Chapter 4

PLANNING PHASE

4.1 INTRODUCTION TO PLANNING PHASE OF A PROJECT

After development of the detailed scope of the project, the project team starts defining and aligning the ways and means to implement the project successfully. Project planning starts with a vision, which is a mental image produced by the imagination to meet the targets of the project. A vision and planning are intertwined (Cleland 1999). According to Duke et al. (1977), a common identifiable element on most successful projects was the quality and depth of early planning by the project management group. Project plan lists the activities required, how long each activity will take, when these activities must take place and how much resources must be spent on each activity to produce the required product or service. Rakos of John J. Rakos & Associates Consultants Ltd., USA remarked in his book on software project management (Rakos 1990) that planning is an iterative process and planning is very difficult, but it must be done perfectly. The plan will be constantly revised as the project progresses and as the stakeholders gain better knowledge and understanding.

Project planning identifies the human resources with required skills, non-human resources to be used for the project and also different risks related to different types of resources and external factors. A design of the system will be built in this planning phase of the project. Statement of Work (SOW), cost estimates, financial plan, risk plan and functional plan form the project plan. Statement of work describes what is going to be accomplished, that is, the tasks and deliverable end products, as well as references to specifications, directives, or standards. All the tasks to be performed are defined and allocated to the resources, by preparing a Work Breakdown Structure (WBS) and the action plan. Once the WBS is satisfactorily developed, all the tasks and activities can be easily scheduled and budget estimates developed in detail.
The process of developing the project plan varies from organization to organization and also varies for different types of projects. Cleland (1999) listed several important work packages within the project planning. According to Meredith and Mantel (2003), any project plan must contain the elements, viz., Overview, Objectives, General approach, Contractual aspects, Schedules, Resources, Personnel, Evaluation methods, and Potential problems.

The project plan is to be first drafted by the project manager with the assistance of the team members and then kept for discussions with senior management and other related people for any suggestions, changes and thereby modifications. The project plan should be flexible to accommodate any changes required to be implemented throughout the project life cycle.

When the total work to be done is envisaged, the plan to do that work depends on the answers to the questions like how the total work can be broken down into smaller tasks in a systematic way, what type of risks and problems are involved in each and every task, what type of and how many resources required, how much budget required to perform each task, which task(s) to be done at what time and in what order, etc.

Based on the above discussions, in the present work the following major activities have been considered in the project planning phase:

- Work breakdown structure (WBS)
- Risk management plan (RMP)
- Project estimates
- Project scheduling
- Project design

### 4.2 WORK BREAKDOWN STRUCTURE (WBS)

Gray and Larson (2003) states that many companies engaged in contracted work refer to scope statements as statement of work (SOW) and other organizations use the term 'project charter'. Tate and Hendrix (1999) define the project charter as an expanded version of the scope statement. Once the statement of project work has been formulated, that total project
work is further studied and analysed to break it down into a set of major activities or major project sub-elements, that are manageable, independent, integratable and measurable. Such process of breaking down the total project work into smaller tasks is called the work breakdown structure (WBS). Hubbard (1993) recommends using the WBS as the fundamental tool for planning. WBS is a top-down hierarchical chart of tasks, sub-tasks, work packages, etc. required to be performed to complete the project. It is a map and outline of the project with different levels of detail. WBS begins with the project as the final deliverable. Major project work deliverables/systems are identified first; then sub-deliverables necessary to accomplish the larger deliverables are defined. The process is repeated until the sub-deliverable detail is small enough to be manageable and where on at least one person can be made responsible to accomplish it. The sub-deliverable is further divided into work packages like programming, testing, etc. as in the case of software projects.

All the sub-tasks thus resulted from the WBS are arranged in a planned manner according to their priority to ease the job of project scheduling. If any further complex activity is identified, it should be reasonably divided as above. Any duplication of works should be removed from time to time to generate effective WBS. The deviations in the WBS that lead to confusion and unnecessary reworks should also be removed.

WBS is an important document and can be tailored for use in a number of different ways. WBS may list each and every piece of work to be accomplished along with its contribution to the whole project. WBS may list the required tools or software or any other things to be procured along with the list of vendors, if any. WBS may also list out the services to be sub-contracted along with the list of contractors, if any. For some activities, if the required skilled people and/or the required equipment are not available in the parent organization, the project manager should include the activities like hiring the services of outside people or sub-contracting the work or purchase of equipment, etc. in the WBS.

The project team in APTS, based on the scope of the project, prepares the action plan and then divides the project work into different activities. The division at the first level will be
done in such a manner that each resulting sub-task can be handled by an individual or a very small group of people depending upon the complexity of work. The division will be continued further and the tasks will be assigned to the respective technical people to prepare the technical and functional designs. APTS started using Microsoft Project software into which all the identified tasks are entered according to priority and different reports like Gantt charts are generated. The same has been observed in most of the other organizations that were surveyed. Kerzner (2004) reports about Computer Associates International, Inc. (CA), that they break down each e-Business program further into lower-level management functions to achieve individual objectives.

The salient variables that influence the WBS of a project are identified and listed in Table 4.2.

<table>
<thead>
<tr>
<th>Salient variables</th>
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<tr>
<td>1. Scope of project or Statement of Work (SOW)</td>
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<td>2. Complex activities</td>
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<td>3. Division of work</td>
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<td>4. Individuality of activity</td>
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<td>5. Manageability of activity</td>
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<td>6. Priority of activity</td>
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<td>7. Deviations</td>
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<td>8. Duplication of works</td>
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<td>9. Work breakdown rate</td>
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4.2.1. Basic SD feedback loops in the system of ‘Work Breakdown Structure’ (a)

Division of work into smaller activities improves the rate of breaking down the work. Hence the causal link connecting the variable ‘Division of work’ with ‘Work breakdown rate’ will be a positive link. The presence of complex activities hinders the activity of dividing the work into smaller activities and leads to increase in deviations in the system of work breakdown structure. Hence the causal link connecting the variable ‘Complex activities’ with ‘Division of work’ has been treated as a negative link and that connecting ‘Complex
activities' with 'Deviations' has been treated as a positive link. Increase in duplication of works leads to more deviations and reduces the effectiveness of WBS. Based on this, the causal link connecting the variable 'Duplication of works' with 'Deviations' will be a positive link and whereas the link connecting 'Duplication of works' with the variable 'Effective WBS' will be a negative causal link. Improvement of effectiveness in WBS encourages the rate of breaking down the work further and hence the causal link from the variable 'Effective WBS' to the variable, 'Work breakdown rate' has been represented as a positive link. The feedback loop formed by all these six causal links will become a positive loop because of the presence of even (two) number of negative causal links.

(b) The causal link between the variables 'Complex activities' and 'Division of work' is a negative link. The increase of complex activities throws a challenge to their manageability and thus shows a negative influence on manageability of the activity. Hence the causal link connecting the variable 'Complex activities' with the variable 'Manageability of the activity' will be a negative link. Manageability of an activity encourages the division of work further into some smaller activities and hence the causal link between the variables 'Manageability of the activity' and 'Division of work' has been treated as a positive link. The feedback loop formed by these three causal links will become a positive loop.

The two feedback loops of the sub-system 'Work Breakdown Structure (WBS)' are given in the figure, Fig. 4.2.1.
4.2.1. SD feedback loops in the system of 'Work breakdown structure (WBS)'

Fig. 4.2.1. SD feedback loops in the system of 'Work breakdown structure (WBS)'

(a)

(b)

4.2.2. Causal loop model of 'Work breakdown structure (WBS)'

The division of work can be easily performed when there is clear scope (or Statement of Work) of the project and good priority, individuality and manageability of the activities. Increase in any one of the four variables, namely, 'Scope or SOW', 'Priority', 'Individuality of activity' and 'Manageability of activity' improves the division of work into activities and hence all the causal links leading from each of those four variables to the variable, 'Division of work' will be positive. These causal links and the two feedback loops explained earlier
will form the causal loop structure of the system of 'Work breakdown structure (WBS)', as shown in the figure, Fig. 4.2.2.

**Fig. 4.2.2. Causal loop model of 'Work breakdown structure (WBS)'**

4.2.3. Stock and flow model of 'Work Breakdown Structure (WBS)'
The stock and flow model has been developed for the system of 'Work breakdown structure (WBS)' of the project and is shown in the figure, Fig. 4.2.3. The two variables, 'Work breakdown rate' and 'Deviations' have been treated as rate variables and the variable 'Effective WBS' as a stock variable. Other variables are auxiliary variables.
4.2.4. Modeling equations for the system of ‘Work breakdown structure (WBS)’

The modeling equations for effective WBS are given in the table 4.2.4. The variables, 'Complex activities', 'Duplication of works', 'Individuality of activity', 'Priority' and 'Scope or SOW' have been initiated with a value of 1 by assuming that they are usually and normally existing. The variable 'Deviations' has been equated to the sum of 'Complex activities' and 'Duplication of works'. The variable 'Manageability of the activity' has been treated as reciprocal of the sum of 'Complex activities' and unity (1). The sum of 'Individuality of Activity', 'Priority' and 'Manageability of the activity' multiplied by 'Scope or SOW' minus 'Complex activities' has been assigned to the variable 'Division of work'. The variable 'Work breakdown rate' has been equated to the sum of 'Division of
work’ and ‘Effective WBS’. The variable ‘Effective WBS’ representing the effectiveness in work breakdown structure has been treated as a level or stock variable with nil (zero) initial value and to be filled by ‘Work breakdown rate’ multiplied by five (5) minus ‘Duplication of works’. All these modeling equations have been fed to the stock and flow model.

A total duration of one (1) month has been assumed for the task of work breakdown structure with a time step of 0.0625 month for simulation.

**Table 4.2.4. SD modeling equations of ‘Work Breakdown Structure (WBS)’**

(i) **INITIAL TIME** = 0 (The initial time for the simulation).
(ii) **FINAL TIME** = 1 (The final time for the simulation).
(iii) **TIME STEP** = 0.0625 (The time step for the simulation).
(iv) **SAVEPER** = TIME STEP (The frequency with which output is stored).

