TECHNIQUES USED IN RISK ANALYSIS OF SOFTWARE DEVELOPMENT

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Abstract: It has become increasingly evident with the rampant project failure that a proactive risk management strategy is a desirable means of preventing failure yet it is clear that Risk Management is not given the emphasis it deserves and further, a risk averse stance is prevalent. This paper reviews some of techniques used in software risk analysis, both quantitative techniques and qualitative techniques considering the appropriateness of each approach to specific scenarios and their limitations which may demystify the reasons surrounding the reluctance of project managers to adopting risk management strategies.

1. Introduction
A majority of software project managers rely on reactive risk management strategy, that is, merely reacting to risks as they occur. (Pressman, 1997). A considerably more intelligent strategy for risk management is to be proactive. A proactive strategy begins at the onset with the Risk Identification Phase, which involves identifying all potential risks to the project, which is, an input to the Risk Analysis phase which involves analysing the risks identified, to determine when, why and where they might occur, and the severity of these risks. The third stage is to implement Risk Reducing Measures depending on the degree of severity of the risks. For example if a particular aspect of a system is seen as high risk is crucial to the systems performance then that particular aspect can be given to more experienced programmers. The final stage is Risk Monitoring which ensures that the Risk Reducing Methods are in fact reducing risks. (Bandyopadhyay, 1999). This paper focuses on the second stage, namely, Risk Analysis, in particular, some of the various techniques applied at this stage.

2. Techniques used in Risk Analysis
Risk Assessment revolves around primarily determining the probability of a risk occurring and the impact of that risks and then ranking the risk in order of severity. The higher ranking risks are given more priority over lower ranking ones. (Ramamooorthy etal, 1993) The techniques using in Risk Assessment fall into basic categories, Qualitative or Quantitative techniques. Qualitative techniques employ descriptive, albeit subjective words to indicate the level of risk, examples include, survey questionnaires and the Delphi Technique. While Quantitative techniques use metrics in order to give a monetary value or a numerical value to indicate the level of risk, an example of such a technique would be the Risk Exposure metric. Further discussion is provided in the following sections.

2.1 Quantitative Techniques
Measurement in the field of software engineering has been largely ignored, while other disciplines like electrical engineering would have not evolved if it was not for measurements. There has been hundreds of software metrics developed over the last few years, but generally the metrics being employed are the ones, that easy to understand and simple to use. (Pighin & Zamolo, 1997). The need for software measurement arises of the software crisis, and it has been suggested that software production is out of control because of the lack of measurement controls and metrics is the only way to achieve objectivity. (Fenton, 1991)

There are two purposes of measurement. Firstly, for assessment, that is to keep track of a software project, these metrics are known as assessment metrics. Secondly prediction, that is to determine future characteristics of the software project, these are called predictive metrics (Pighin, Zamolo, 1997). As Risk Analysis is predominately about the future, predictive metrics are used to determine what is the probability of a risk occurring, and what loss would be incurred if such a loss were to occur but assessment metrics can be also used in the risk monitoring phase, to ensure that the risk action is functioning effectively.
Quantitative techniques in risk analysis, translate risk, into numbers and are mathematically or computationally based. These techniques provide often numerical probabilities or frequencies, or the consequences and likelihood of identified risks. The values used in these techniques are either obtained from historical databases or are estimates thus they still contain some extent of uncertainty, due to the possible use of subjectively attained values. (Baker, et al.,1998)

2.1.1 Risk Exposure
Because risk implies a potential loss, two elements of risk must be estimated: the probability that risk will become a problem and the effect the problem will have on the project’s desired outcome(Fairley,1994). One of the more common metrics used to determine the severity of a risk is Risk Exposure which is defined by the formula below:

\[
\text{Risk Exposure} = \text{Probability(UO)} \times \text{Loss(UO)}
\]

where Prob(UO) is the probability of an unsatisfactory outcome, and Loss(UO) is the loss to the parties affected if the outcome is unsatisfactory.

For example, suppose, the probability that the requirements will change is 0.3 and the cost of this impact is R50 000 then the Risk Exposure is R15000. It is evident that the risk exposure and probability can change over time, thus the project manager must keep contract track of it (Pfleeger,1998).

The notion of risk exposure can aid managers on reducing both the probability and the extent of the loss. For instance, if staff turnover is one of the risks a project faces, then the probability of such a risk occurring can be reduced by empowering exemplary performers. And the loss can be reduced by good configuration management to make it easier for new replacements to master existing software modules if the team members leave(Boehm & DeMarco,1997).

