CHAPTER - 5

ANALYSING RISK FACTORS FOR RESOURCE ALLOCATION
USING BAYESIAN NETWORKS IN SECURE SOFTWARE
DEVELOPMENT

5.1 INTRODUCTION

Nowadays, in software development processes, risk management is an important one. The management of any organization aims to achieve its objective by monitoring and reducing risks, whether working in the public sector or private sector. Risk could significantly increase or impede the ability of an entity to achieve its present or future business objectives. Risk management is a main concept associated with the safety and financial integrity of an organization, and its strategic development, risk assessment. The risks must be identified, analysed, monitored and managed so that they are maintained in particular limit, accepted by the entity’s management. Risk management process is still in progress and the results are generated in the aspect of accepting, eliminating or reducing risks that affect the achievement of objectives. The aim is to optimize the entity’s exposure to risk in order to avoid threats, prevent losses and utilize opportunities.

Human Resource Management (HRM) is the process of recruitment, selection of workers, providing proper induction and orientation, delivering the proper training to improve skills, assessment of worker, providing proper compensation and benefits, inspiring, keeping proper relations with labour, maintaining workers' welfare, safety and health with respect to labour laws of diligence state or country. HRM deals with the process of managing the people from a macro perspective point. HRM can be defined as the process of governing people in an organization in a well-structured manner. The Capability Maturity Model Integration (CMMI) is defined as the process model which concludes a clear explanation of what an organization should do to enhance the performance. With five “maturity levels” or three “capability levels,” the CMMI describes the most significant elements that are necessary to build good
products, or deliver proper services, and wraps them all up in a comprehensive model. The CMMI also helps us to recognize and achieve measurable business goals, build better products, keep customers happier, and ensure that workers are working as efficiently as possible.

The aim of this chapter is to implement risk recognition and risk reduction strategies in global software development (GSD). GSD systematic literature reviews (SLR) research focuses on finding what research has been conducted in the area and to deduce if the SLRs furnish appropriate risk and risk reduction advice to give guidance to organizations involved with GSD. Saleh proposed a trustworthy software security requirements behaviour model can be used to make web services and applications secure and trustworthy [87]. Bernstein, Mclean and Wilhelm defined trustworthiness in the aspect of software industry, and also summarized some suggestions about trustworthy software research methods [88], [89], [90]. Developing trustworthy software is a multifaceted problem of security engineering, software engineering and risk management. Thus, making secure software starts with predominant software engineering practices, increased with sound technical practices, and supported by risk management practices that promote trustworthy software development. In order to develop trustworthy software, a structured process risk control is required. This study demonstrated that a significant relationship existed between risk and project success. The present study investigates an adaptive system of integration technical risk assessment model, which is based on Bayesian belief networks coupled with parametric models.

This model gives statistical information for decision makers, enhancing risk management of complex projects. This model can be used to derive an optimized risk management method for the process of trustworthy software development, with constraints of process cost and duration. The results show that risk management is critical to improve trustworthiness but risk management is an effective complement, rather than the most basic process, to improve the trustworthiness of software. The proposal to use Bayesian networks as a framework for reliability analysis has given rise to a research trend comparable with classical reliability formalism and Bayesian networks. Bayesian networks have been used as an important tool to utilize different information, including probabilistic or deterministic information of complex
relationships among variables. They constitute an appropriate research framework which is easy to use in interaction with experts, as well as in the reliability field [98]. In specific, significant research interest exists in the use of Bayesian networks models for software system reliability assessment and software engineering risk or quality prediction [99], [100], [101].

5.2 RISKS IN SOFTWARE DEVELOPMENT

Risk in Software development project is defined as the product of the risk factor surrounding a software development project and the impact associated with failure. The factors which threaten the success of software development are the cause of emerging uncertainty surrounding a software development project. These factors are known as “risk factors” which affects the effective completion of a development project. There are many risks in software development process.

