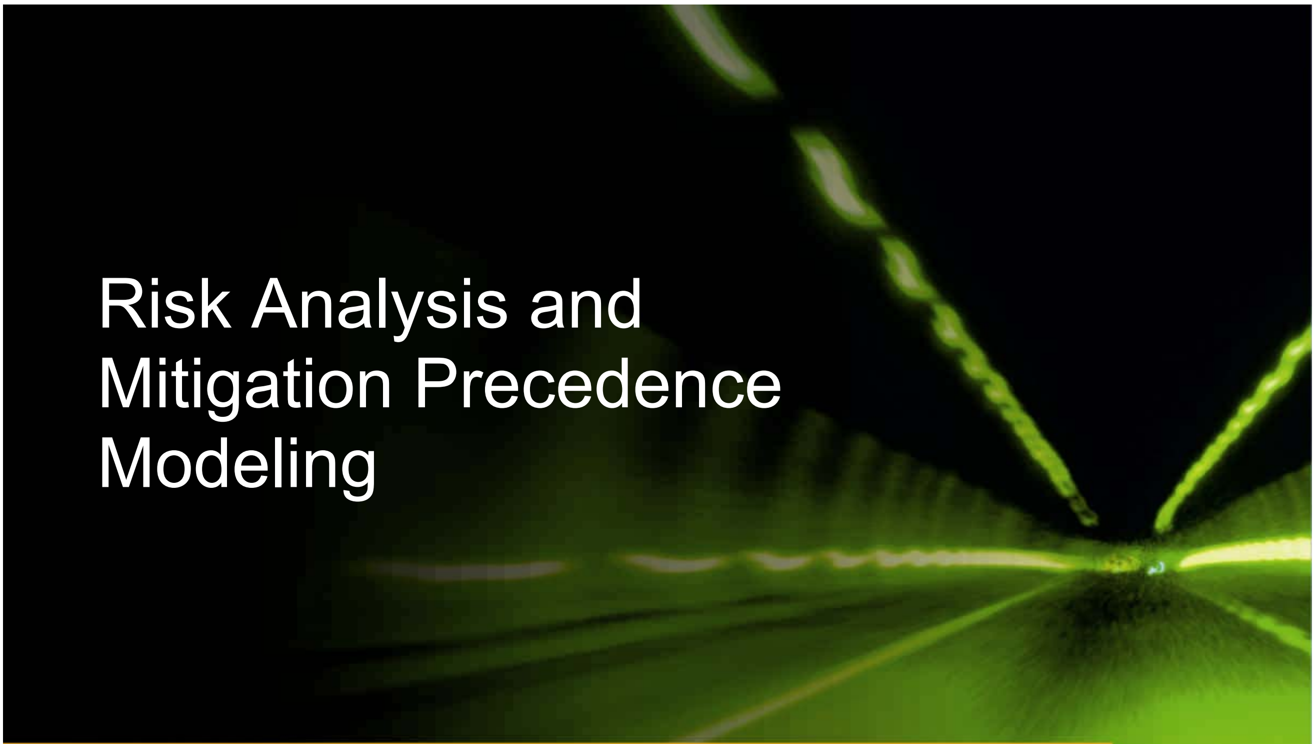

Risk Analysis and Mitigation Precedence Modeling

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Leveraging project management for excellence, growth and transformation

Contents

1.1 Abstract:

Risk analysis is crucial process in project management. Present risk analysis models analyze risks independently and are static. That is, current models don't account for the effect of one risk on another and don't predict how the risks might behave in future. This model introduces the concept of risk dependencies with a mathematical model which makes risk analysis sophisticated and futuristic.

Index Terms: **RIF, Risk Dependency, Contribution factor, Alone mitigation factor, Total Mitigation factor and Risk Exposure.**

1.2 Introduction

The term risk has its own meaning and perspective in different processes. In the present scenario risks can also be viewed as an opportunity to gain competitive advantage. Thus based on this insight risk can be defined as "A probable event which has potential negative or positive impact on the business process or project objective".

