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OWNERS RISK REDUCTION TECHNIQUES USING A CM

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EXECUTIVE SUMMARY

This report describes a framework for performing risk analysis for construction capital projects. Emphasis is placed on the role of CM and how best CM can conduct the risk analysis process. As a by-product of the research a comprehensive risk catalog is developed and included as Appendix A. Also, a survey was conducted to establish the state-of-practice of risk analysis in the CM industry and included as Appendix B.

Problems of cost overrun and delays have been plaguing major capital projects; owners and the public (in public projects) feel that appropriate measures are needed to plan projects and manage risks effectively. Several causes have been cited for cost overruns including initial omission of essential components, optimistic preliminary estimates, estimating methods utilized, project definition changes, and scope creep. Use of innovative project management and control strategies and techniques to better estimate, contain, and manage capital costs can help improve these problems. One of the innovative project management techniques that can help in reducing the exposure of owner is an appropriate risk analysis that can be applied at various stages of project lifecycle.

Traditional methods of coping with project risks and uncertainties mainly consist of establishing contingency budget which are estimated as a percentage of various project components. The contingency budget calculated thus does not provide an indication of the level of confidence granted by such budget. Probabilistic risk assessment techniques will provide an analytical basis for the established contingency budgets by modeling the impact of risk factors with data ranges (both for cost and schedule). A Risk Event or Risk Factor, in the context of this report, is defined as any event with the possibility of loss or injury. By combining possible ranges of various risk factors, the analyst will be able to calculate the possible range of cost and duration for the whole project. With this information, it would be possible to establish a sufficient contingency budget based on the confidence level desired by the owner. This approach will tie the contingency budget to confidence level, *i.e.*, the higher confidence levels will require higher contingencies. As an example, if an owner wants to be 90% certain that the budget would be sufficient, he has to allocate a larger contingency compared to the case where he would be content with a 50% confidence.

This report describes the risk analysis process according to the following steps: cost and schedule validation, identification of risk factors, quantification of risk factors,

calculation of the total effect of risks (on cost or schedule or both), mitigation of major risk factors, and implementation of the risk mitigation recommendations (Fig. E1). In each step the role of CM is explained and suggestions are made as to the most effective way of conducting the analysis. The purpose of the report is not to provide a mathematical treatise on the subject of risk assessment; rather, it has been written in such a way to be of use to a wide variety of project participants.

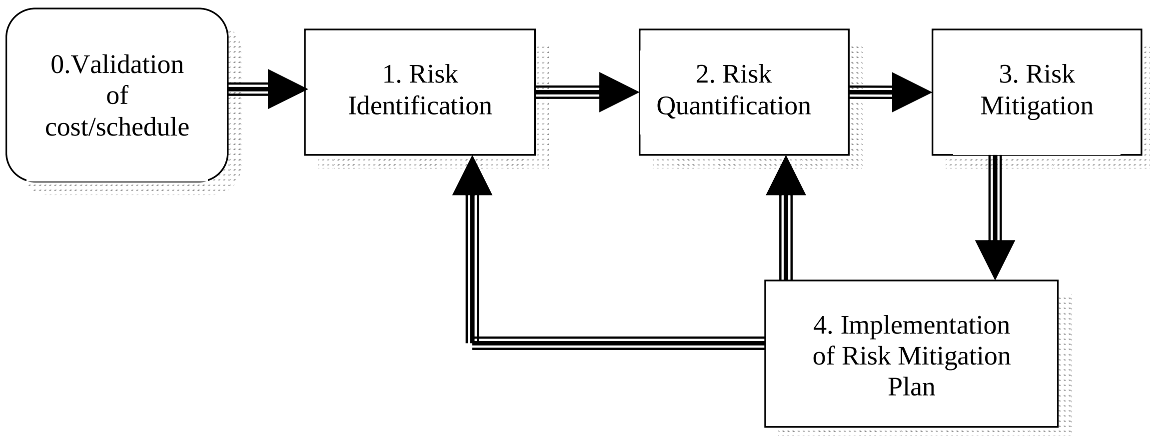

Figure E1 – Overview of Risk Analysis

Risk assessment starts with a thorough review of the project's scope, cost, and schedule. The purpose is to determine whether these are accurate representations of the project. The review establishes base project conditions with the cost and schedule stripped of all contingencies. The risk analysis team will then identify all potential risks and opportunities that may affect the project. As part of this report, a risk catalog has been developed that can be used as a checklist for the identification process. After risks are identified, each risk is ranged (cost and/or schedule). Using appropriate mathematical procedures, the combined effect of risks on cost and schedule is calculated and represented in the form of a statistical distribution. Using this distribution, one can establish a reasonable and defensible contingency budget for the project.