Figure 5.1: Types of risks
5.2.1 Schedule Risk

The risk associated with the uncertainty in implementing the tasks as per schedule comes under this. These risks have severe effects on the economy and may lead to failure. Schedules often slip due to following reasons:

- Inaccurate time estimation
- Less resource (staff, systems, skills of individuals etc.) tracking capability.
- Less capacity to identify complex functionalities

5.2.2 Budget Risk

Risk associated with the budget of the project,

- Inexact budget estimation.
- Expanding project scope in irregular manner

5.2.3 Operational Risk

Risks occurred due to inappropriate process implementation. Causes of operational risks:

- Improper prioritization
- Lack of responsibilities
- Inadequate resources
- Lack of communication in team.

5.2.4 Technical Risk

Risks associated with the technical implementation of the project. Causes of technical risks are:

- changing the requirements continuously
- Lack of update in technology.
- Complex operations involved.
5.3 PROGRAMMATIC RISK

External risks beyond the operational limits. These external events can be:

- Lack of fund
- Dynamic changes in policy and priority
- Dynamics in government rule

Various aspects of human being involved and its impact in a software development process are termed as human factors. The human factor is the element which is responsible for the effective team formation in the development process. People have many choices set targets in life by considering different options what they have. These choices will be influenced by the psychological factors. This will be useful for modelling the human factors in risk management.

5.3.1 Necessity of Risk Management

Minimizing project risks is important in software development process. Investigation on risk management in software development has especially concentrated on forming instructions for different tasks. It helps to avoid project failure due to improper schedule, budget constraints and dissatisfaction of customer expectations. Risk management handles the project in the aspect of risk identification and rectification in order to develop control measures [102]. Rectification may not mean abandoning the task that involves risk. The tasks which are rated as high risk tasks are essential to register the uniqueness of the product over other competitive products in the market. The main motivation of risk management is to identify all possible risks associated with that project, evaluate their severity, and impacts, and then to decide control actions. Minimizing unpredicted issues which are arising during the course of the project is the main idea behind risk management. Improper planning in risk control may lead to tempestuous completion of the project. Software development, risk management involves in the process which is used to derive the preventative strategy in order to complete the project within the specified limit of time and money. It may lead to reduce project cost and time required to complete the project and to increase the quality of the product. Improper risk management may lead to loss of revenue and
customer satisfaction which causes negative impact on the product. Once the risk factors are successfully recognized and evaluated, the next step is to control the risk.

5.4 HUMAN RESOURCE FACTORS IN RISK MANAGEMENT

Every industry is involved with software area which provides automation in real time applications in an efficient manner. So there is a need to develop trustworthy software for various fields. Software development is the process which is based on human based intellectual activity. During implementation, various issues, especially issues related to appropriate representation of developers participating in the development processes may occur. As well-known software development is a human-centered process, the process and the performance are influenced by human factors. Effect of human factors in the development process may be customer oriented (influencing the software development market) or developer oriented i.e. (Influencing the development process) and finally having a distinguishable impact on success by being a manager.

Human factors associated with the development process can be viewed from different aspects such as psychological, cognitive, management and technical. Different human factors may influence different levels of impact in the process and it may vary from organization to the individual. Even though human factors have specific importance in software development, it should not be overlooked in the risk management process which may lead to improper assessment. So there is a need to identify and describe the human factors in an efficient manner to avoid the potential losses associated with the risk. In the following sections we are going to see the factors which are noticeable with respect to software development. In the following we discuss those factors which appear to be the most important with respect to software development.

5.4.1 Productivity

Persons involved in the development process can be represented in terms of their productivity. Productivity can be explained as the amount of output per unit of input. Time required to complete the process can be derived from the relationship between person’s productivity and time taken by the person. Personal productivity of a person will vary according to the time. In order to fix the productivity of a person,
productivity of a person over a long time period should be taken into consideration. Otherwise it leads improper assessment.

5.4.2 Skills, Experiences and Learning

Individual experiences and skills have strong influence on the personal productivity. Skill can be defined as the ability of a person to a task. Skills can be categorized based on domains and the phase of its production. Phase of production deals with the stages of development process such as designing, coding, testing. And also experience plays an important role in productivity. Experience will help to handle uncertainty arising during the development process. So the experience has a significant influence on the process of solving the problems. From experience, one can develop his/her skills. So experience is the basement to develop skills. This approach is also known as learning by doing. Doubling the experience productivity can be increased in an efficient manner.