A fundamental risk analysis technique is the Decision Tree(Boehm,1991). Decision analysis is the examination of decisions by breaking them into the sequences of supporting decisions and the resulting uncertain occurrences. These sequences are represented by decision trees. The decision tree is a concept that combines two or more planning alternatives, their respective alternate outcomes and their probabilities into a single tree structure(Brockers,1995).The Risk Exposure metric in conjunction with the Decision Tree can be used to form a composed risk exposure, for instance for each scenario, there are, several possible outcomes. A combined risk exposure can be determined for each possible scenario. In the figure 1 below, the Risk exposure A is determined by multiplying the P(UO) and L(UO) for Outcome 1. Then the combined Risk exposure is determined by summing the risk exposure for each choice.

**Figure 1 : Decision Tree Analysis of risks related to several outcomes**

The risk exposure metric can be used to determine the degree of attention each risk should be given. The next stage would be determining what steps are needed to take control of the risks. To aid decision making about risk reduction, the cost of reducing the risk must be considered the Risk Leverage metric can be utilized. If the leverage value is not high enough to justify the action, then a less costly or a more effective reduction technique, should be considered. The Risk Leverage metric is defined as follows:

\[
\text{Risk Leverage} = \frac{(\text{Risk exposure before reduction} - \text{Risk exposure after reduction})}{\text{Cost of risk reduction}}
\]

The problem with Risk Exposure metric is attaining accurate estimates of the Probability and Loss factors. Estimates can be improved by prototyping, benchmarking, and simulation (Boehm,1991).

2.1.2 Module Risk
Sherer(1994) described methodology for assessing failure risk of individual modules using Module risk metric which is estimated as the product of the expected number failures resulting from faults in the module and the expected loss of a fault in the module which is expressed as follows:
\[ R^M(T) = N^M(T) \times L^M(T) \]  

(3)

where

\( L^M(T) \) is the expected magnitude of loss due to
faults in module M

\( N^M(T) \) expected number of failures during
operational time T

Expected loss of a Module M during
operational time T can be expressed as:

\[ L^M(T) = \sum_i p(U_i^M) \times \sum_j p(H_j/U_i^M) \times C_j(T) \]  

(4)

where

\( p(U_i^M) \) is the probability of use i for module M

\( p(H_j/U_i^M) \) is the probability that Hazard j
occurs when M has use i

\( C_j(T) \) the consequence of the hazard.

**Module Use Distribution** \( p(U_i^M) \)

A module may have more than one use, and
\( p(U_i^M) \) is the probability of \( U_i \) being invoked.

**Hazard Probability Distribution** \( p(H_j/U_i^M) \)

For each use of a module there are several
hazards. Consider use U1 having 3 hazards,
H1,H2,H3. The probability of H1 occurring for
U1 would be \( p(H_1/U_1^M) \)

**Consequence assessment** \( (C_j(T)) \)

For each hazard there is consequence, which is
assessed by weighing each scenario’s potential loss by its likelihood. Thus \( C_1(T) \) would be the consequence of H1 occurring.

### 2.2 Qualitative Techniques

Qualitative Techniques translate risk into
descriptive variables, and distinguishes the
possibility of a risk occurring in a linguistic
manner. Risk is described as “low” if that risk
is unlikely to occur. It is an analysis in relative
terms of the outcome and probability of a risk,
for example, a high risk compared to low risk.

This technique is highly dependent on
the experience of the analyst and thus highly
subjective and prone to inconsistencies.
(Baker, et al,1998) It is valuable as an
analytical process in the planning and control
of a project. Examples include, Scenario
Analysis, Fuzzy Metrics, and Questionnaires,
the Delphi Technique with qualitative
questions can be used here too(McGaughey,1994).

#### 2.2.1 Delphi Technique

The Delphi technique is a collaborative
technique for building consensus involving
independent analysis and voting by experts
given perfect Feedback as to how their
judgement matches that of the remainder of the
group as a whole. (McNamee,1999) The
Delphi technique uses a series of
questionnaires and summarized feedback
reports from preceding responses.

This approach is useful for generating and
clarifying ideas, reaching consensus,
prioritizing, and making decisions on
alternative actions. Since face-to-face
interaction is not a requirement, the Delphi
technique could be used with groups that
would not ordinarily meet together. The
Delphi technique relies upon expert judgement
but attempts to overcome the problems of
individual bias(Shedd,1995).

#### 2.2.2 Scenario Analysis

Scenario Analysis will acknowledge
uncertainties and highlight critical sources of
uncertainty. It will develop a range of possible
future scenarios and strategies, and
acknowledge when data becomes meaningless.
Scenario Analysis will NOT hide or remove
uncertainty, develop one solution, or obtain
unavailable market information. This approach
helps companies to be responsive to different
futures, but does not select a future(Molka-
Danielsen,1996).