This paper proposes an integrated approach to risk analysis process which is more planned, opportunistic and robust. The proposed risk analysis model concentrates on risk analysis part of risk management process and offers a logically structured way to quantify and mitigate risk. This article is organized as follows:

a) Risk Influence Factor, which deals with vulnerability of system with respect to external factors.

b) Risk Network Generation, is divided into two parts: What-If and Why Analysis which is risk discovery process and Risk Dependency Analysis which is actual process of Risk Network Generation.

c) Risk Prioritization, in this phase each node in the risk network is analyzed based on cost time benefit and time priority associated with it.

d) Risk dependency analysis, in this phase, each risk inside top priority groups will be analyzed and prioritized based on the mitigation factors.

e) Mitigation Analysis, which signifies mitigation effort variation with respect to time.

1.3 Risk Influnce Factor Analysis

Risk Influence Factor [1] *(RIF)* signifies all the factors are influencing a risk category as per the present condition under which project is undertaken. It plays a significant role in estimating the basic dimensions of a risk in terms of probability of risk's occurrences. RIF's analysis can be best represented by Bayesian Networks [3] in which each RIF represents a parent node to a risk node which is identified. For instance suppose a risk of Human Resource (HR) category is identified in a project, before estimating its impact and probability of occurrence, all RIFs should be mapped with respect to time of occurrence of the upcoming risk. Salary, Place of Joining and motivation for higher studies, Opportunities within project/Company can be some RIFs which can influence a risk of HR category. A general statement can be put forward "The more influential are RIFs for a risk category, the more chances of risk to happen in that category and impact depends upon the current phase of project". Thus RIFs portray a basic picture of risks which is helpful in estimating the parameters like probability of risk occurrence. The formula to calculate probability of occurrence of a risk node is:

$$P(R) = P(R|\ PA(R_{RIF}) \quad (1)$$

Where $PA(R_{RIF})$ represents all the RIF acting on the risk of particular category

1.4 Risk Netwok Generation

All Risk model is based on the subjective notion of probability and assumptions. Therefore, this model is based on the following assumptions:

a. The exposure of a risk E(R) is a function of time(t) and mitigation effort(M), mathematically it can be expressed as :

$$E(R_i) = f(t,M)$$

Variation of risk exposure on time can be realized when mitigation effort (M) $\approx$ 0 which

results in three possible scenarios:

i. $E(R_i)$ is directly proportional to t; with the increase in time risk exposure increases.

ii. $E(R_i)$ is inversely proportional to t; with the increase in time risk exposure decreases.

iii. $E(R_i)$ is independent to t; Risk Exposure remains unaffected by time.

Note: The proposed risk analysis model deals with the scenario where Risk Exposure is directly dependent on time (Scenario i).

A. Risk Discovery

Risk discovery is an important activity in risk analysis process which applies to all phases of the project. The process of risk discovery has to be revisited periodically and its frequency depends on project health.

Apart from the standard process, two variants will be covered in detail:

a. What-If and Why analysis

b. Risk Dependency Analysis

1. What If And Why Analysis

This approach takes input as "What-If" scenario for each risk category in the project and then answer "Why" for the "What-If". That is, "What-If" identifies the potential fault points in the projects and the answer to the question "Why" provides proper validation and authentication for the risk (fault-points) discovered. The scenario in a typical project which is discussed below makes "What-If" understanding more clear:

"What-If": Requirement Change (Risk Category: Client) *"Why":* Requirement document is not clear enough.

"What-If": Too less design Engineers. (Risk Category: Human Resource) *"Why":* The coming project is to be built on new design tool.