1. Complex activities = 1.
2. Duplication of works = 1.
3. Individuality of activity = 1.
5. Scope or SOW = 1.
6. Deviations = Complex activities + Duplication of works.
7. Division of work = Scope or SOW * (Individuality of activity + Priority + Manageability of the activity) – Complex activities.
8. Manageability of the activity = 1/(1 + Complex activities).
9. Work breakdown rate = Division of work + Effective WBS.
10. Effective WBS = INTEG (Work breakdown rate*5 – Duplication of works, 0).

4.2.5. Simulation results of the system of ‘Work Breakdown Structure (WBS)’
The stock and flow model of the system of WBS is simulated and it resulted in the improvement of the effectiveness of WBS. Pattern of growth behaviour is observed in both the effectiveness of work breakdown structure and the work breakdown rate. Their final
value reached 100 that mean 100%. The patterns of growth in those two variables are shown by the graphs given in the figure, Fig. 4.2.5.

*Fig. 4.2.5. Patterns of growth behaviour in the system of ‘Work Breakdown Structure’*

<table>
<thead>
<tr>
<th>Effective WBS</th>
<th>Work breakdown rate</th>
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<tbody>
<tr>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>75</td>
<td>150</td>
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<tr>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
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</tbody>
</table>

4.2.6. Sensitivity analysis results of the system of ‘Work Breakdown Structure (WBS)’

From the sensitivity analysis of the automatic simulations of the stock and flow model of the WBS, it has been observed that the five variables, namely, ‘Duplication of works’, ‘Complex activities’, ‘Scope or SOW’, ‘Individuality of activity’ and ‘Priority’ of the activity are showing considerable influence on the effectiveness of WBS. Figures, Fig.4.2.6(i)–(ii) show the sensitivity analysis results carried out for effective WBS by changing the value of one of those five variables, by keeping other variables at their initial values. In each figure, for comparison, the graph I (red colour) shows the simulation result with the initial values of the variables, whereas the graph II (blue colour) shows the sensitivity analysis result for the change made in one of the five variables. Fig. 4.2.5(i)a deals with change in ‘Scope or
SOW’, Fig. 4.2.5(i)b deals with change in ‘Individuality of activity’ and Fig. 4.2.5(i)c deals with change in priority. Figures, Fig. 4.2.5(ii)a and (ii) b deal with changes in the variables, ‘Complex activities’ and ‘Duplication of works’ respectively.

(i) When ‘Scope or SOW’ is increased from 1 to 1.2, considerable high growth is observed in the effectiveness of WBS, when compared with the other two variables ‘Individuality of activity’ and ‘Priority’, which are showing slight growth in ‘Effective WBS’.

Fig. 4.2.5 (i)a. Sensitivity analysis (changing ‘Scope’) of ‘Work Breakdown Structure’.

(ii) Similarly, the increase of ‘Complex activities’ from 1 to 1.2 (Fig. 4.2.5(ii)a) is showing high decay in the behaviour of effectiveness of WBS when compared with the increase in ‘Duplication of works’ when it is increased highly from 1 to even 1.5 (Fig. 4.2.5(ii)b).
That is, a small increase in complex activities is highly reducing effectiveness of WBS when compared with duplication of works.

**Fig. 4.2.5 (ii)a. Sensitivity analysis (changing ‘Complex activities’) of ‘Work Breakdown Structure’**.

From the above sensitivity analysis results, it has been observed that the two variables, namely, ‘Scope or SOW’ and ‘Complex activities’ have higher influence on the effectiveness of WBS, the former one showing the growth and whereas the latter one showing the decay. This result is supporting the fact that improvement in scope or statement of work (SOW) eases the process of breaking down the total work meaningfully and effectively, because of the clarity in the work to be done. In addition, when the complex activities increase, the effectiveness of WBS decreases, because the presence of complex activity needs more effort to be put on breaking it down into works as small and manageable as possible.

All the above observations are well agreeing with the common experiences in any project in connection with the activity of breaking down the total or part of project work.
4.3 RISK MANAGEMENT PLAN (RMP)

Risks are those unexpected events that cause problems. Risk is a measure of the probability and consequence of not achieving a defined project goal. It is a combination of an abnormal event (or failure) and consequences of that event (or failure) to a system's operators, users, or environment. Project risks include cost, funding, schedule, contract relationships, political, technical, test, logistics, development, engineering and environmental risks and some of these risks are highly uncontrollable.

Risk management plan (RMP) is a document that tries to generate a list of all the possible risks that could affect the project, their severity, ways to mitigate their effect or control them or safeguard the project from their influence. This needs brainstorming exercises for the project team members to identify the potential problems that may occur while the project progresses. A list consisting of as many probable risks as possible is to be prepared and those risks are analysed with their impacts on the project at different stages. In the risk identification process, the events and the consequences they produce are to be focused and they are treated as risks. Based on the severity and the occurrences, the risks are to be prioritized. Against each risk, the method to mitigate its severity or avoid it at different stages of project development should be described in the risk management plan. Sometimes, the risks of natural calamities, power failures, etc., which are not under the control of the project manager, team members or even the organization, occur unexpectedly. The RMP should include the precautionary steps to be taken to protect the project from such uncontrollable risks.

According to Meredith and Mantel (2003), the process of managing risk is not a static one, rather it is ongoing, with constant updating as more risks are identified, as some risks vanish, as others are mitigated. In the planning process, it is useful to review the major risks that affect the project. The known risks will be those identified during the project selection process and these are apt to focus largely on the market reaction to a new process or product, the potential feasibility of an innovation and like matters. Hence, risk management plan for the project must be started at this stage so that further risk identification can be extended to include the technology of the process or product, the project's schedule, resource base, and a
myriad of other risks facing the project but not really identifiable until the project plan has begun to take form. In some organizations, one of the outcomes of the project planning process will be the formulation of the project's risk management group and the initial RMP that the group develops during the process of planning the project. Risk management group develops an RMP that includes proposed methodologies for managing the identified risk, the group's budget, schedule, criteria for dealing with risk, and required reports.

Generally, there are five phases within the risk management cycle and each phase needs to be addressed. The five phases are: (1) Identification of risk, where the project's potential risk issues will be compiled and their occurrence assessed, (2) Analysis of severity of the risk to study how severely the risk affects the project activity or activities and the ultimate project, (3) Quantification of risk based on its frequency of occurrence and severity, and this is represented by the quantity 'risk value', (4) Mitigation of risk, where all the possible options will be studied to reduce the risk even by spending money, and (5) Tracking the risk to ensure its continued control. Risk planning is the detailed formulation of this program of action for management of risk and it is to be developed and documented. Risk planning is iterative and includes the entire risk management process, resulting in risk management plan (RMP).

The project risk may be possible from any corner of the project life cycle. There are different factors that create risks to the project and the project management. Important of them are application factors, staff factors, project factors, project methods, hardware/software factors, changeover factors, supplier factors, environmental factors, health and safety factors, natural hazards, etc. (Hughes and Cotterell 2002).

Kerzner (2004) reported about Sun Microsystems, a worldwide leader in enterprise network computing and technical network computing and the home of the worldwide Java technology paradigm, that a crucial feature of the project management service is an emphasis on risk management and before project managers begin work on a project, they conduct a risk workshop with the customer and the partners to develop the foundation for risk planning and
administration. There they analyse each identified risk to assess the impact on schedule, costs, and quality.

In APTS, there was no specific risk management plan being implemented to solve the risks. However, in the case of risks that arise due to sudden resignation of a staff member, APTS implements a procedure by insisting such technical person(s) to submit the resignation in advance before three months to quit and during this resignation notice period, the technical person has to complete any pending work as per the schedule within that notice period and train and guide any other additional technical people supposed to replace that technical person who is going to quit the organization. Any virus or system problems will be handled by the System Administration division, which sends its people on daily rounds attending computer problems in different departments. The hardware division attends the hardware problems. This way, APTS could protect its projects from risks. It was observed that there was a good communication system that helps to notice the risks to alert the senior management take necessary actions to mitigate those risks.

Many organizations surveyed in Malaysia expressed that the incomplete and continuously changing requirements specification is becoming the main cause of risks. The project manager in United Arab Agencies Bhd., Malaysia informed that they are facing risks at different stages of the project. Regarding requirements specification, often the users forget to include some objectives at the beginning and recommend during the implementation phase. In the design phase, the amount of work each module produces must be determined by the people from the technical and business backgrounds, or otherwise there will be some potential risks possible. The firm has not claimed any risks during coding stage. Regarding resources management, the project manager of this firm reported that they are facing a big risk when the working adults leave the job after some time and this makes the company loose the skilled people and also investment made on training such workers. He also admitted the fact that this problem is quite common in almost all the IT companies all over the globe. To mitigate such risk, the project manager of United Arab Agencies Bhd. suggested that the IT companies should come up with incentives scheme to hold the valuable
technical people. To avoid the risks in the development stages, he suggested that the project manager should be given good machines, tools and skillful human resources.

The Assistant Manager for IT of MCIS Zurich Insurance, Malaysia informed that the main risk they are facing is during the requirement stage because the requirements specification is poorly written and rapidly changing. He reported that they are facing big challenge to solve the complex module at higher risk and suggested that such high-risk modules should be rigorously tested and verified. A project manager of QuickNet Communications expressed that it is very hard to estimate the skills of a software developer to be kept on an activity of the project and sufficient time should be spent for estimation of skills of such people. When the skills of a team member are not estimated properly and the person is not suitable and capable to do that activity, such risk becomes a great threat to the progress and performance of the activity and even the total project.

In view of the above discussions, the different salient variables that influence the Risk Management Plan (RMP) have been identified and listed in Table 4.3.