Learning plays an important role in developing the skill. Applying the learned tricks in real time application turns into experience. Applying the learned tricks in an efficient manner will lead to a way to develop our skills. Learning capacity is the key factor to introduce changes in the product. By learning new technologies, one can incorporate the advancement in the existing product. Integrating new technologies in the product will use to enhance the uniqueness of a product. Customer satisfaction can be provided by doing this. Learning capability of a person is directly proportional to the productivity of that person.

5.4.3 Emotional Factors

Experience deals with long term positive influence on the process associated with the development. In the process of development there may be short term fluctuations which will lead to a serious problem. Negative emotions are the key factors which are indirectly proportional to the productivity. Variety emotions related with the human are enjoyment, hope, relief, pride, gratitude, boredom, anxiety, or disappointment. Negative emotions will lead to a negative impact on the productivity. Emotions can be influenced by the task, Possibility of doing and other characteristics according to the situation. With respect to boredom, it may lead to reduce self-motivation, involving in various activities which in turn reduce the quality and performance of the product.
Internal motivation is associated with the thinking of person about the work or project. It cannot be compensated with the extra hours working. It may lead to failure of the project in unpredicted manner.

There is a contradictory mediator in emotions. For example, anxiety may increase the exterior motivation although there is a chance of blocking the activities of a person. Contradictory mediator will produce significant impacts on the product according to the situation. In order to avoid failure due to lack of intrinsic motivation, leadership quality of the team head should be high. Leadership quality should deal with decentralizing the work among team members, increasing intrinsic motivation among team members, perfect scheduling of task, punctuality, appraising the activities of team members, Proper communication with the members. Partiality influences the leadership style in negative manner. Stress can be defined as the factor related to disturbing perception. The causes of stress can be workload, misunderstanding, etc. If the person is not recognized for his/her work, it will lead a person in negative manner which reduces his/her intrinsic motivation and thus in turn become the key factor for stress.

5.4.4 Entity Factors

Interpersonal relationships can be categorized into two categories. First category deals with the social relationship such as coordination between the team members, communication between the members, leadership style, and horizontal coordination. This type of interpersonal relationship will be considered as official one. Second category is deals with personal relationship between the team members and this will be considered as informal. Team cohesion will be achieved if there is job satisfaction and well group atmosphere. Good team cohesion will lead to improved productivity. Team cohesion can achieved with the help of good leadership quality.

Coming to the size of the team, separation of team members should be done in a conditional manner. Because smaller team size will lead to a reduction in self-motivation among team members and larger team size will lead to reduce proper communication and allocation of work. Proper communication between the team members is an important key factor to complete the project successfully. Improper communication will lead to a reduction in quality of the product. Culture is also a
significant factor in risk management which influences the productivity. Persons from different countries, states, and districts may be present in a team. Cultural diversity leads to the influence of different languages in the process. Different languages may affect the system performance because of improper communication.

5.5 PROPOSED METHODOLOGY

Trustworthiness of software is an important key factor to satisfy the customer expectations. Trustworthiness of a product depends upon the risk management involved in the various stages of process. Risk associated with the development may lead to decline in trustworthiness. The software process network model can be constructed based on the following processes: Planning, Requirement, Design, Development, Testing and Implementation. Risk can be occurred during any of these processes. Risk involved in these stages may have different types of impact on the product. According to that trustworthiness of the product will vary.

In this study risk factor deals with the uncertainty associated with the human factors which involved in the software development process. There are many human factors involved in the software development process such as psychological factors, skills, learning capacity of a person, productivity of a person, leadership quality of a person, Experience of a person etc. These factors have different levels of impact on the outcome of a project. So there is a need weigh the factors according to its impact on the product.