Here in both above scenarios, it is evident that "What-If" & "Why" scenario helps us to discover & identify new risks like "Requirement Change" and "Too less design Engineers". It can be observed that "Why" itself recursively generates potential risks like "New design tool" from second scenario or "Lack of proper communication between onsite and offshore team" from first scenario. Therefore, the "What-If" & "Why" scenario should be recursively executed till "Why" does not regenerate any more risks. Hence, the process of Risk discovery and identification is explained in the figure 1.1 below:

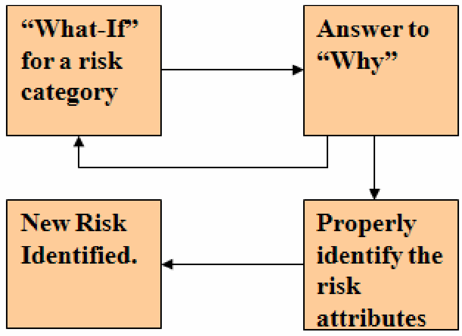


Fig 1.1: Risk Identification process based on "What-If and Why" Analysis

B. Risk Dependency Analysis

Risk dependency analysis is fundamental activity in the proposed model. The idea behind the risk dependency derived from an old proverb "Problem does not come alone.", that is, if the individual problem is scrutinized then lot of small and big problems can be identified that are attached to a given problem. Likewise, the risk should not be treated as individual entity as it is perceived in the current project risk models rather it should be perceived as the related entities which overall influences the decision making process in mitigating the risk. This model identifies the dependencies between the risks and analyses risks based on the identified relationship(s). We will here discuss an algorithm which builds risk network based on the risks identified by "What-If & Why Analysis" described above.

Algorithm 1: Generating Risk Network

INPUT: Risk set R identified through "What-If & Why Analysis" process, that is, R = {R1, R2, R3…. Rn)

For each risk element R_x belonging risk category C_m;

1. In same category C_m, identify risk R_y which may affect R_x.

If (R_y does not belong to risk set R, validate it through "What-If &Why Analysis");

Add R_y to risk set R.

If (No edges are present between R_x and R_y and

If R_x is largely affected by R_y);

then the relationship structure would be:

$R_y \longrightarrow R_x$

If (No edges are present between R_x and R_y and R_x is largely affecting R_y,)

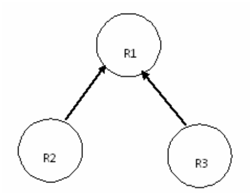
then the relationship structure would be:

$R_x \longrightarrow R_y$

2. Follow the same process as step 1 for R_x for risk categories other than C_m

End: When the whole risk set relationship analysis is done.

The algorithm1 discovers new risks which are validated through "What-If & Why Analysis" and builds risk network of all the risk. To elaborate the Risk dependency analysis in detail, consider a generic example in which R1, R2, R3, R4 and R5 are identified in the risk discovery phase. For each risk discovered, for example, R1 is taken first and it was observed that R2, R5 (belonging to same category of R1) and R3 (belonging to different category from R1) risk influences R1. This can be graphically put like:



R2 risk is affected by R4 and R5. R3 is affected by R5 and R6 (New risk found in process of analyzing dependency). R6 risk affects R3 and R5. Thus the risk network tree will assume the shape as:

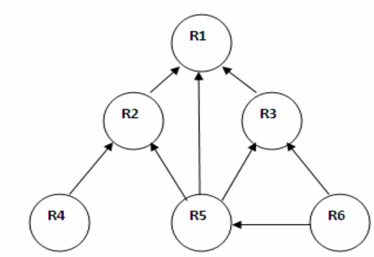


Fig 3.4: Risk network tree based on above assumption

Thus mathematically risk dependency can be viewed as partially connected graph defined by G=(V,E), where V={Ri : i ɛ N and R is the all risk discovered}, that is they are risk nodes discovered which is represented as circle with the risk name along with risk attributes like risk category, risk exposure, time for mitigation, total mitigation factor. All these attributes will be discussed later in the paper. E={ Ri ← Rj ; Rj is affecting Ri with dependency factor Cji }, that is, they are the edges which connects two dependent risk with some dependency factor Cji. The risk network which is obtained is a directed acyclic graph (DAG) which inherits Bayesian characteristics. [2]

The risk dependency analysis can help in identifying new risks. Suppose in a critical project, it was identified that customer involvement is minimal in a project. Hence, it can be identified as a potential risk. If it is identified as a risk, then from the below discussion we will see how the risk dependency process helps us to identify some new risks based on this risk.

