:** A development project is considered to be of embedded type, if the software being developed is strongly coupled to hardware, or if stringent regulations on the operational procedures exist. development project is considered to be of embedded type, if the software being developed is strongly coupled to hardware, or if stringent regulations on the operational procedures exist. Team members may have limited experience on related systems but may be unfamiliar with some aspects of the system being developed.

* Observe that in deciding the category of the development project, in addition to considering the characteristics of the product being developed, we need to consider the characteristics of the team members. Thus, a simple data processing program may be classified as semidetached, if the team members are inexperienced in the development of similar products.
* For the three product categories, Boehm provided different sets of constant values for the coefficients for the two basic expressions to predict the effort (in units of person-months) and development time from the size estimation given in kilo lines of source code (KLSC). But how much effort is one person-month?
* Person-month (PM) is a popular unit for effort measurement. It should be carefully noted that an effort estimation of 100 PM does not imply that 100 persons should work for 1 month. Neither does it imply that 1 person should be employed for 100 months to complete the project.
* The effort estimation simply denotes the area under the person-month curve (see Figure 3.3) for the project. The plot in Figure 3.3 shows that different number of personnel may work at different points in the project development. The number of personnel working on the project usually increases or decreases by an integral number resulting in the sharp edges in the plot. We shall elaborate in Section 3.9 how the exact number of persons to work at any time on the product development can be determined from the effort and duration estimates



**General form of the COCOMO expressions**

* The **basic COCOMO model** is a single variable heuristic model that gives an approximate estimate of the project parameters. The basic COCOMO estimation model is given by expressions of the following forms:
* Effort = *a*1 × (KLOC)*a*2 PM
* Tdev = *b*1 × (Effort)*b*2 months
* where,  KLOC is the estimated size of the software product expressed in Kilo Lines Of Code.
* *a*1*, a*2*, b*1*, b*2 are constants for each category of software product.
* Tdev is the estimated time to develop the software, expressed in months.
*  Effort is the total effort required to develop the software product, expressed in person-months (PMs).
* According to Boehm, every line of source text should be calculated as one LOC n irrespective of the actual number of instructions on that line. Thus, if a single instruction spans several lines (say *n* lines), it is considered to be *n* LOC. The values of *a*1*, a*2*, b*1*, b*2 for different categories of products as given by Boehm [1981] are summarized below.
* He derived these values by examining historical data collected from a large number of n actual projects.

**Estimation of development effort:** For the three classes of software products, the formulas for estimating the effort based on the code size are shown below:

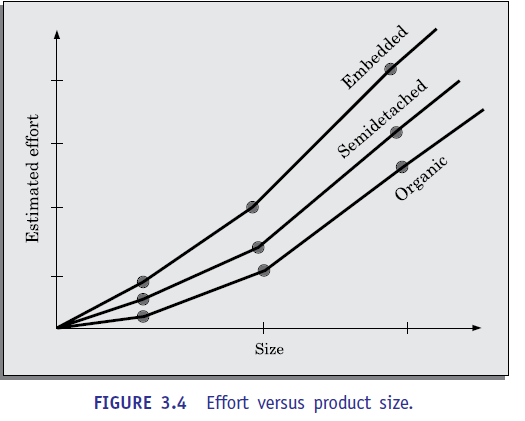
* Organic: Effort = 2*.*4(KLOC)1*.*05 PM
* Semi-detached: Effort = 3*.*0(KLOC)1*.*12 PM
* Embedded: Effort = 3*.*6(KLOC)1*.*20 PM
* **Estimation of development time:** For the three classes of software products, the formulas for estimating the development time based on the effort are given below:
* Organic: Tdev = 2*.*5(Effort)0*.*38 Months
* Semi-detached: Tdev = 2*.*5(Effort)0*.*35 Months
* Embedded: Tdev = 2*.*5(Effort)0*.*32 Months We can gain some insight into the basic COCOMO model, if we plot the estimated effort and duration values for different software sizes. Figure 3.4 shows the plots of estimated effort versus product size for different categories of software products.