The steps are as follows:
1) Discuss key uncertainties
2) Rank the environmental uncertainties.
3) Create future scenarios.
4) Try out the companies strategic
   choices under each future scenario.
   Actions can be classified as:
   - beneficial in all futures;
   - valuable in some futures, but not
     harmful in any;
   - valuable in some futures but harmful
     in others;
   - outcome in some futures is
     unacceptable;

A set of scenarios can be very useful for the
success of risk analysis but scenarios are
chosen in an ad hoc fashion, thus are usually
guided by the experience of domain experts.
Therefore, it is likely that some important
scenarios are overlooked, in complex
systems(Cukic etal,1998).

#### 2.2.3 Fuzzy Metrics

The risk assessment model employs a special
kind of reasoning known as scalable
monotonic chaining which maps the risk
specified in individual rules to an intermediate
risk measuring fuzzy set. The result of this
mapping is a scalar value from the domain of
the risk metric indicating the degree of risk for
a particular model factor. The monotonic reasoning results for each rule summed to produce a final risk value. This value is used to find the actual project risk.

Suppose we had the following rules (see Figure 2):
- if project duration is long then risk is increased
- if project staffing is large then risk is increased

We then map these risks to an intermediate risk measuring fuzzy set, INCREASED.RISK. The result of this mapping is a scalar value from the domain of the risk metric indicating the degree of risk for this factor. The results, for each rule is summed up to produce a final risk value. This value called TOTAL RISK is used to find the actual project risk. (Cox, 1994)

3. Conclusion

Quantitative risk analysis techniques are usually favoured over Qualitative risk analysis techniques as these techniques provide systematic and documental approach for the management of risk. The quantitative methods are more objective and are based on models and metrics and qualitative methods are more subjective, for example one analyst can report certain risk as “high” while another may report rate the same risk as being “medium”. Thus the words, “high” and “medium” are relative terms and thus, does not provide an accurate evaluation of the risk.

The first aspect to consider when using a quantitative method is whether an imprecise measure is cost effective in order to justify its use. The most desirable metric is a direct measurement of the property of interest which not always possible with risk analysis as risk is inherently about the future and thus making predications is unavoidable thus the metric is only as effective as the expert that is employing them. The more experience or knowledgeable the expert the more accurate the prediction is. Guarro (1986) advocates the use of quantitative techniques as feeding subjective estimations into a objectively based model is more desirable than basing decisions on subjective decision schemes. But the model itself maybe subjective as there as all models are abstractions of reality as no model can include all the catalytic factors. Being cognisant of the subjectivity does not imply that it should be accounted for as making provisions for assumption errors is tantamount to “double-counting the effects of uncertainty” if uncertainty is accounted for in the model itself (Kitchenham et al, 1997)

But the inaccurate estimates, does not negate the need for attaining historical data, as forming a historical database of measures could make predictive measure more accurate in future. One method of capturing expert knowledge and making it widely available is through knowledge-based tools such as expert systems. Since risk management requires expert knowledge, it is a natural application for knowledge-based approaches (Toth, 1994). The second consideration is that the insistence on quantifying a risk can lead to a “paralysis of analysis” and a breakdown in communication about risks. (Williams, et al, 1997)

Qualitative techniques are usually employed at the beginning of the Risk Management Process to identify and rank risks. Those risks with a high or intermediate rank may be further analysed through quantitative techniques. Thus methods such as Scenario Analysis can be used in the initial stages. Fuzzy metrics is not popular due to its “complexity” (Baker, 1998).

The time spent identifying, analysing and managing risks pays itself back in many ways. Both Quantitative methods and Qualitative are useful at different junctions the later is more appropriate in the earlier stages and the Quantitative techniques can be used to provide a more accurate estimate of the risks identified in the using the Qualitative techniques.

Irrespective of the technique applied, Risk Analysis in itself can be risky, firstly one can overestimate the risk and then spend considerable time and effort in eradicating a risk that is unlikely to occur. Secondly one can underestimate a risk and then be lulled into a false sense of security (Charette, 1991). Thirdly risk analysis is time consuming, and there is also the potential, for overanalysing risk which
results in stagnation in a “paralysis analysis” mode which results in indecision.

Ultimately risk analysis cannot divorce itself from the nature of software, and it difficult to quantify and make predictions about an entity that is not entirely comprehensible. The reservations in the merit of conducting Risk analysis techniques due to inaccuracy does not outweigh its usefulness during decision making as the choices made are “more informed and wise rather than isolated, or worse, repetitions of past mistakes”(Bell,1989). Thus at the very least, risk analysis can facilitate risk aware culture rather taking reactive approach to risk and assuming the nonexistence of risks.

4. References


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