If the entire factor’s impact is considered equally while evaluating the risk, it may lead to improper risk assessment. Bayesian network model based risk assessment is introduced in this paper. Different types of human factors have different probability of risk on the product. So in order to estimate trustworthiness of a product there is a need to calculate joint probability of all human factors on the product.

5.5.1 Bayesian Network

Probabilistic reasoning is important in artificial intelligence. In this study, Bayesian network dealing with probabilities is introduced for the purpose of evaluating trust worthiness.
Graphical models for reasoning under uncertainty condition can be implemented using Bayesian network in which nodes represent variables and arcs represent a direct connection between them. Quantitative strength of the connections between variables in a Bayesian network model should update the probabilistic beliefs about them as new information becomes available. Bayesian network model is also known as belief network, direct acyclic graphical model which represents a set of random variables and their conditional dependencies.

In this thesis Bayesian network is used to calculate the risk value of different factors in different stages of development. Nodes in the Bayesian network may represent observable quantities, latent variables, unknown parameters or hypotheses. Arc between the nodes which is also known as edges represent conditional dependencies. Nodes which are not connected with arc represent the variables that are conditionally independent of each other. Nodes connected with arcs represent the dependence between the nodes. Probability function associated with the nodes takes a particular set of values of the node’s parent variables as input and provides the probability of the variable represented by the node as output. Probabilistic queries about the variables and their relationships can be answered by the Bayesian network model [104]. The network can be used to evaluate the updated knowledge of the state of a subset variable when other variables related to the subset variables are observed. This process of computing the posterior distribution of variables is known as
probabilistic inference. This posterior distribution provides sufficient statistic for detection applications, where the probability of decision error should be minimized. Complex problems can be solved by a Bayesian network. Bayesian network representation is considered as a joint probability distribution representation. The structure of the problem which is being modelled can be captured with a Bayesian network.

Bayesian inference obtains the posterior probability as a consequence of two antecedents, a prior probability and a "likelihood function" obtained from a statistical model for the observed data. Bayesian inference enumerates the posterior probability according to Baye’s theorem:

\[
P(HY|EV) = \frac{P(EV|HY)P(H)}{P(EV)} \quad \text{………………….. (5.1)}
\]

Where, \(P(HY|EV)\) represents a conditional probability. \(HY\) stands for any hypothesis whose probability may be affected by the data. The evidence \(EV\) corresponds to new data that were not used in computing the prior probability. \(P(HY)\), the prior probability, is the probability of \(HY\) before \(EV\) is observed.

This indicates one's previous estimate of the probability that a hypothesis is true, before gaining the current evidence. \(P(HY|EV)\), the posterior probability, is the probability of \(HY\) given \(EV\), i.e., after \(EV\) is observed. The probability of a hypothesis given the observed evidence should be known. \(P(EV|HY)\) is the probability of observing \(EY\) given \(HY\). As a function of \(HY\) with \(EV\) fixed, this is the likelihood. The likelihood function should not be confused with \(P(HY|EV)\) as a function of \(HY\) rather than of \(EV\). It indicates the compatibility of the evidence with the given hypothesis.

Sometimes \(P(EV)\) is called the marginal likelihood or model evidence. This factor is the same for all possible hypotheses being considered. This means that this factor does not enter into determining the relative probabilities of different hypotheses. For different values of \(HY\), only the factors \(P(HY)\) and \(P(EV|HY)\) affect the value of \(P(HY|EV)\). As both of these factors appear in the numerator, the posterior probability is proportional to both. More precisely the posterior probability of a
hypothesis is determined by a combination of the inherent likeliness of a hypothesis and the compatibility of the observed evidence with the hypothesis. More concisely, posterior is proportional to likelihood times prior.

Bayes' rule can also be written as follows:

\[ P(HY|EV) = \frac{P(EV|HY)P(HY)}{P(EV)} \]  

(5.2)

Where, the factor \( \frac{P(EV|HY)}{P(EV)} \) represents the impact of \( EV \) on the probability of \( HY \).

### 5.5.2 Bayesian Network Based Risk Assessment

Risk is defined as the product of probability of risk occurrence and impact of risk on the product [105]. Probability of risk occurrence can be calculated using Bayesian network model. Probability of risk occurrence is the product of experimental impact value calculated from Bayesian network and risk identification weighing function in the aspect of cost, time, CMMI.