<table>
<thead>
<tr>
<th>Table 4.3. List of salient variables in the system of ‘Risk Management Plan’</th>
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<tr>
<td><strong>Salient variables</strong></td>
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<tr>
<td>1. Effective WBS</td>
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<td>2. Contingency planning</td>
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<tr>
<td>3. User cooperation</td>
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<td>4. Management support</td>
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<tr>
<td>5. Risk reduction action plan</td>
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<td>6. Risk value</td>
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<td>7. Occurrence</td>
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<td>8. Severity</td>
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<td>9. Controllability</td>
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<td>10. Testing and Reviews</td>
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<td>11. Risk Identification</td>
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<td>12. Development risks</td>
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<tr>
<td>13. Management of changes</td>
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<td>14. Training</td>
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<tr>
<td>15. Staff risks</td>
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<tr>
<td>16. Unclear skills</td>
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<tr>
<td>17. Incentives for performance</td>
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<tr>
<td>18. Availability of staff</td>
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<tr>
<td>19. Uncontrolled risks</td>
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<tr>
<td>20. External risks</td>
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<tr>
<td>21. Natural hazards</td>
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4.3.1. Basic SD feedback loops in the system of ‘Risk Management Plan (RMP)’

(a) When the process of risk identification is enhanced, better actions can be planned to reduce that risk. Based on this, the causal link from the variable ‘Risk Identification’ to the variable ‘Risk reduction action plan’ has been treated as a positive link. Increase in the occurrence of a risk increases its identification and also increases the quantity of risk, that is, ‘risk value’, which can be represented as the product of occurrence, severity and controllability of a risk. Hence the two causal links connecting the variable ‘Occurrence’ with the two variables, namely, ‘Risk Identification’ and ‘Risk value’ have been treated as positive links. When the quantity of a risk becomes high, it should be given top priority to reduce it and this leads to improvement of risk reduction action plan to mitigate such risk. Based on this argument, the causal link between the variables ‘Risk value’ and ‘Risk reduction action plan’ has been assigned positive sign. The feedback loop formed by all these four positive causal links will also be positive.

(b) Most of the external risks and natural hazards are uncontrolled risks and their growth leads to more number of uncontrolled risks and high risk identification. Hence the causal links connecting those two types of risks to the variables, ‘Uncontrolled risks’ and ‘Risk Identification’ will be positive. The feedback loop formed by these four positive causal links will become a positive loop.

(c) The causal links connecting the variable ‘Occurrence’ to the two variables, namely, ‘Risk value’ and ‘Risk Identification’ are positive links. When a risk has undergone testing and reviews, it will be possible to understand the risk in detail and mitigate it to possible extent, that is, reducing the quantity of such risk. The technique of testing and reviews will also reduce the risks in project development. Hence the causal links from the variable ‘Testing and Reviews’ to the two variables, namely, ‘Risk value’ and ‘Development risks’ have been treated as negative links. When development risks increase, their identification increases and hence the causal link between the variables, ‘Development risks’ and ‘Risk Identification’ is positive. The feedback loop formed by the interactions between the above five different variables will become a positive feedback loop, because of the presence of even (two) number of negative causal links.
(d) The risks being experienced from the staff working on a project will increase the risk identification and also risks in project development. Hence the two causal links connecting the variable ‘Staff risks’ with the variables ‘Risk Identification’ and ‘Development risks’ have been treated as positive links. The causal link between the variables ‘Development risks’ and ‘Risk Identification’ is positive. The feedback loop formed by these three positive causal links will also be positive.

(e) When the skills of the staff are not clear, staff risks are possible. The more the unclear skills the more will be the staff risks and hence the causal link between the variables ‘Unclear skills’ and ‘Staff risks’ is positive. Provision of necessary training to the staff reduces the staff risks and improves the skills of the staff and hence the effect of unclear skills of the staff will be reduced. Based on this, the two causal links connecting the variable ‘Training’ with the variables ‘Staff risks’ and ‘Unclear skills’ have been treated as negative links. The feedback loop formed by these three causal links will be a positive loop because of the presence of even (two) number of negative causal links.

All the five feedback loops in the system of ‘Risk Management Plan (RMP)’ are shown graphically in the figure, Fig. 4.3.1.
4.3.1. SD feedback loops in the system of ‘Risk Management Plan (RMP)’

4.3.2. Causal loop model of the system of ‘Risk Management Plan (RMP)’

Staff risks can be mitigated by applying the procedures like (1) incentives for performance, (2) make more availability of staff, and (3) providing training to the staff to improve their skills. Development risks can be reduced by effective management of changes to the application, and by conducting more testing and reviews. The two causal links connecting the variables, ‘Incentives for performance’ and ‘Availability of staff’ with ‘Staff risks’ have been treated as negative links. Similarly, the two causal links from ‘Management of changes’, and ‘Testing and Reviews’ to ‘Development risks’ are treated as negative links.
When a risk, whether it may be a staff risk, development risk, external risk or natural hazard, is identified, the risk reduction action plan will be updated with upgraded techniques to tackle that risk. Value of a risk increases with the increase in any/both of occurrence and severity of the risk and decreases by the application of more controllability and testing and reviews. Hence the causal links from the two variables, 'Severity' and 'Occurrence' connecting to the variable 'Risk value' have been treated as positive links and whereas the links from 'Controllability' and 'Testing and Reviews' to 'Risk value' as negative links.

The risk reduction action plan also improves with the help of effective work breakdown structure (WBS), management support, user cooperation and contingency planning. Effective WBS enables the project team to be clear about different activities to be performed at different stages and phases of the project. That WBS can give an overview of the possible risks in the project activities. To understand and mitigate some potentials risks, management support of the organization and cooperation of the user/customer play an important role by motivating and encouraging the team members to handle such risks. Contingency planning acts as an insurance plan and guides for reducing risk. Hence the causal links connecting the four variables, namely, 'Effective WBS', 'Management support', 'User cooperation' and 'Contingency planning' with 'Risk reduction action plan' are positive links. When the risk reduction action plan is developed, the scope of the risk management plan (RMP) improves. As far as RMP is concerned, it guides the project team and other project stakeholders\(^1\) to take care of the project from all the possible risks.

All the above causal links and the five feedback loops explained earlier form the causal loop structure for the system of risk management plan and is shown in the figure, Fig.4.3.2.

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1. Project stakeholders are the people or the organization(s) that have stake (or interest) in the project.
4.3.3. Stock and flow model of the system of ‘Risk Management Plan (RMP)’

From the causal loop model, the stock and flow model has been developed for the system of ‘Risk Management Plan (RMP)’ of the project and is given in the figure, Fig. 4.3.3. The two variables, ‘Risk reduction action plan’ and ‘Uncontrolled risks’ have been treated as rate variables, whereas RMP expansion has been treated as the level (or stock) variable.
4.3.4. Modeling equations for the system of ‘Risk Management Plan (RMP)’

The system dynamics modeling equations have been developed for the respective variables and are listed in the table 4.3.4. In the present work, the risk management plan has been treated as continuous process because of addition and deletion of risks from time to time throughout the life cycle of a project. Hence the time duration for the activity of risk management plan has been assumed as 12 months with initial time as zero (0) and time step for simulation as 0.125 month.

It has been assumed that there is satisfactory availability of staff, management support, user cooperation, training to the staff and proper testing and reviews followed by availability of
effective WBS. Also it has been assumed that there are external risks. Hence the variables representing all these factors have been assigned a value of 1, which means 100% existing. It has also been assumed that initially there is no contingency planning and no natural hazards. Based on this, both the variables ‘Contingency planning’ and ‘Natural hazards’ have been assigned a null value (0). Incentives for performance and management of changes have been treated as being implemented moderately and hence assigned a value of 0.5 each, meaning 50% implementation.

Each of the important properties of the risk, namely, occurrence, severity and controllability has been assigned an initial value of 1. Occurrence and severity of a risk increase the risk value, whereas controllability and performing testing and reviews will reduce the risk value. Based on this logic, the modeling equation for the risk value has been written as the product of severity and occurrence, divided by the product of the two variables, controllability and testing and reviews.

Without proper training, the skills of a person will be doubtful and hence the variable ‘Unclear skills’ has been equated to the reciprocal of the variable ‘Training’. Staff risks start with the unclear skills and they can be reduced by incentives, availability of staff and providing proper training. Hence the variable ‘Staff risks’ has been equated to the ratio between the variable ‘Unclear skills’ and the sum of the three variables, namely, ‘Incentives for performance’, ‘Availability of staff’ and ‘Training’.

The development risks have been equated to the staff risks divided by the sum of the two variables, ‘Management of changes’ and ‘Testing and reviews’. Risk identification has been equated to the sum of development risks, external risks, natural hazards and staff risks and multiplied by the variable, ‘Occurrence’. The rate variable, ‘Risk reduction action plan’ has been equated to the sum of contingency planning, effective WBS, management support, user cooperation, RMP expansion and the product of risk value and risk identification. Another rate variable, ‘Uncontrolled risks’ has been equated to the sum of external risks and natural hazards. The stock variable, ‘RMP expansion’ has been equated to the integration of one-fourth of risk reduction action plan, starting from an initial value of zero (0).
Table 4.3.4. SD modeling equations of the sub-system 'Risk Management Plan'

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A)</td>
<td>INITIAL TIME = 0 (The initial time for the simulation).</td>
</tr>
<tr>
<td>(B)</td>
<td>FINAL TIME = 12 (The final time for the simulation).</td>
</tr>
<tr>
<td>(C)</td>
<td>TIME STEP = 0.125 (The time step for the simulation).</td>
</tr>
<tr>
<td>(D)</td>
<td>SAVEPER = TIME STEP (The frequency with which output is stored).</td>
</tr>
</tbody>
</table>

1. Availability of staff = 1.
2. Management support = 1.
3. User cooperation = 1.
4. Training = 1
5. Testing and Reviews = 1.
7. External risks = 1
8. Contingency planning = 0
9. Natural hazards = 0
10. Incentives for performance = 0.5
11. Management of changes = 0.5.
15. Risk value = (Occurrence * Severity)/Controllability * Testing and Reviews.
16. Unclear skills = 1/Training.
17. Staff risks = Unclear skills/(Incentives for performance + Availability of staff + Training).
18. Development risks = Staff risks/(Management of changes + Testing and Reviews) (Contd....)
4.3.5. Simulation results of the system of ‘Risk Management Plan (RMP)’

The modeling equations have been fed to the respective variables in the stock and flow model and the model has been simulated. Pattern of growth behaviour is observed in the two variables, namely, ‘RMP expansion’ and ‘Risk reduction action plan’. The final value of each variable is about 85, which means 85%. These initial simulation results are shown in the figure, Fig. 4.3.5. To study the effect of other variables on the behaviour of RMP, sensitivity analysis has been carried out.