Parent Risk: Minimal Customer Involvement

Risk Category: Customer category

The process of risk dependency is for new risk discovery is as follows:

Step 1: Identify child risk that can add strength to parent risk within the parent *category.*

After analyzing the various factor in the customer domain. It can be inferred that customer acceptance could be potential risk as they might not acceptance the design, because of the reason that their participation was minimal.

Step 2: Identify the risks of other categories that may after the parent risk. It could be:

Project specific factor:

Requirement changes

There is maximum chance that the requirement of customer may change which is due to the parent risk.

Quality category:

Quality Commitment

If the customer involvement is minimal then there are chances that it might affect the overall quality of the product as expected by customer.

These new identified risks should be validated through WHAT IF AND WHY analysis before considering them as a risk. Thus risk dependency identification might help us in identifying new potential risk. Again the above example is just a demonstration; conditions may differ from project to projects. For example in some projects there might not be any problem if the customer involvement is low. Therefore in those projects there is no question of analyzing this further. Here it can be inferred that risk is very subjective concept which assumes different meaning in different context. It should be viewed relatively than absolutely as it is done is current model.

The question is how to define the dependency factor (how much child risk contributes parent in terms of impact) of child risk. This will be followed in more detail in the following section.

a) RISK DEPENDENCY FACTOR

Risk dependency factor signifies how much the child risk contributes to the parent risk on project.

Consider a generic example in which two risks are connected with dependency factor $_{Cmn}$ as shown below in figure:

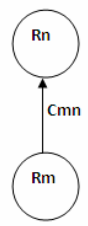


Fig: 3.5: Risk dependency between two risks.

Here in Fig 3.5, arrow from R_m to R_n denotes direction of impact of risk R_m over its parent R_n which is denoted by C_{mn}. The value of C_{mn} can be calculated as follows:

$C_{mn} = (P(R_n| R_m)) * (I(R_m) / (I(R_n) + I(R_m)))$ (2)

Where, $P(R_n| R_m)$ represents conditional probability of R_n (Child Risk) risk when R_m (Parent Risk) has already occurred and $(I(R_m) / (I(R_n) + I(R_m))$ represents the contribution of parent risk impact over child risk.

It can be figured out that for strong dependencies, the probabilities of occurrence of child risk shows high degree of correlation with parent risk. That is, if there is high probability of occurrence parent risk then there will be high chances of child risk to happen when connected via strong dependency relationship.

Thus co-relation helps us to estimate and validate the probability of occurrence.

1.5 Risk Proritization

After the risk is discovered and its attributes are defined, the next step is to prioritize the risk. Unlike the current model, this model makes use of the current assumption described in paper. Hence, this model does not take impact as prime factor to prioritize the risk rather it takes other factors to churn out the opportunity factor associated with the risk.

In this model risk is prioritized based on the three parameters:

a. Risk Exposure.

b. Mitigation Exposure.

c. Risk dependency analysis.

1. RISK EXPOSURE ANALYSIS

   In this phase of risk analysis, risk exposure is calculated which signifies how much a process is exposed to a given risk. This is calculated by simple formula:

   RE (R) =Impact * probability of occurrence (3)

   Here, Impact of a risk on project must be analyzed based on the effect of a risk on project goals. Therefore, for each project goal impact should be graded on scale of 1-10. And the final impact of risk will be:

   $Impact(Ri) =\sum Impact(ProjectGoals)/\sum j$ (4)

Here, $\sum$ Impact (Project Goals) is summation of impact on all project goals for a risk Ri. and $\sum j$ is total number of project goals identified in a project. Thus Impact of a risk is average of its impact on project goals. Probability of occurrence signifies the chance of occurrence of risk during project execution. It should be noted that while analyzing the risk dependency the Impact and probability of occurrence should satisfy the inequalities mentioned in Eq. 1.