**Observations from the effort-size plot**

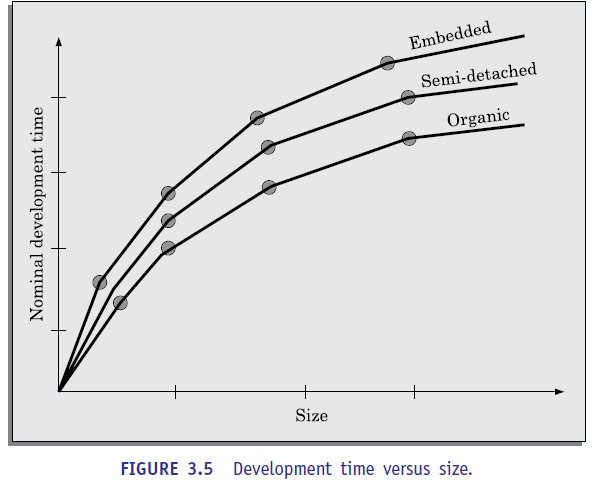
* From Figure 3.4, we can observe that the effort is somewhat super linear (that is, slope of the curve>1) in the size of the software product. This is because the exponent in the effort expression is more than 1. Thus, the effort required to develop a product increases rapidly with project size. The reason for this is that COCOMO assumes that projects are carefully designed and developed by using software engineering principles

**Observations from the development time—size plot**

* The development time versus the product size in KLOC is plotted in Figure 3.5. From Figure 3.5, we can observe the following:
* The development time is a sublinear function of the size of the product. That is, when the size of the product increases by two times, the time to develop the product does not double but rises moderately. For example, to develop a product twice as large as a product of size 100KLOC, the increase in duration may only be 20 per cent. It may appear surprising that the duration curve does not increase super linearly—one would normally expect the curves to behave similar to those in the effort-size plots. This apparent anomaly can be explained by the fact that COCOMO assumes that a project development is carried out not by a single person but by a team of developers.



* From Figure 3.5 we can observe that for a project of any given size, the development time is roughly the same for all the three categories of products. For example, a 60 KLOC program can be developed in approximately 18 months, regardless of whether it is of organic, semi-detached, or embedded type. (Please verify this using the basic COCOMO formulas discussed in this section). However, according to the COCOMO formulas, embedded programs require much higher effort than either application or utility programs. We can interpret it to mean that there is more scope for parallel activities for system programs than those in utility or application programs.



* **Cost estimation**

From the effort estimation, project cost can be obtained by multiplying the estimated effort (in man-month) by the manpower cost per month. Implicit in this project cost computation is the assumption that the entire project cost is incurred on account of the manpower cost alone. However, in addition to manpower cost, a project would incur several other types of costs which we shall refer to as the overhead costs. The overhead costs would include the costs due to hardware and software required for the project and the company overheads for administration, oﬃce space, electricity, etc. Depending on the expected values of the overhead costs, the project manager has to suitably scale up the cost arrived by using the COCOMO formula.

* **Implications of effort and duration estimate**

The effort and duration values computed by COCOMO are the values for completing the work in the shortest time without unduly increasing manpower cost.

* **Staff-size estimation**

Given the estimations for the project development effort and the nominal development time, can the required staﬃng level be determined by a simple division of the effort estimation by the duration estimation? The answer is “No”. It will be a perfect recipe for project delays and cost overshoot. We examine the staﬃng problem in more detail in Section 3.9. From the discussions in Section 3.9, it would become clear that the simple division approach to obtain the staff size would be highly improper.

* **Development environment:** Development environment attributes capture the development facilities available to the developers. An important parameter that is considered is the sophistication of the automation (CASE) tools used for software development.

**RISK MANAGEMENT**

* Every project is susceptible to a large number of risks. Without effective management of the risks, even the most meticulously planned project may go haywire. We need to distinguish between a risk which might occur from the risks that have already become real and are currently being faced by a project.
* If a risk becomes real, the anticipated problem becomes a reality and is no more a risk. If a risk becomes real, it can adversely affect the project and hamper the successful and timely completion of the project. Therefore, it is necessary for the project manager to anticipate and identify different risks that a project is susceptible to, so that contingency plans can be prepared beforehand to contain each risk. In this context, risk management aims at reducing the chances of a risk becoming real as well as reducing the impact of a risks that becomes real. Risk management consists of three essential activities—
* Risk identification,
* Risk assessment, and
* Risk mitigation

**Risk Management Approaches**Risk management approaches can broadly be classified into reactive and proactive approaches. The later approach is much more effective in risk handling and therefore used wherever possible. In the following, we briefly discuss these two approaches

**Reactive approaches**Reactive approaches take no action until an unfavorable event occurs. Once an unfavorable event occurs, these approaches try to contain the adverse effects associated with the risk  
and take steps to prevent future occurrence of the same risk events. An example of such  
a risk management strategy can be the following. Consider a project in which the server  
hosting the project data crashes. Once this risk event has occurred, the team members may  
put best effort to recover the data and also initiate the practice of taking regular backups,  
so that in future such a risk event does not recur. It is similar to calling the emergency  
firefighting service once a fire has been noticed, and then installing firefighting equipment  
in all rooms of the building to be able to instantly handle fire the next time it is noticed.  
It can be seen that the main objective of this is to minimize the damage due to the risk  
and take steps to prevent future recurrence of the risk.