**Fig. 4.3.5. Patterns of growth behaviour in the system of ‘Risk Management Plan’**
4.3.6. Sensitivity analysis results of the system of 'Risk Management Plan (RMP)'

Sensitivity analysis has been performed by varying the value of each of the important variables, namely, 'Occurrence', 'Controllability', 'Severity', 'Training', 'Testing and Reviews' and 'Contingency planning'. The graphical sensitivity analysis results are shown in the figures (i) to (v) of Fig. 4.3.6. In each figure, the graph I (red colour) is the simulation result with the initial values of the variables, whereas the graph II (blue colour) is the resultant of the sensitivity analysis by varying the value of a variable.

(i) When the value of the variable 'Occurrence' alone is increased from its initial value of 1 to 1.5, a lot of growth is observed in RMP expansion, which has finally touched a value of about 120, which means 120%. This is validating the fact that when a particular risk has more occurrences, the project team will consider it as one of the potential risks and develop a risk management plan to mitigate it and hence the existing RMP expands further to accommodate that particular risk and plans to mitigate it.

(ii) By increasing the value of the variable 'Controllability' from its initial value of 1 to 1.5, decay behaviour is observed for RMP expansion. This observation supports the fact that with the help of good control mechanisms, some risks can be mitigated and hence the risk management plan gives least importance to such risks. The RMP concentrates on potential risks that need a lot of study and analysis to mitigate their affects. In the risk management plan, the highly controllable risks will be given least priority and importance.
(iii) When the value of 'Severity' is increased from 1 to 1.5, growth behaviour is observed in RMP expansion crossing a value of 100 that means 100%. This observation validates the fact that when a risk has more severity, the risk management plan will give considerable importance to that risk and elaborates the methodology to deal with such risks.

(iv) Increase in the value of 'Training' from 1 to 1.5 produced some decay in the behaviour of RMP expansion. This is validated by the fact that when the staff is sufficiently trained, they will be able to handle some risks independently and thereby avoid giving more importance to such risks in the risk management plan. Taking this into view, the risk management plan tries to avoid focusing more on those risks with which the staff is more familiar and knowledgeable to mitigate them independently.
(v) When the value of the variable, 'Testing and Reviews' is increased from 1 to 1.5, good growth is observed in the behaviour of RMP expansion, touching finally a value of 100 that mean 100%. This observation can be validated by the fact that continuous testing and reviews of the work and the risks involved therein enables the project team identify the potential problems and risks and elaborates the risk management plan to accommodate such risks.

![Fig. 4.3.6. (v) Sensitivity analysis of 'Risk Management Plan'.](image)

(vi) To see the effect and importance of contingency planning on risk management plan, its value is increased from 0 (nil) to 1. By this, the RMP expansion increased by nearing 90 that means 90%. Contingency plan is just like an insurance plan to protect the project from risks and growth in contingency plan leads to growth in the risk management plan and this fact is validating the above observation.

![Fig. 4.3.6. (vi) Sensitivity analysis of 'Risk Management Plan'.](image)

From the above sensitivity analysis results, it has been observed that occurrence, severity and testing and reviews are showing high influence on risk management plan and of these three variables, the variable 'Occurrence' is showing the highest influence. The variables, controllability, training and contingency planning are also showing considerable influence on RMP. The observations support the importance of contingency planning and testing and reviews of risk to protect the project from risks.
4.4 PROJECT ESTIMATES

An ‘estimate’ is an assessment of the likely quantitative result and project estimates include estimates of effort (duration) and costs. Establishment of an estimation process early in the project life cycle is essential and results in greater accuracy and credibility of estimates and a clearer understanding of the factors that influence the development costs. Rakos (1990) remarked that government departments have learned that software estimates produced at the definition phase are useless and this is almost true in the case of other organizations and other types of projects also. In the conceptual phase, all the estimates carried out are the first approximate estimates and schedules and they will be used to have a rough estimation of the cost and time of the proposed project to decide the feasibility of the project and propose to the user and parent organization.

Cost and effort estimations are important aspects of the management of software maintenance projects. Software development and maintenance are labour-intensive activities; the project cost is strictly tied to the required effort, that is, to the project staffing (Antoniol et al 2004).

Estimates are useful to quantitatively define success or failure and their level and the subsequent improvements or degradations in the products, processes and people. They are also useful to make meaningful and useful managerial and technical decisions and identify trends. Hence the estimates of time and cost should be made with much care and accuracy. The quality in the estimates will enhance reduction in the deviations from the actual plan through out the project life.

Project estimates are made up of estimates of effort, required human and non-human resources, cost, activity duration and the risks involved in each activity. Gray and Larson (2) lists different factors that influence the quality of estimates of time and cost - padding estimates, planning horizon, project duration, skills of the people, project structure and organization, and organization culture. Hughes and Cotterell (2002) states that over-estimates and under-estimates create serious problems in the way of delaying the works and reducing quality respectively.
While developing the WBS by dividing the total project work into tasks, sub-tasks, work-packages, etc., the project manager should estimate the time required to complete such sub-works in terms of person-hours/days/weeks/months. There are several methods available to estimate the activity durations. They are similarity to other activities, historical data, expert advice, Delphi technique, Three-point technique, Wide-band Delphi technique, etc. Activity duration is a random variable, because what factors will be operative when work is underway on an activity and how long will it take are not known at the beginning of estimation. The project manager should define the activity to a level of granularity so that the estimates have a narrow variance – that is, the estimate is as good as it develops at the planning stages of the project. During the project development, there are several causes of variation of actual activity duration – (i) varying skill levels of the people assigned to work on the activity, (ii) unexpected events or risks like random acts of nature, vendor delays, power failures, etc. and (iii) interruption of work time of efficient people (Wysocki et al 2000).

Estimation techniques: Any organization should maintain good estimation techniques, which will give meaningful and reasonable values of estimates of the effort for each activity, the required resources, possible risks and the total cost. There are many estimation techniques in use. Delphi technique is a group method wherein each team member will give a reasonable estimate and such estimates of all the team members will be collected, discussed and a mean or a best consolidated and reasonable estimate will be taken as the estimate for that activity. Another technique, called ‘three time probabilistic method’ (or, three point technique) takes three different estimates - Optimistic (assuming that everything goes well), Pessimistic (assuming that everything goes wrong) and Most-likely (assuming the common value that is most-likely possible) – and then by using the equation, $E = (O + 4xM + P)/6$, the estimated value (E) will be calculated. For IT projects, there are some specific methods like COCOMO (Constructive Cost Model), Function Point (FP) analysis, etc. to estimate effort. Use of good estimation techniques improves the accuracy of project estimates.

In APTS, different estimation techniques will be implemented. When the project team estimates the total effort in terms of person days or months for the project using different
techniques like Function points, etc., the accounts department supplies the data on the hourly and daily costs of the concerned technical persons to be kept on the project depending upon their category of employment and scale of pay. With the help of this data, the total cost of the project will be evaluated and the cost schedule will be prepared.

In NHCL, for estimating the cost of a software skills testing module, the time required by the technical content developers, reviewers, language editors, data entry operators, conduct of beta tests, and thereby the costs of the module at different stages along with overhead costs and administrative costs are estimated. Some modules, having good demand in the market and having very few experts available, might be estimated adding some padding costs.

*Overestimates:* Most of the estimators are inclined to add a little padding to increase the probability and reduce the risk of being late. If everyone at all levels of project goes on adding a little padding to reduce risk, the project duration and cost are seriously overstated. This context refers two important laws. One is Parkinson’s law, which states “Work expands to fill the time available”. This implies that given an easy target, the staff will work less hard. Another law is Brooke’s law, which states “Putting more people on a late job makes it later”. That is, the effort required to implement a project will go up disproportionately with the number of staff assigned to the project.

*Underestimates:* An under-estimate might cause the project to take shorter time than a more generous estimate. The danger with this is the effect on quality; less experienced staff might respond to the pressing deadlines by producing sub-standard work and the staff working on the project will be under increasing work pressure. This leads to declination in quality of the project.

*Planning horizon:* Estimates of current events are close to 100% accurate, but are reduced for most distant events. The accuracy of time and cost estimates should improve as the project moves from conception phase to the point where individual work packages are defined.
Project duration: Long-duration project increases the uncertainty in estimates. Time to implement new technology expands in an increasing non-linear fashion, until the concerned team members get familiarity to use it and that new technology accommodates satisfactorily into the system. Keeping in mind the actual project time demanded by the user, the project duration is to be estimated properly. The project time makes up the total project duration and it is influenced by the duration of each activity of the project.

The variation on individual items within the estimate is much greater, and consequently any system of cost control based on a comparison of actual and estimated cost must be of dubious value (Smith, 2002). According to Jones (1998), many projects are doomed by poor cost and schedule estimates than by technical, political or team problems. Molokken and Jorgensen (2003) state that the average estimation error of software projects is high.

In APTS, for the projects of APGLI and MPHS, many project teams have been changed due to the lengthy durations of the projects. Most of the technical people at the level of programmers and project leaders normally stay for a maximum period of 3 years in APTS and when the duration of the above projects expands due to many reasons, the project team will be continuously refreshed with added new faces and the new team’s warm up time adds another problem to the already existing problems. For example, for the MPHS project, in the beginning it was decided to implement IBM’s DB2 database in the computers at all the Mandal Revenue Offices (MROs) to act as the database for the different software applications developed by APTS. When the database gave problems, after analyzing the reasons from different corners, it was decided to shift to Oracle database and accordingly changes were made in the developed software applications and the systems were upgraded with Oracle database. All these efforts delayed the project. Hence the issues of long duration and shifting to new technology create a lot of problems to the project leading to further delays.

From the survey reports of different organizations, it was expressed that at least 20% of any software project undergoes changes due to various reasons. The most common changes to the project are requested either by the user or the project team members to try to improve the produce or service.
Skills of the estimators: Accuracy of estimates depends on the skills of the people making the estimates. The estimator should select the appropriate estimation techniques for a particular activity to estimate the effort as accurately as possible.