2. MITIGATION EXPOSURE

   Mitigation Exposure signifies the amount of positivity gained in business process when a particular risk is mitigated to a large extent. Hence this factor in the risk analysis explores the opportunity angle of a particular risk. As the business process has major axis viz. time and cost, hence the Mitigation exposure takes these axes into account and formulates on the following factors:

a) Cost Benefit Factor

b) Time factor

Both the factors will be taken up in detail in following section.

a. COST BENEFIT FACTOR

This factor describes the relative cost benefit associated with the risk. It can be defined as follows:

CBF (R) = (1- (Cost of Mitigation/Amount on stake))*10 (5)

Whereas, *Amount on stake,* can be calculated through the schedule slippage which is standard followed in most of the software projects. Apart from this, when amount on stake cannot be directly computed from schedule slippage then amount of stake can be looked as the risk category fraction in the project cost that it carries away. It can be useful when the nature of risk is subjective, that is, there is no way to calculate the Amount on stake objectively. It can be calculated as:

Amount on Stake= Cost Impact Factor * Risk category share in project cost (6)

Whereas the Cost impact factor to be graded on scale of 1-10, this represents the impact of the risk on the risk category cost in project.

Cost Impact Factor	Factor Value
STRONG	0.7 to 1.0
MEDIUM	0.4 to 0.7
WEAK	0.1 to 0.4

Table 4.1: Showing Cost Impact Factor

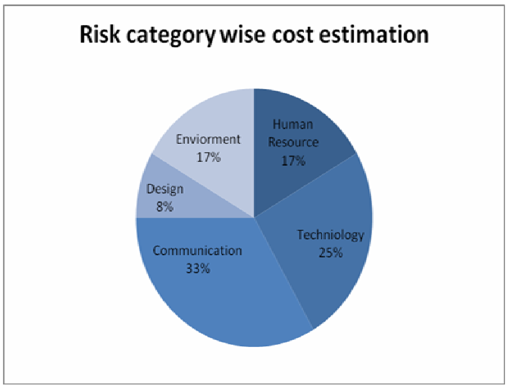


Fig 4.1: A hypothetical cost based categorization of risk category.

Suppose a hypothetical cost based categorization of risk category in a project as depicted in the Fig 4.1.Here we see the overall project cost is divided among the risk categories which are identified in the project, the amount on stake in the above equation is the relative share of the risk of a risk's category pie. Like suppose a risk in

HR category expected to occur then the amount of stake is the risk share in HR occupied pie.

The above pie share expected to be roughly completed in pre-project analysis depending on the requirements and SLAs and other business documents.

Cost of Mitigation is the total cost involved in mitigating the risk. It involves the both direct costs like Human resource utilization cost, software/hardware cost, Logistic utilization cost and hidden costs like penalty clause in SLA and others.

b. TIME FACTOR

This factor signifies the relative time factor associated with the risk. It is based on the assumption that risks which have higher time of mitigation should come low in mitigation. That is risk of near visibility of occurrence should be taken up against others. The time factor can be calculated as follows:

TF (R) = ETM/TTM (7)

Where,

a. Total time for mitigation (TTM) is the time period in working hrs from when the risk is identified till the time the given risk is expected to trigger.
b. Expected time for Mitigation (ETM) is the time required to mitigate the risk to a large extent.