Risk Management consists of risk mitigation (Step 3) and implementation of mitigation plan (Step 4). A list of risk factors identified and quantified in Steps 1 and 2 (Fig. E1) will be used to develop strategies for mitigation. For each major risk factor, a remedial action with its associated cost will be devised and incorporated into the project's Risk Management Plan. The Risk Management Plan is the road map for the implementation phase where the owner's representative will be responsible for follow up and documentation of actions taken.

The report also covers some related but important issues such as who is in the best position to conduct the risk analysis, who should be included in the analysis team, when should the analysis be conducted, and what is an effective format for conducting the analysis.

It is concluded that the risk analysis is a valuable source of information for the owner, and that the Agency CM is the natural choice for conducting the analysis. Both the CM and the owner can benefit from a carefully developed Risk Management Plan.

1. INTRODUCTION

BACKGROUND

Dealing with risks is one of the most important elements of managing capital projects. According to a recent *Engineering News Record* article (ENR 2005) "most of the world's largest international construction firms believe properly managing and pricing risk is their biggest challenge, according to a new survey of 25 megafirm CEOs…" Executives surveyed said that poor forecasting, risk identification and cost escalation were the three top reasons for reduced project margins. This awareness of the importance of project risks is not limited to contractors. Many of the large owners have focused their attention to managing project risks as systematic risk management for major capital projects has become more widespread in recent years. Part of the reason for the owners' interest, especially those in public sector, is the problem of cost overruns and long delays plaguing large public projects. Cost overruns and schedule delays in construction projects are not new. Merewitz (1972) calculated cost overruns in about 200 "large projects" including transportation projects. The analysis found that BART (Bay Area Rapid Transit) projects experienced an average of 45% cost overrun. This was found to be similar to other rapid transit projects but worse compared to all other projects types. In another study Merewitz (1973 a & b) focused on a sample of 66 transportation projects for investigating the cost overrun issue. He used regression analysis to show that cost overruns are positively related to project size, engineering uncertainty, inflation, project scope increase, length of time between planning and completion of project, delays, and inexperience of administrative personnel.

More recent works by Flyvbjerg et al. (2002, 2003) were based on a sample consisting of 258 transportation infrastructure projects. The projects included 58 rail, 33 fixed link (tunnels and bridges), and 167 road projects. The authors compared estimated cost at the time of decision to build with the actual cost of the completed projects. They concluded that cost escalation in transportation projects (including rail, highway, tunnel, bridge) in the United States, Europe, and other parts of the world was commonplace and stemmed from overly optimistic estimates of cost at the point of making the decision to build. They showed that 9 out of 10 projects experienced capital cost overrun with an average overrun of 28%. The cost overruns were 44.7% for rail, 33.8% for fixed link, and 20.4% for road projects. The proposed potential solutions to these underestimation issues included process improvements and governmental vigilance in the review and analysis of these estimates. The authors also concluded that the issue of cost overruns had been present in mega projects worldwide and for decades. They showed that no learning curve effect could be seen in the estimation process because today's projects were experiencing cost overruns as projects did decades ago despite the improvement of technologies. They also showed that cost overruns had not significantly improved in transportation projects over the course of the past 90 years. Examples of cost overruns are not limited to transportation projects. Power generation projects, pipelines, and many other types of capital projects have also suffered from budget and schedule problems.