Estimation time: Managers from MCSB and QuickNet communications stressed the importance of giving sufficient time for estimations. Estimations made in hurry lead the project to a lot of uncertainty along with many errors.

Following the above discussions, the different salient variables that influence the accuracy of project estimates have been identified and listed in Table 4.4.

Table 4.4. List of salient variables in the system of 'Project Estimates'

<table>
<thead>
<tr>
<th>Salient variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Good estimation techniques</td>
</tr>
<tr>
<td>2. Planning horizon</td>
</tr>
<tr>
<td>3. Staff coordination</td>
</tr>
<tr>
<td>4. Skills of estimators</td>
</tr>
<tr>
<td>5. Project estimates</td>
</tr>
<tr>
<td>6. Activity duration</td>
</tr>
<tr>
<td>7. Project time</td>
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<tr>
<td>8. Effort estimates</td>
</tr>
<tr>
<td>9. Resource estimates</td>
</tr>
<tr>
<td>10. Risk estimates</td>
</tr>
<tr>
<td>11. Cost Estimates</td>
</tr>
<tr>
<td>12. Project duration</td>
</tr>
<tr>
<td>13. Accuracy of Estimates</td>
</tr>
<tr>
<td>14. Underestimates</td>
</tr>
<tr>
<td>15. Overestimates</td>
</tr>
<tr>
<td>16. Errors</td>
</tr>
<tr>
<td>17. Estimation time</td>
</tr>
<tr>
<td>18. Change requests</td>
</tr>
</tbody>
</table>

4.4.1. Basic SD feedback loops in the system of 'Project Estimates'  
(a) The increase in activity duration means spending more time on the activity and this increases the cost estimates. When the resource estimates for an activity increases, the cost estimates also increase. Hence the causal links from the two variables, 'Activity duration'
and 'Resource estimates' connecting to the variable 'Cost estimates' will be positive links. When the resource estimates for the activity increases, the activity duration can be easily controlled and hence the causal link connecting 'Resource estimates' with 'Activity duration' will be negative. The feedback loop formed by these causal links will be a negative loop because of the presence of odd (one) number of negative causal links.

(b) When effort estimates are increased, there will be increase in both activity duration and resource estimates to perform the task with that effort. Hence the causal links connecting the variable 'Effort estimates' with the two variables, 'Activity duration' and 'Resource estimates' have been treated as positive links. The causal link between 'Resource estimates' and 'Activity duration' is negative. As there is only one negative causal link, the feedback loop formed by these three causal links will be a negative loop.

(c) The increase in effort estimates will also increase the cost estimates and hence the causal link connecting 'Effort estimates' with 'Cost estimates' is a positive link. The causal link between 'Effort estimates' and 'Resource estimates' and that between the variables 'Resource estimates' and 'Cost estimates' are also positive. The feedback loop formed by these three positive causal links will be a positive loop.

(d) The increase in either or both of effort estimates and cost estimates will increase the total project estimates and hence the causal links connecting the two variables 'Effort estimates' and 'Cost estimates' with the variable 'Project estimates' will be positive. The causal link between 'Effort estimates' and 'Cost estimates' is also positive. The feedback loop formed by these three positive links will become a positive loop.

(e) Underestimates shorten the activity durations and thereby the project completion time. So, the causal link between 'Underestimates' and 'Project duration' will be negative. According to Hughes and Cotterell (2002), the danger with the underestimates is the negative effect on quality. Underestimates reduce the accuracy of estimates for successful projects and hence the causal link from 'Underestimates' to 'Accuracy of Estimates' has been treated as negative link. The increase in project duration also reduces the accuracy of
estimates and hence the causal link between the two variables, ‘Project duration’ and ‘Accuracy of Estimates’ has been treated as negative link. The feedback loop formed by all these three negative causal links will be a negative loop, because of the odd number of negative links.

(f) Increase in activity duration increases the cost estimates and also project estimates and hence the causal links connecting the variable ‘Activity duration’ with the two variables ‘Cost estimates’ and ‘Project estimates’ will be positive. The causal link between ‘Cost estimates’ and ‘Project estimates’ is also positive. The feedback loop formed by these three positive causal links will be positive.

(g) Like underestimates, overestimates also reduce the accuracy of estimates by increasing errors in the estimates. Hence the causal link connecting the variable ‘Overestimates’ with ‘Accuracy of Estimates’ will be a negative link and that connecting ‘Overestimates’ with ‘Errors’ will be a positive link. The improvement in the accuracy of estimates reduces the errors and hence the causal link between the variables ‘Accuracy of Estimates’ and ‘Errors’ will be negative. Because of the presence of even (two) number of negative causal links, the feedback loop formed by the three causal links will be a positive loop.

(h) The system of project estimates should have good accuracy by increase of various types of estimates in the project. Hence it has been assumed that the causal link between the two variables, ‘Project estimates’ and ‘Accuracy of Estimates’ is a positive link. The causal link between ‘Project duration’ and ‘Accuracy of Estimates’ is a negative link. The total project time is made up by the total project duration and is influenced by the duration of each activity of the project. Increase in activity duration not only increases the project estimates, but also project time. Hence the causal links from the two variables, ‘Project duration’ and ‘Activity duration’ connecting to the variable, ‘Project time’ have been treated as positive links. The causal link connecting the variable ‘Activity duration’ to ‘Project estimates’ is positive. Because of the presence of one (odd number) negative causal link, the feedback loop formed by these five causal links will become a negative loop.
(i) Overestimates and underestimates as well increase errors and hence the causal links connecting the two variables ‘Overestimates’ and ‘Underestimates’ with the variable ‘Errors’ have been treated as positive links. Overestimates increase the project duration, whereas underestimates decrease the project duration. Hence the causal link from ‘Overestimates’ to ‘Project duration’ will be positive and that from ‘Underestimates’ to ‘Project duration’ will be negative. The feedback loop formed by these four links will be negative because of the presence of only one (odd number) negative causal link.

(j) Skills of estimators reduce the errors in the estimates and thereby improve the accuracy of estimates and hence the causal link connecting the variable ‘Skills of estimators’ to the variable ‘Errors’ will be negative and that to the variable ‘Accuracy of Estimates’ will be a positive link. The causal link from the variable ‘Underestimates’ to the variable ‘Errors’ will be positive and that to the variable ‘Accuracy of estimates’ will be negative. The feedback loop formed by these four causal links will be a positive loop because of the presence of even (two) number of negative links.

(k) The causal link connecting the variable ‘Skills of estimators’ with the variable ‘Accuracy of Estimates’ is a positive link and the link between ‘Skills of estimators’ and ‘Errors’ is negative. The causal link connecting ‘Accuracy of Estimates’ with ‘Errors’ is a negative link. The feedback loop formed by these three causal links will become a positive loop because of the presence of two (even number) negative causal links.

All the above eleven feedback loops are shown in the figure, Fig. 4.4.1.
4.4.1. SD feedback loops in the system of 'Project Estimates'

4.4.2. Causal loop model of the system of 'Project Estimates'

Improved staff coordination and good estimation techniques will definitely improve the accuracy of project estimates. When the project planning horizon increases, the accuracy of the estimates will be uncertain, that means the accuracy of estimates decreases. Hence the
causal links connecting the variables, 'Staff coordination', 'Good estimation techniques' with 'Accuracy of estimates' are positive links and that connecting 'Planning horizon' with 'Accuracy of estimates' is a negative link. Using these causal links and the eleven feedback loops explained earlier, a causal loop model has been developed for the system of 'Project Estimates' and is shown in the figure, Fig. 4.4.2.

Fig. 4.4.2. Causal loop model of 'Project Estimates'

4.4.3. Stock and flow model of the system of 'Project estimates'

A stock and flow model has been developed for the system of 'Project Estimates' based on the inter-relationships between the different variables that influence the system. The three variables, namely, 'Project estimates', 'Errors', and 'Project time' have been treated as rate
variables, whereas 'Accuracy of Estimates' and 'Project duration' as stock (or level) variables. Fig. 4.4.3 represents the model.

![Stock and Flow diagram of 'Project Estimates']

4.4.4. Modeling equations for the system of 'Project estimates'

The duration of the activity of project estimates in the planning phase of a project has been assumed as 2 months, with initial time = 0 and final time = 2 months and the time step for simulation as 0.25 month.

From the surveys, it has been observed that an activity of a project generally needs an average effort of about 10 to 12 working days (nearly 9.6 month) in a month consisting of a total number of 20 working days and is assigned to at least one person and in some cases maximum two persons. Based on this, the variable, 'Effort estimates' has been equated to
0.6 and to keep maximum 2 people on each activity, the variable ‘Resource estimates’ has been equated to ‘Effort estimates’ divided by 0.3. The activity duration is equated to the ratio of effort estimates and resource estimates. The variable ‘Cost estimates’ has been equated to the exponential of the sum of activity duration, effort estimates and resource estimates. Risk has been initiated to 5. The variable, ‘Project estimates’ has been equated to the product of activity duration and the sum of cost estimates, effort estimates and risk estimates.

The two variables ‘Overestimates’ and ‘Underestimates’ have been initiated to 0.5 each by assuming that the estimates may have both overestimates and underestimates.

The planning horizon, staff coordination, good estimation techniques and the skills of estimators have been assumed as normal by assigning a value of 1 to each of those four variables. Based on the feedback of the survey reports that a project generally undergoes about 20% of changes due to change requests, the variable ‘Change requests’ has been assigned a value of 0.2 (20%). The estimation time has been initiated as 0.1 month.

The rate variable ‘Errors’ is assumed as the ratio of the sum of overestimates and underestimates and the sum of 1 and natural logarithm of the sum of skills of estimators and accuracy of estimates. Project time is assumed as the sum of the activity duration and the value of project duration accumulated from time to time. The stock variable ‘Project duration’ is equated to the integration of the sum of project time and overestimates minus underestimates, with initial value as 1.

The important level variable ‘Accuracy of Estimates’ has been equated to the integration of different contributions of different influencing variables shown in the stock and flow diagram, with an initial value of 0 (zero).