It can be expressed as,

\[ P = P_{ij} \cdot RI_j = P_{ij}^* \cdot f(Cost_j, Time_j, CMMI) \]  

(5.3)

Where \( P_{ij} \) represents the probability of risk occurrence, \( RI_j \) is the risk identification effectiveness, \( P_{ij}^* \) is the experimental value calculated from Bayesian network impact of risk factor can be defined in terms of impact of sub deliverables in sub process which is defined as the product of experimental impact value calculated from Bayesian network and risk control weighing function based on time, cost, CMMI. Impact of risk factor can be expressed as,

\[ I_{ij} = I_{ij}^* \cdot RC_j = I_{ij}^* \cdot f^2(Cost_j, Time_j, CMMI) \]  

(5.4)

Where \( I_{ij} \) represents the impact of risk, \( RC_j \) is the risk control effectiveness, \( I_{ij}^* \) is the experimental value calculated from Bayesian network. The occurrence of risk \( R_{ij} \) can be expressed as,

\[ R_{ij} \sim B(j, P_{ij}) \]  

(5.5)
Total risk can estimated as follows:

$$E_{tot,j} = \sum_{i=1}^{n}(R_{ij}.I_{ij}) = \sum_{i=1}^{n}(R_{ij}.RI_{j}(Cost, Time, CMMI). I_{ij}.RC_{j}(Cost, Time, CMMI).$$


(5.6)

Trustworthiness affected by the process risk can be expressed as,

$$T_{Risk} = (T_{1}, ..., T_{5})_{1 \times 5}.W_{5 \times 1} = (E_{tot,1}, ..., E_{tot,6})_{1 \times 6}. \begin{pmatrix} IM_{1,1} & ... & IM_{1,5} \\ ... & ... & ... \\ IM_{6,1} & ... & IM_{6,5} \end{pmatrix}_{6 \times 5}. \begin{pmatrix} \omega_{1} \\ \vdots \\ \omega_{5} \end{pmatrix}_{5 \times 1}$$


(5.7)

Where, impact element $IM_{m,n}$ indicates the level of the $m^{th}$ sub-deliverable’s impact on the $n^{th}$ trustworthiness attribute.

Trustworthiness can be affected by process quality and risk factors associated with the development process. Trustworthiness should be evaluated by considering both process quality and risk factors. Process quality can be expressed as,

$$T_{PQ} = f^{P}(Cost, Time, CMMI)$$


(5.8)

Trustworthiness can be evaluated from the difference between trustworthiness affected by process quality and risk reduction.

$$T = T_{PQ} - T_{Risk}$$


(5.9)

Thus the constraints considered to calculate trustworthiness of a product leads to provide effective risk management process. In our study Human resource based risk is the key factor behind the risk management process. Better risk management process involved in the development process helps to avoid complete cancellation of a product and will lead to register the uniqueness in the market.
5.6 RESULT AND DISCUSSION

The proposed measurement model is simulated to analyse software process risk under different circumstances and levels of risk occurrence. In addition, risk process management model is utilized to optimize risk management expenditure. According to the proposed methodology, a program is developed to simulate a risk management in software development processes. A conceptual Bayesian network was built based on the risk factors during the whole process. Final trustworthiness depends on the influence of risk factors in each process deliverables. Different factors involved in software development process such as psychological factors, skill, learning capacity, experience, team coherence and co-ordination breakdowns. Different stages involved in software development process include Planning, requirement, design, development, testing, and implementation. According to these details Bayesian network is created and probability of risk occurrence is evaluated. Bayesian network is used to calculate the joint probability distribution. In order to calculate the joint probability distribution, individual probability should be defined. Table 5.1 represents the predefined risk factors value according to different stages of development. Table 5.2 represents the predefined impact value according to different factors in different stages of development. By using these predefined values joint probability is evaluated using Bayesian formula.