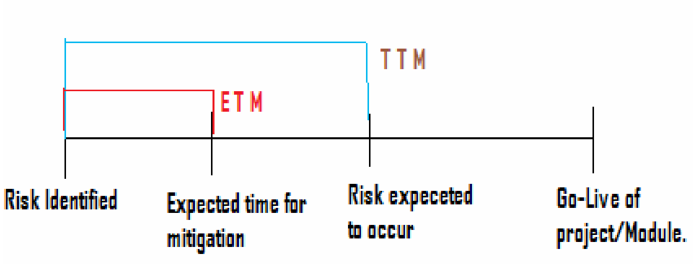


Fig 4.2: Depicting ETM and TTM in time analysis

It should be noted that for constant risk which does not varies with the time should be given constant value for the above ratio analyzing the above part.

After having all the above analysis, the alone mitigation strength which signifies the drive for mitigating particular risk, can be calculated as follows:

AMF(R) = RE (R) * ME (R) (8)

Where mitigation exposure of risk R can be calculated as ME(R) = (CBF(R) + TF (R)) / 2 (9)

1.6 Risk Dependency Analysis

This manuscript talk of collectivism in risk mitigation is talked than the individualism, that is, risks are viewed as related entities rather than with respect to risk mitigation analyzed. Therefore it will show how these dependencies affect in decision for mitigating the risk. Assume that C_{ji} denotes the dependency factor of $risk_J$ on $risk_i$.

Total Mitigation Exposure factor (TMF) denotes overall the willingness to mitigate a risk. The Total Mitigation Exposure Factor for risk R_i can be calculated as follows:

TMF (Ri) = ∑ i ∑j (AMF(Ri) + TMF (Rj) * Cjj) (10)

Where riski and riskj are connected risks through dependency factor Cji. and j є R -> [1,n] ,i є R -> [j-1,n] where n is number of nodes in graph. The above formula takes each risk alone mitigation factor (AMF) into consideration and iterates though each child risk to calculate the total mitigation factor of a risk. That is, TMF is summation of alone mitigation factor of parent risk and the individual contribution of child risk towards the mitigation factor of parent risk.

Applying the formula (9) on the Figure 3.4 the Total Mitigation factor of each risk based on the above formula is:

a. $TMF(R_5)=AMF(R_5)$
b. $TMF(R_4)=AMF(R_4)$
c. $TMF(R_2)=AMF(R_2)+TMF(R_5)*C_{25} +TMF(R_4)*C_{24}$
d. $TMF(R_3)=AMF(R_3)+ TMF(R_4)*C_{34}$
e. $TMF(R_1)=AMF(R_1)+TMF(R_2)*C_{12}+ TMF(R_4)*C_{14}+ TMF(R_3)*C_{13}$

Where AMF is alone mitigation factor and TMF is Total mitigation factor of a risk.

Here for R_5 and R_4 AMF and TMF are same as there is no child risk is connected to it, that is, no risk is affecting its alone mitigation factor. Hence based on the TMF of each risk, each risk should be prioritized for mitigation.

1.7 Mitigation Analysis

Once all these factors are decided upon, risk can be extrapolated in future to visualize its behavior in future which can be defined though risk mitigation line. Hence risk mitigation line can help in planning business process in better way.

Risk Mitigation curve is defined by the simple linear equation:

$TMF\ (R_i) = S\ (R_i) * T_M + TMF\ (R_i)_o$ (11)

Where, $TMF\ (R_i)_o$: Initial Total Mitigation Factor of risk R_i and Expected time for mitigation (T_m) (ETM) and $S(R_i)$ represents slope of the line which is equal to

$(TMF(R_i)_{Minimal}-TMF(R_i)_o)/T_M$ (12)

Where $TMF\ (R_i)_{Minimal}$, which is shown by green line in fig 6.1, is the minimal value for $TMF\ (R_i)$ for which the risk can be accepted or no longer beneficial to mitigate it.

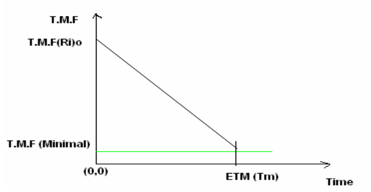


Fig: 6.1: Analysis of TMF with Time

The amount of mitigation can be calculated at a given instance will be{TMF$(R_i)_o$ -TMF $(R_i)_t$} / TMF $(R_i)_o$.