All these modeling equations are listed in Table 4.4.4.
Table 4.4.4. SD modeling equations of the system of 'Project Estimates'

(A) INITIAL TIME = 0 (The initial time for the simulation).
(B) FINAL TIME = 2 (The final time for the simulation).
(C) TIME STEP = 0.25 (The time step for the simulation).
(D) SAVEPER = TIME STEP (The frequency with which output is stored).

(1) Effort estimates = 0.6.
(2) Resource estimates = Effort estimates/0.3.
(3) Activity duration = Effort estimates/Resource estimates.
(4) Cost estimates = EXP(Activity duration + Effort estimates + Resource estimates).
(5) Risk estimates = 5.
(6) Project estimates = (Cost estimates + Effort estimates + Risk estimates) * Activity duration.
(7) Overestimates = 0.5.
(8) Underestimates = 0.5.
(9) Planning horizon = 1.
(10) Staff Coordination = 1.
(11) Good estimation techniques = 1.
(12) Skills of estimators = 1.
(13) Change requests = 0.2.
(14) Estimation time = 0.1.
(15) Errors = (Overestimates + Underestimates)/(1 + LN(Skills of estimators + Accuracy of Estimates)).
(16) Project time = Activity duration + Project duration.
(17) Project duration = INTEG (Project time + Overestimates - Underestimates, 1).

Contd......
\[ \text{Accuracy of Estimates} = \text{INTEG} (20 \times \text{Project estimates} \times \text{Estimation time} \times \\
\text{Skills of estimators} \times \text{Staff Coordination} \times \text{Good estimation techniques})/(\text{Overestimates} \times \\
\text{Project duration} \times \text{Underestimates} \times \text{Change requests} \times \text{Planning horizon}), 0). \]

4.4.5. Simulation results of the system of ‘Project Estimates’

The stock and flow model of ‘Project Estimates’ along with the modeling equations has been simulated. Different patterns of behaviour have been observed in the variables ‘Errors’, ‘Accuracy of Estimates’ and ‘Project duration’ as shown in the figure, Fig. 4.4.5. Decay behaviour has been observed in ‘Errors’, whereas an exponential growth has been observed in the two variables ‘Accuracy of Estimates’ and ‘Project duration’. That is, throughout the project duration the accuracy of estimates is increasing with decrease in the errors. The errors decrease exponentially for a certain period and then decrease very slowly by settling at some value near 0.2 meaning that errors are common but can be minimized. The same thing has been expressed by some software organizations like MCSB, QuickNet, etc.

Fig. 4.4.5. Patterns of behaviour in the system of ‘Project Estimates’
4.4.6. Sensitivity analysis results of the system of ‘Project Estimates’

The stock and flow model of ‘Project estimates’ has been treated with automatic simulations by varying the values of different variables that influence the important variable ‘Accuracy of Estimates’. The sensitivity analysis results are shown in the figures (i), (ii), (iii) and (iv) of Fig. 4.4.6. In each figure, the graph I (red colour) represents the behaviour with the initial values of the variables, whereas the graph II (blue colour) represents the sensitivity analysis result by varying the value of any one of the influencing variables.

(i) As a special interest of study and analysis of the impact of underestimates and overestimates on the accuracy of estimates, the model has been simulated by varying the value of either ‘Underestimates’ or ‘Overestimates’ from their initial value of 0.5. When the value of ‘Underestimates’ is increased from 0.5 to 3, it is observed that the accuracy of estimates followed its initial pattern of growth for more than half of the simulation time and then slowly started increasing further exponentially for a while and then started decreasing drastically below zero. This result is providing evidence to the fact reported by Hughes and Cotterell (2002) that there is a limit for the underestimates to be made to complete the project within short time and that limit consumes all the float time of the project and when the total float time of the project is consumed, the project will be in problems and delays mount. The present result obtained is also showing a limit for the improvement of accuracy of estimates followed by a drastic decay. So, the effect of underestimates on a project is well forecasted from this system dynamics simulation model.

![Fig. 4.4.6.(i) Sensitivity analysis of ‘Project Estimates’](image-url)
(ii) In the case of overestimates, when its value is increased from 0.5 to 3, it is observed that
the growth of accuracy of estimates is highly slowed down from its initial pattern of
growth behaviour. This result interprets that even though growth of overestimates does
not kill the project, it will reduce the quality of estimates. This result is validating the
usual experience in the projects and also the literature reports that overestimates may
spoil the quality and delay the project, but not as serious as underestimates.

![Fig. 4.4.6.(ii) Sensitivity analysis of 'Project Estimates'.](image)

(iii) Following the feedback and suggestions of some software organizations like MCSB,
QuickNet communications, etc. that sufficient time should be spent on estimates to make
them more accurate, when the value of the variable 'Estimation time' is increased from
0.1 to 0.2 (doubled), a tremendous growth is observed in the accuracy of estimates. This
result is supporting the fact that sufficient time spent on estimations leads to detailed
analysis and development of good estimates and thereby improving the accuracy in the
estimates.

![Fig. 4.4.6.(iii) Sensitivity analysis of 'Project Estimates'.](image)
(iv) When the value of the variable 'Skills of estimators' is increased from its initial value of 1 to 1.5, considerable growth has been observed in the accuracy of estimates. This result is validated by the fact that it is the estimators that do the estimations using their knowledge and skills and when they have more skills, the accuracy in their estimations will be improved further.

![Sensitivity analysis of 'Project Estimates'](image)

**Fig. 4.4.6.(iv) Sensitivity analysis of 'Project Estimates'**

4.5 PROJECT SCHEDULING

A project schedule is the conversion of project action plan expressed in the form of work breakdown structure (WBS) into an operating timetable. It clearly indicates when each of the project's activities is planned to occur and what resources the project will need and it also determines the best means of achieving the project's general and specific objectives. This involves identification and optimization of the project's overall requirements, resource availability and internal and external constraints and activity sequencing. Whatever type of project (small or big) it may be, the project schedule should be refined and expanded as the project proceeds (Hughes and Cotterell 2002). To begin, some activities require completion of other activities (called predecessor activities) and these requirements are known as precedence requirements. Based on such dependencies among activities, the tasks will be sequenced and scheduled.

The most common project scheduling techniques are network planning models (or network diagrams) like PERT (Program Evaluation and Review Technique) and CPM (Critical Path
Method), Gantt or bar charts and Milestone charts. Network planning models can better handle the inter-dependencies between the activities when compared with other techniques. PERT is event-oriented and probabilistic in nature and is used for R&D projects where the risks in calculating time durations have a high variability. CPM uses one time estimate that represents the normal time and hence it is deterministic in nature. It is activity-oriented and is useful for construction projects that are based on accurate time estimates. Gantt charts are easy to understand, maintain and construct, but they do not contain detailed information due to their simplicity.

Scheduling of the project has to cover the cost schedules, time schedules and resource schedules. Each of these schedules is prepared starting from the information contained in the project work-breakdown structure (WBS). Most important activity in the project scheduling is the sequencing of activities based on the interdependencies between them and the estimates of the three important elements—cost, time and resources—required to perform the activities.

Cost estimates are not a budget. A cost estimate becomes a budget when it is time-phased. Each work package estimate requires a time-phased budget. The work package duration and others are used to develop the project network that schedules the starting and finishing times of work packages. The time-phased budgets for work packages are then assigned to scheduled time periods to determine the financial requirements for each period over the life of the project. These time-phased budgets should mirror how the actual cash needs will occur (Gray and Larson 2003).

The activities with estimations of time, cost and resources required will be networked in a sequence to achieve the objective of the project. Any changes in either the cost or time or resources, are to be considered and analysed and necessary changes should be incorporated in the scheduling plan. The resulting networking of the activities improves the scheduling process.
According to Pressman (1997), there are a number of basic principles to guide software project scheduling – (1) Compartmentalization (which is nothing but work breakdown structure), (2) Interdependency (relationships between the activities or tasks), (3) Time allocation (allocating times to each task), (4) Effort validation (allocation of defined number of staff to each task depending on the effort required), (5) Defined responsibilities (assigning each task to a specific team member), (6) Defined outcomes (each task having a defined outcome), and (7) Defined milestones (each task associated with a project milestone).

When the work breakdown structure (WBS) is well developed, the interdependencies between different activities will be very much clear and this leads to their well sequencing. Then the outcome of each activity and the project milestones will also be clear and all these things improve the rate of scheduling the activities assigning proper start and end dates based on their durations.

It has been observed from the surveys, mainly in APTS, regarding some failed projects, that one of the vital causes for failure is improper scheduling, that is, without taking into view all the possible risks that disturb the schedules. A manufacturing manager of Osram Opto Semiconductors (Malaysia) reported that the main problem for doing any project in their organization is in line maintenance and even usage of project management information systems like MS Project software could not solve such problems and hence scheduling the resources is becoming a challenging task. The MIS Manager of Adaptive Micro Systems (Malaysia) also expressed the management problems in project scheduling and those problems appear mostly in delivery of developed IT products to their overseas head office (USA).

Following the above discussions, all the salient variables that influence the system of ‘Project Scheduling’ have been identified and listed in Table 4.5.
Table 4.5. List of salient variables in the system of ‘Project Scheduling’

<table>
<thead>
<tr>
<th>Salient variables</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Effective WBS</td>
<td>11. Delay</td>
</tr>
<tr>
<td>2. Clear Interdependencies</td>
<td>12. Activity duration</td>
</tr>
<tr>
<td>3. Sequencing of activities</td>
<td>13. Start day</td>
</tr>
<tr>
<td>4. Defined outcome</td>
<td>14. End day</td>
</tr>
<tr>
<td>5. Clear milestones</td>
<td>15. Inconsistencies</td>
</tr>
<tr>
<td>6. Activities scheduling rate</td>
<td></td>
</tr>
<tr>
<td>7. Effort validation</td>
<td></td>
</tr>
<tr>
<td>8. Accurate estimates</td>
<td></td>
</tr>
<tr>
<td>9. Constraints</td>
<td></td>
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<tr>
<td>10. Changes</td>
<td></td>
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</tbody>
</table>

4.5.1. Basic SD feedback loops in the system of ‘Project Scheduling’

(a) When the WBS is effectively developed, the relationships between different activities will be more clear and scheduling those activities can be done with more ease. Hence the two causal links connecting the variable ‘Effective WBS’ with the variables, ‘Clear Interdependencies’ and ‘Activities scheduling rate’ have been treated as positive links. The more the clarity in interdependencies of activities, the more will be their sequencing. Based on this, the causal link between the two variables ‘Clear Interdependencies’ and ‘Sequencing of activities’ has been treated as a positive link. The improvement in the sequencing of activities increases the rate of scheduling them and hence the causal link between the variables ‘Sequencing of activities’ and ‘Activities scheduling rate’ will also be positive. The feedback loop formed by these four positive causal links will become a positive loop.