Table 5.1: Predefined risk factor probability in different stages of development

<table>
<thead>
<tr>
<th>Human Risk Factors</th>
<th>Planning</th>
<th>Requirement</th>
<th>Design</th>
<th>Development</th>
<th>Testing</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psychological factor</td>
<td>0.6</td>
<td>0.7</td>
<td>0.95</td>
<td>0.9</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Skill</td>
<td>0.8</td>
<td>0.7</td>
<td>0.95</td>
<td>0.9</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Learning</td>
<td>0.5</td>
<td>0.6</td>
<td>0.95</td>
<td>0.85</td>
<td>0.75</td>
<td>0.6</td>
</tr>
<tr>
<td>Experience</td>
<td>0.8</td>
<td>0.7</td>
<td>0.95</td>
<td>0.8</td>
<td>0.75</td>
<td>0.7</td>
</tr>
<tr>
<td>Team coherence</td>
<td>0.7</td>
<td>0.6</td>
<td>0.75</td>
<td>0.9</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Co-ordination – Breakdown</td>
<td>0.9</td>
<td>0.7</td>
<td>0.9</td>
<td>0.9</td>
<td>0.7</td>
<td>0.9</td>
</tr>
</tbody>
</table>
For example joint probability of learning factor in development stage is calculated based on the details such as predefined individual probability of learning factor in development stage, joint probability of skill factor based on the details such as predefined individual probability of learning factor in the development stage, joint probability of the skill factor in the development stage with respect to planning, joint probability of the skill factor in the development stage with respect to the requirement, joint probability of the skill factor in the development stage with respect to the design.

Table 5.2: Predefined impact value in different stages of development

<table>
<thead>
<tr>
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<td>0.75</td>
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<td>0.75</td>
<td>0.9</td>
<td></td>
</tr>
</tbody>
</table>

Thus our proposed performs accurately in the process of risk probability calculation. In order to calculate the total risk associated with the development process there is a need to know the impact matrix. Table 6.3 shows the probability of impact on the different quality of deliverables.
Table 5.3: Risk impact matrix

<table>
<thead>
<tr>
<th>Human Risk Factors</th>
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<th>Development</th>
<th>Testing</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability</td>
<td>0.102</td>
<td>0.104</td>
<td>0.023</td>
<td>0.028</td>
<td>0.105</td>
<td>0.102</td>
</tr>
<tr>
<td>Data security</td>
<td>0.200</td>
<td>0.209</td>
<td>0.186</td>
<td>0.102</td>
<td>0.116</td>
<td>0.200</td>
</tr>
<tr>
<td>Quality</td>
<td>0.290</td>
<td>0.284</td>
<td>0.387</td>
<td>0.287</td>
<td>0.202</td>
<td>0.290</td>
</tr>
<tr>
<td>Privacy</td>
<td>0.196</td>
<td>0.111</td>
<td>0.204</td>
<td>0.273</td>
<td>0.202</td>
<td>0.196</td>
</tr>
<tr>
<td>Safety</td>
<td>0.197</td>
<td>0.187</td>
<td>0.108</td>
<td>0.192</td>
<td>0.095</td>
<td>0.197</td>
</tr>
</tbody>
</table>

Figure 5.3: The parameters to be given to the Bayesian network as inputs
Figure 5.4: Joint probability distribution of different risk factors in different stages of software development

Figure 5.5: Probability distribution of impact factors in different stages of software development
Figure 5.6: Total risk in different stages of software development process

Figure 5.7: Risk involved in the development process
5.7 CONCLUSION

In this analysis, we have proposed Bayesian based risk assessment in software development process in which additional risk factors associated with human resource are included. The proposed system first identifies the risk factors associated with human resource. There are many risk factors associated with human resource. Each of these risk factors are weighed and taken in account to evaluate the risk associated with the development process. Bayesian based risk assessment process model is introduced in this work. Risk control techniques are applied to the problem identified in the evaluation stage. Risk managerial techniques, Configuration management techniques are the important resolution techniques in the distributed software system. The proposed risk assessment technique performs better because the factors considered to evaluate the risk have great influence on the productivity of the system.