**Proactive approaches**

The proactive approaches try to anticipate the possible risks that the project is susceptible to. After identifying the possible risks, actions are taken to eliminate the risks. If a risk cannot be avoided, these approaches suggest making plans to contain the effect of the risk.

For example, if man power turnover is anticipated (that is, some personnel may leave the project), then thorough documentation may be planned. Also, more than one developer may work on a work item and also some stand-by man power may be planned. Obviously, proactive approaches incur lower cost and time overruns when risk events occur and therefore is much more preferred by teams. However, when some risks cannot be anticipated, a reactive approach is usually followed.

**Risk Identiﬁcation**

Risk identification is somewhat similar to the project manager listing down his nightmares. For example, project manager might be worried whether the vendors whom you have asked to develop certain modules might not complete their work in time, whether they would turn in poor quality work, whether some of your key personnel might leave the organization, etc.

* **Project risks:** Project risks concern various forms of budgetary, schedule, personnel, resource, and customer-related problems. An important project risk is schedule slippage. Since, software is intangible, it is very diﬃcult to monitor and control a software project. It is very diﬃcult to control something which cannot be seen. For any manufacturing project, such as manufacturing of cars, the project manager can see the product taking shape. He can for instance, see that the engine is fitted, after that the doors are fitted, the car is getting painted, etc.
* **Technical risks:** Technical risks concern potential design, implementation, interfacing, testing, and maintenance problems. Technical risks also include ambiguous specification, incomplete specification, changing specification, technical uncertainty, and technical obsolescence. Most technical risks occur due the development team’s insuﬃcient knowledge about the product.
* **Business risks:** This type of risks includes the risk of building an excellent product that no one wants, losing budgetary commitments, etc.

**Risk Assessment**

* The objective of risk assessment is to rank the risks in terms of their damage causing potential. For risk assessment, first each risk should be rated in two ways:

The likelihood of a risk becoming real (*r*).

The consequence of the problems associated with that risk (*s*).

Based on these two factors, the priority of each risk can be computed as follows:

* *p* = *r* × *s*

where, *p* is the priority with which the risk must be handled, *r* is the probability of the risk becoming real, and *s* is the severity of damage caused due to the risk becoming real. If all identified risks are prioritized, then the most likely and damaging risks can be handled first and more comprehensive risk abatement procedures can be designed for those risks.

**Risk Mitigation**

After all the identified risks of a project have been assessed, plans are made to contain the most damaging and the most likely risks first. Different types of risks require different containment procedures. In fact, most risks require considerable ingenuity on the part of the project manager in tackling the risks.

There are three main strategies for risk containment:

* **Avoid the risk:** Risks can be avoided in several ways. Risks often arise due to project constraints and can be avoided by suitably modifying the constraints. The different categories of constraints that usually give rise to risks are:
* ***Process-related risk:***These risks arise due to aggressive work schedule, budget, and resource utilisation.
* ***Product-related risks:***These risks arise due to commitment to challenging product features (e.g. response time of one second, etc.), quality, reliability, etc.
* ***Technology-related risks:***These risks arise due to commitment to use certain technology (e.g., satellite communication).

A few examples of risk avoidance can be the following: Discussing with the customer to change the requirements to reduce the scope of the work, giving incentives to the developers to avoid the risk of manpower turnover, etc.

* **Transfer the risk:** This strategy involves getting the risky components developed by a third party, buying insurance cover, etc.
* **Risk reduction:** This involves planning ways to contain the damage due to a risk. For example, if there is risk that some key personnel might leave, new recruitment may be planned. The most important risk reduction techniques for technical risks is to build a prototype that tries out the technology that you are trying to use.
* For example, if you are using a compiler for recognizing user commands, you would have to construct a compiler for a small and very primitive command language first. There can be several strategies to cope up with a risk. To choose the most appropriate strategy for handling a risk, the project manager must consider the cost of handling the risk and the corresponding reduction of risk. risk leverage = cost of reduction
* Even though we identified three broad ways to handle any risk, effective risk handling cannot be achieved by mechanically following a set procedure, but requires a lot of ingenuity on the part of the project manager. As an example, let us consider the options available to contain an important type of risk that occurs in many software projects—that of schedule slippage.