(b) Growth in effectiveness of WBS will improve the clarity in milestones of activities in the project and hence the causal link between the variables ‘Effective WBS’ and ‘Clear milestones’ will be positive. Clarity of milestones of project improves the scheduling rate of activities and hence the causal link connecting the variables ‘Clear milestones’ and
'Activities scheduling rate' will be a positive link. The causal link between 'Effective WBS' and 'Activities scheduling rate' is a positive link. The feedback loop formed by these three positive links will be a positive loop.

(c) Constraints on time, cost, resources, etc. slow down the rate of scheduling the activities and increase inconsistencies in scheduling. Hence the causal link connecting the variable 'Constraints' with 'Activities scheduling rate' will be negative and that with 'Inconsistencies' will be positive. Similarly, continuous changes in the project reduces the accuracy of estimates and increases inconsistencies in scheduling the activities. Hence, the causal link connecting the variable 'Changes' with 'Accurate estimates' will be a negative link and that connecting with 'Inconsistencies' will be a positive link. Increase in accuracy of estimates will speed up the process of scheduling the activities and hence the causal link between the variables 'Accurate estimates' and 'Activities scheduling rate' will be positive. The feedback loop formed by these five causal links will be a positive loop because of the presence of even (two) number of negative links.

(d) Accurate estimates lead to correct estimation of effort and validate the required effort and hence the causal link connecting the variable 'Accurate estimates' with 'Effort validation' will be a positive link. When the effort has been estimated satisfactorily, that is, the effort is validated satisfactorily, the scheduling of activities will be done with more ease. Hence the causal link between the two variables 'Effort validation' and 'Activities scheduling rate' will be positive. The causal link connecting the variable 'Accurate estimates' with 'Activities scheduling rate' is a positive link. The feedback loop formed by these three positive causal links will be a positive loop.

(e) The causal link connecting the variable 'Constraints' with 'Inconsistencies' is a positive link, whereas the causal link connecting 'Constraints' with 'Activities scheduling rate' is a negative link. Consistency in project scheduling reduces the inconsistencies and encourages the process of scheduling the activities. Hence the causal link from the variable 'Consistent Project Scheduling' to the variable 'Inconsistencies' will be a negative link, whereas the link from 'Consistent Project Scheduling' to 'Activities scheduling rate' will be a positive link.
The feedback loop formed by the four causal links will be a positive loop since there are two negative causal links.

(f) Increase in changes leads to more delay and hence the causal link between the variables ‘Changes’ and ‘Delay’ will be positive. Increase in both changes and delay reduces accuracy of estimates. Hence the two causal links from the two variables ‘Changes’ and ‘Delay’ connecting to the variable ‘Accurate estimates’ will be negative links. The feedback loop formed by these three links will be a positive loop, because of the presence of even (two) number of negative causal links.

(g) When the end day of an activity is extended further, there will be increase in the duration of the activity and delay in completing the activity. Based on this, the two causal links connecting the variable ‘End day’ with the variables ‘Activity duration’ and ‘Delay’ have been treated as positive links. When the start day of an activity is extended, the activity duration will be reduced, assuming that the end day is fixed. Hence the causal link between the variables ‘Start day’ and ‘Activity duration’ will be a negative link. When the activity is not started as per the schedule and it is started late, that is, start day is extended, there will be more delay. Hence the causal link between the variables ‘Start day’ and ‘Delay’ will be a positive link. The feedback loop formed by these four causal links will be a negative loop because of the presence of one (odd number) negative causal link.

(h) The causal links connecting the variable ‘End day’ with the two variables ‘Activity duration’ and ‘Delay’ are positive links. When an activity is delayed more, the activity duration will be more. Hence the causal link between the variables ‘Delay’ and ‘Activity duration’ will be positive. The feedback loop formed by these three positive causal links will be a positive loop.

(i) Delay in an activity spoils the accuracy of estimates and validation of effort as well. Hence the causal links connecting the variable ‘Delay’ with the two variables ‘Accurate estimates’ and ‘Effort validation’ will be negative links. The causal link between ‘Accurate estimates’ and ‘Effort validation’ is a positive link. The feedback loop formed by these three
causal links will become a positive loop because of the presence of two negative causal links.

All the above 9 (nine) feedback loops are shown diagrammatically in the figure, Fig. 4.5.1.

Fig. 4.5.1. *SD feedback loops in the system of ‘Project Scheduling’*
4.5.2. Causal loop model of the system of ‘Project Scheduling’

When there is a defined outcome from either an activity or group of activities, there will be more clarity in the milestones of the project. Hence the causal link connecting the variables ‘Defined outcome’ and ‘Clear milestones’ will be a positive link. Along with this link and the nine (9) feedback loops explained earlier, the causal loop model has been developed for the system of ‘Project Scheduling’ and is shown in the figure, Fig. 4.5.2.

Fig. 4.5.2. SD causal loop diagram of ‘Project Scheduling’
4.5.3. Stock and flow model of the system of 'Project Scheduling'

A stock and flow model has been developed for the system of 'Project Scheduling' based on its causal loop model. The two variables 'Activities scheduling rate' and 'Inconsistencies' have been treated as rate variables, whereas the variable 'Consistent Project Scheduling' has been treated as a level or stock variable. The stock and flow model is shown in the figure, Fig. 4.5.3.

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**Fig. 4.5.3. Stock and Flow diagram of 'Project Scheduling'**

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4.5.4. Modeling equations for the system of 'Project Scheduling'

The necessary modeling equations for the stock and flow model of the system of 'Project Scheduling' are given in Table 4.5.4. A total duration of one (1) month has been assumed for the activity of project scheduling and hence the final time has been assigned a value of 1 and the initial time as 0 month with the time step for simulation as 0.125 month.

It has been assumed that the project has normal constraints, defined outcome and effective work breakdown structure (WBS) and hence each of the three variables, namely, ‘Constraints’, ‘Defined outcome’ and ‘Effective WBS’ has been assigned an initial value of 1. The variable ‘Clear interdependencies’ is made equal to ‘Effective WBS’, ‘Sequencing of activities’ equated to the exponential of ‘Clear Interdependencies’ and the variable ‘Clear milestones’ is equated to the product of ‘Effective WBS’ and ‘Defined outcome’.

Based on the feedback of some software organizations about the change requests that on an average a project may undergo at least 20% changes, the variable ‘Changes’ has been assigned a value of 0.2. The two variables, ‘Start day’ and ‘End day’ have been assigned initial values as 1 and 5 respectively, by assuming that the start day of an activity is the first day and end day is the 5th day. Delay has been equated to the product of changes and the sum of start day and end day. Activity duration is made equal to the difference between end day and start day plus delay.

The variable ‘Accurate estimates’ has been equated to the reciprocal of the product of changes and delay plus 1. Effort validation has been assumed as the ratio of accurate estimates to delay. Based on the different influences of different variables, the rate variable ‘Activities scheduling rate’ has been assigned to a lengthy expression divided by constraints and also a numerical value of 0.45 to limit the value of rate variable around 100. The level variable ‘Consistent Project Scheduling’ has been equated to the integration of the activities scheduling rate starting from an initial value of 1. Finally, the variable ‘Inconsistencies’ has been equated to the product of constraints and sum of changes and unity and then divided by consistent project scheduling.
Table 4.5.4. SD modeling equations of the system of 'Project Scheduling'

<table>
<thead>
<tr>
<th>(A)</th>
<th>INITIAL TIME = 0  (The initial time for the simulation).</th>
</tr>
</thead>
<tbody>
<tr>
<td>(B)</td>
<td>FINAL TIME = 1   (The final time for the simulation).</td>
</tr>
<tr>
<td>(C)</td>
<td>TIME STEP = 0.125 (The time step for the simulation).</td>
</tr>
<tr>
<td>(D)</td>
<td>SAVEPER = TIME STEP (The frequency with which output is stored).</td>
</tr>
</tbody>
</table>

(1) Constraints = 1.
(2) Defined outcome = 1.
(3) Effective WBS = 1.
(4) Clear Interdependencies = Effective WBS.
(5) Sequencing of activities = EXP (Clear Interdependencies).
(6) Clear milestones = Effective WBS * Defined outcome.
(7) Changes = 0.2.
(8) Start day = 1.
(9) End day = 5.
(10) Delay = Changes*(Start day + End day).
(11) Activity duration = End day - Start day + Delay.
(12) Accurate estimates = 1/(1 + Changes*Delay)
(13) Effort validation = Accurate estimates/Delay
(14) Activities scheduling rate = ((Effective WBS + Sequencing of activities + Clear milestones + Effort validation)*Accurate estimates + Consistent Project Scheduling)/Constraints/0.45.
(15) Consistent Project Scheduling = INTEG (Activities scheduling rate, 1).
(16) Inconsistencies = Constraints * (1 + Changes)/Consistent Project Scheduling.
4.5.5. Simulation results of the system of ‘Project Scheduling’

The stock and flow model developed for the system of ‘Project Scheduling’ has been simulated. Fig. 4.5.5. shows the simulation results without changing the initial values of variables given in the modeling equations of Table 4.5.4.

Growth behaviour is observed in the variables ‘Activities scheduling rate’ and ‘Consistent Project Scheduling’, whereas decay behaviour observed in the variable ‘Inconsistencies’. This observation can be validated by the fact that when the consistency in project scheduling increases, the rate of scheduling activities will speed up by reducing any inconsistencies from time to time. The final value of ‘Activities scheduling rate’ is about 85 that means 85%.