Thus the mitigation can follow any curve which depends on the mitigation strategy followed to mitigate that risk. Therefore, along with linear flavor of risk mitigation it can follow non-linear curves like logarithmic curve, which can be followed if the risk is falls in top priority category. For the sake of simplicity, linear curve is talked about.

Risks that do not vary with the time can be realized as a line parallel to the time axis, that is its TMF and Risk exposure does not changes with time.

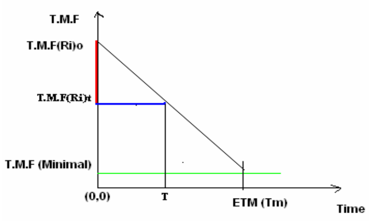


Fig: 6.2: Mitigation achieved after some time t

All other factors like C_{ij} follow the same equation with the above calculated slope. Hence at any given point of time the TMF of a risk can be predicted. Note that the value derived by this is not the actual value but it is an estimated value of that risk at that point of time. Hence actual TMF value at times can be in 3 regions of the above curve:

Below the line: If actual TMF value is below the line then, it can be followed that risk mitigation strategy is way above the expectations. Hence it is positive sign.

On the line: If actual TMF value is on the line then, it can be followed that risk mitigation strategy is at par the expectations.

Above the line: If actual TMF value is above the line then, it can be followed that risk mitigation strategy is below the expectations. Hence it is negative sign; something more in terms of effort should be put to mitigate the same.

Having the clear understanding of the above, we can graphically conclude which risk in the future will have what impact on business process at a given point of time. In the above figure, curve signifies the maximum actual value that can TMF of a risk can take up at any given point of time. Again this can be standardized for a particular process. TMF value above than this curve denotes that mitigation is not is not complying with the mitigation plan. One way to define that threshold curve mentioned above is to assume a circle having centre at

any point on the line and radius as a unit (1 or 2). The d/dx (tangent) on the diametric point defines the threshold region which will be parallel to the line defined by above equation.

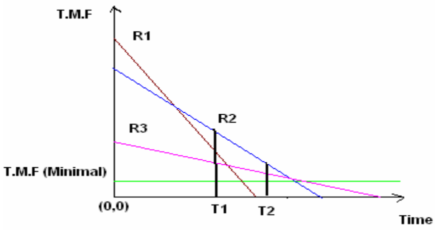


Fig 6.3: Plotting a set of risks in graph together

Now, considering all the risks together and plotting them together (Fig 6.3) will generate a picture how the risks are going to behave in future and thus we can estimate what all risk can come up as high priority. Here in the Fig 6.3, initially, that is at t=0, the order of risk priority was R1> R2 > R3. Then at t1 time according to graph the order of risk priority changed to R2 > R1 > R3. And finally at time t2, the order of priority took the shape like R2 > R3.Thus with this kind analysis the business process can be planned in more robust and sophisticated way.

1.8 Conclusion

The Integrated Risk Analysis Model enlists all the parameters that is used by existing Risk Analysis Models in software project management and introduces concept of risk dependency which came out to be beneficial and crucial factor in Risk Analysis. It is shown that how to identify the dependencies between risk and how it can be used in risk analysis through a series of mathematical formulations. Through a series of mathematical formulations, the risk behavior and amount of mitigation at any point of time can be predicted. Therefore it is robust and futuristic than the current models of risk analysis.

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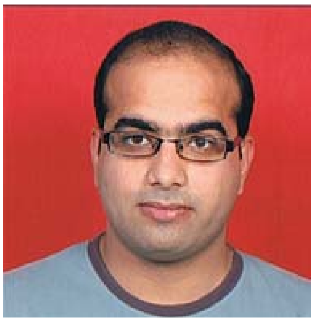
1.10 Author(s) Profile



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