*Fig. 4.5.5. Patterns of behaviour in the system of ‘Project Scheduling’*
4.5.6. Sensitivity analysis results of the system of 'Project Scheduling'

The stock and flow model of 'Project Scheduling' has been undergone automatic simulations by varying the values of one or more different important influencing variables, namely, 'Effective WBS', 'Changes', 'Constraints', 'Start day' and 'End day'. All the results of sensitivity analysis are shown graphically in the figures, Fig. 4.5.6(i) to (v). In each figure, graph I (red colour) represents the behaviour with initial values, whereas graph II (blue colour) represents the behaviour resulted from sensitivity analysis.

(i) When the value of 'Effective WBS' is increased from its initial value of 1 to 1.2, considerable growth is observed in the behaviour of the two variables 'Consistent Project Scheduling' and 'Activities scheduling rate', whereas the decay in the behaviour of 'Inconsistencies' decreased slightly from its initial pattern of behaviour. The value of 'Activities scheduling rate' closely approached 100 that mean 100%. Usually, in development companies, when the work breakdown is done more effectively, there will be more consistency in scheduling the activities of the project and this encourages and speeds up the process of scheduling the activities by reducing any inconsistencies. Hence the sensitivity analysis result is said to be validated by the common experience in the projects.
(ii) To study the effect of changes on the system of project scheduling, the value of the variable 'Changes' is increased from its initial value of 0.2 (20%) to 0.3 (30%). Then a considerable decay from the initial behaviour is observed in the behaviour of the variables 'Consistent Project Scheduling' and 'Activities scheduling rate', whereas the decay in the behaviour of 'Inconsistencies' started from a value somewhat higher than that observed with the initial values, that means some growth in the inconsistencies. Almost all the surveyed software departments and organizations expressed their problems with the continuous changes in the requirements specification leading to continuous changes in the project plan and project schedule and delays in the project. The result obtained from the sensitivity analysis is supporting this fact by saying that
when the changes to the project are increased, the consistency in scheduling the project will be spoiled by disturbing the process of scheduling the activities.

**Fig. 4.5.6. (ii) Sensitivity analysis of 'Project Scheduling'**

(iii) When the value of 'Constraints' is increased from its initial value of 1 to 1.2, tremendous decay is observed in the behaviour of the two variables 'Consistent Project Scheduling' and 'Activities scheduling rate', whereas the decay in the behaviour of 'Inconsistencies' started from a value considerably higher than that observed with the initial values, that means much growth in the inconsistencies. The software organizations like MCSB and Apex communications in Malaysia expressed that they are not having enough resources to handle the project and they are constrained to do the project with the available meager resources and those situations are leading to a lot of delays in the project. They also
expressed that when the time also becomes a constraint then their problems will be more and more. The sensitivity analysis result also says that the increase in constraints highly affects the consistency in scheduling the project and the ease of scheduling the activities by showing negative effects and increasing inconsistencies in scheduling. Hence the sensitivity analysis result is validating the real world experience with the project constraints.

**Fig. 4.5.6.(iii) Sensitivity analysis of 'Project Scheduling'**

![Graph showing consistency in project scheduling](image)

Inconsistencies

(iv) To study the influence of changes in start day and end day as well of an activity, each of their values has been increased by 1 from their initial values of 1 and 5 respectively. By this change, some decay is observed in the behaviour of consistency in project
scheduling and activities scheduling rate, whereas the decay in inconsistencies started from a meagerly higher value, that means a very meager growth in inconsistencies. Actually, when the values of both start day and end day are changed simultaneously and equally, there will be no change in the activity duration or the project duration, but there will be disturbance in the project plan and the project schedule. Hence the sensitivity analysis result is validating this fact by saying that the changes in both start day and end day lead to disturbances in the consistency and ease of scheduling the project and its activities.

Fig. 4.5.6.(iv) Sensitivity analysis of 'Project Scheduling'

- Consistent Project Scheduling

- Activities scheduling rate

- Inconsistencies

Time (Month)
(v) To study the delay in more detail by extending only the end day of the activity, sensitivity analysis has been carried out by increasing the value of end day from its initial value of 5 to 8. This means the delay is increased by 3 days more. By this change, the same behaviour as generated under the result (iv) has been observed, that is, decay in the behaviour of consistency in project scheduling and activities scheduling rate and starting of decay in inconsistencies from a meagerly higher value, that means a very meager growth in inconsistencies. As explained under the result (iv), this result can also be validated with the real world experience in projects.

![Fig. 4.5.6.(v) Sensitivity analysis of 'Project Scheduling'](image-url)

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The other variable 'Defined outcome' is showing very meager improvement in the behaviour of 'Activities scheduling rate' and 'Consistent Project Scheduling' and hence, its effect is not shown graphically separately.

4.6 PROJECT DESIGN

The project design phase defines how the project is to be implemented. In the case of software projects, the design covers the coding, testing and documentation structures. The majority of the project documentation will be created during the design phase. Management will review the documents for accuracy and completeness. The major activity of design phase is to create the top and medium levels of the project system design and document it in the Design specification. The second activity in this phase will be designing the Acceptance Test Plan (ATP). The ATP is a document listing the tests that will be used to demonstrate all the system functions to the user in the acceptance stage after completing the project work. The design specification should be reviewed thoroughly and declared error-free. Design of a system consists of two major steps: first the system will be divided into its functional components, and second, all these components will be interconnected.

The design process includes selection of best people to form a design team, allotting enough time to do design, conducting meetings to share and discuss ideas, weighing the better options and then documenting the project design with necessary structured diagrams. When the project design is done, the whole thing must be tested by reviewing thoroughly to ensure that all the functional specification requirements are met, the design is easy to program and maintain, and it can be implemented on time and on budget. According to Rakos (1990), some of the detailed design will invariably lead to changes in requirements.

The design activity of the project presents clear picture to develop the project. In IT projects, the project design generally comprises of design of structures, interfaces, features and logical design, physical design, module design, and component design. When all these basic designs are well done, the project design will have an elaborate view. Any changes
that come in the way must be included into the designs and the project design should be updated from time to time. When the relationships between different entities are made clear and improved, the design will be improved by reproducing the same relationships in the appropriate design items. The design of the project should be so clear that it simulates all aspects of the project. The design includes both logical and physical design of all features, structures and interfaces of the project, at all levels of module, component and detailed system. The design activity also develops the test plans to be used to test the outcomes of the project at different stages of the development so as to fulfill the objectives of the project. Quality of the project should be ensured at all stages of the project and this should be assured by the strengths of the design of the project. The strengths of the design are tested by developing and upgrading the prototype of the project system and simulating it. The design of the project includes detailed documentation and drawings clearly describing the logic followed to solve the problem.

The design should be approved by both the parent organization’s senior management and the client. The design should mimic the behaviour of the proposed final outcome of the project. If any changes take place in the requirements during the progress of the project, necessary changes are to be made not only to the scope of the project, but the design of the project so as to achieve the objectives of the project.

In all the organizations surveyed, except one or two, the activity of project design is being carried out perfectly and in detail. In one organization, it was observed that the project was being designed roughly and the project team started the development work directly and checked the outputs of different modules and the integrated project and carried out corrections continuously taking into an overview that was passed on by the project manager. When questioned about this un-systematic way, the simple answer was that they were busy and they didn’t want to waste valuable time in designing and preparing maps and instead they could start from the development of prototype and modify it till completion of project. It was also observed in that organization that due to such unplanned and un-systematic development process, there was a lot of communication gap between the team members leading to continuous reworks with mounting pressures and frustration among the staff.
Another observation made was that the senior management was not caring about the problems of team members or the methodology being implemented by the project manager to get the project done and instead they were pressing for the completion of project to earn quick money. The project managers exploited this tendency of senior management and applied a lot of pressure on the team members without giving any guidelines, putting effort or involving in the work except demanding them to get the project completed by whatever means even without proper design and plan.

In APTS, during the process of evaluation of bidders in some software projects, the competent bidders are requested to demonstrate the prototype application developed by them to show their level of understanding of the requirements of the user department. For this purpose, the bidders are allowed to visit the user department to do preliminary study of the system and then start designing the prototype. The prototype design will give them rough estimation of the project cost, duration and other requirements.

The evaluation of prototype design focuses on whether the design is in approximate congruence with the real system, that means whether the design is roughly simulating the behaviour of real system or real application. When a prototype application satisfies the requirements, the prototype design would be treated as a base. If the bidder wins the project work order, a detailed study of the system will be carried out and the prototype design will be modified from time to time to produce a detailed design. The detailed prototype design is further modified in order to reproduce the satisfactory simulated behaviour of the real solution. That prototype will be treated as the final model and necessary modifications in the design of other units and components, program structures, flow charts, etc. will be carried out to get the final design of the project. The supplier/developer has to handover the design documents that have been developed from time to time to APTS or the concerned user Government department for evaluation purposes.

Following the above discussions, the important salient variables that influence the system of 'Project Design' have been identified and listed in Table, 4.6.
Table 4.6. List of salient variables in the system of 'Project Design'

<table>
<thead>
<tr>
<th>Salient variables</th>
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</thead>
<tbody>
<tr>
<td>1. Scope of the project</td>
</tr>
<tr>
<td>2. Changes</td>
</tr>
<tr>
<td>3. Relationships</td>
</tr>
<tr>
<td>4. Features</td>
</tr>
<tr>
<td>5. Structures</td>
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<tr>
<td>6. Interfaces</td>
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<tr>
<td>7. Logical design</td>
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<tr>
<td>8. Physical design</td>
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<tr>
<td>9. Module design</td>
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<tr>
<td>10. Component design</td>
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<tr>
<td>11. Detailed design</td>
</tr>
<tr>
<td>12. Drawings</td>
</tr>
<tr>
<td>13. Documentation</td>
</tr>
<tr>
<td>14. Prototype development</td>
</tr>
<tr>
<td>15. Simulation of the system</td>
</tr>
<tr>
<td>16. Test plans</td>
</tr>
<tr>
<td>17. Quality assurance</td>
</tr>
</tbody>
</table>

A system dynamics influence model has been developed for the system of 'Project Design' and is shown in the figure, Fig. 4.6.

Fig. 4.6. SD influence diagram of the system 'Project Design'