So if cost overruns have always affected large projects, what has caused the recent surge of interest in risk assessment? What seems to be changing is the public attitude towards this trend, outcry in the face of huge overruns, and the inconvenience to the public because of project delays. This attitude has affected the public confidence in infrastructure agencies, and this in turn has led to rejection of necessary project funding and support for many major projects (Reilly, *et al* 2004). Typical examples include the negative votes for tax increases to support large infrastructure projects.

These concerns have caused some public agencies to employ alternative methods of cost estimating. Some owners have realized that it will not be realistic to come up with a single "number" for the project estimate very early in the project's lifecycle. At best, given the multitude of uncertainties, one can come up with a range of values for the project cost and finish time. Arriving at a reasonable range for project costs can only be achieved by following a systematic examination and evaluation of cost and schedule assumptions and pricing of all the major risks and opportunities that potentially can affect the project.

As an example, the Department of Transportation of the State of Washington has been requiring a formal risk analysis for all their major capital projects since 2002 (Reilly, *et al* 2004). Their efforts have resulted in the development of a risk assessment system called Cost Estimate Validation Process (CEVP); every project considered for funding should go through this process so that the project estimate and schedule can be validated. Since 2003, the Federal Transit Administration (FTA) has been requiring a formal risk assessment for all the New Starts projects that apply for federal funds. Also, Federal Highway Administration (FHWA) has started using principles of risk assessment on many of their funded projects. In all these efforts, it is understood that the project cannot be reasonably estimated with a single "number" because of various uncertainties present at early stages of project development. It would be more prudent to provide a reasonable range for budget and qualify each specific estimate figure with a confidence level.

OBJECTIVES OF THE REPORT

The main objective of this report is to develop a framework and guideline for risk identification and mitigation to help the Agency CM and the owner better cope with capital project risks. A detailed risk checklist has been developed as part of this effort that is described in the risk identification portion of this report, and included in its entirety in Appendix A. Also, an extensive industry-wide survey has been conducted to obtain a clear picture of the status of the CM industry in the area of risk assessment. The results of this survey are presented in Appendix B. It is acknowledged that most of the data presented so far involves transportation projects. This is partly because these projects have more visibility and their issues and problems directly affect the public. Because of this, their issues are more widely reported in the literature. Also, the complexity of some of these projects has prompted project owners to look for ways to reduce the risks and uncertainties. Because of this, many of recent articles address transportation projects. It is emphasized however that the methods described here is applicable to vertical projects as well as horizontal projects.

CM'S ROLE

The Agency CM can play an important role in the risk analysis process. Agency CM is purely advising the owner and his foremost loyalty and dedication is to the owner and the owner's interests. This unique relationship will be of paramount importance in the process of risk management. In fact, compared to other project delivery systems, Agency CM is arguably the most effective for managing project risks because the CM's interest is at no point at odds with the owner's. In many cases the CM is brought on board early in project development.

The CM will be in a position to design an effective risk management system which includes identification, quantification, and mitigation of project risks. The owner has a range of options in dealing with each major risk factor such as accepting, sharing, transferring, or avoiding the risk. Each of these options has its own consequence. The CM can help the owner make the optimal decision in most of these cases.

This research focuses on the Agency CM's role in providing risk assessment services to a public agency. Based on our feedback from our industry advisors, we presume that most of Agency CM's clientele consists of public agencies, while private owners often utilize CM-at-risk contractors. Despite this emphasis on public agencies, the material covered is sufficiently general in nature; this means that this report can also be used as a guide for risk analysis in case the owner is a private enterprise.

PROJECT UNCERTAINTIES

The underlying assumption in risk analysis is that because of the uncertainties present in various phases of project lifecycle, the project budget and schedule estimates may be subject to variations. Risk analysis will not necessarily identify mistakes or estimating errors. As the project goes through various development phases (*i.e.,* conceptual design, preliminary engineering, final design, *etc.*) more information becomes available and project scope becomes clearer. This new information allows the project team to be more precise with their estimates and narrow down the range of possible cost and duration of the project.

Figure 1 gives an overview of this process. It is evident that at earlier stages, the project estimate has a larger variance. As an example, during the conceptual design, there is a strong possibility that scope will be added or subtracted from the project. By the time the final design is completed and the project is put to bid, the only variance could be due to competition among bidders and the potential for change orders during construction.

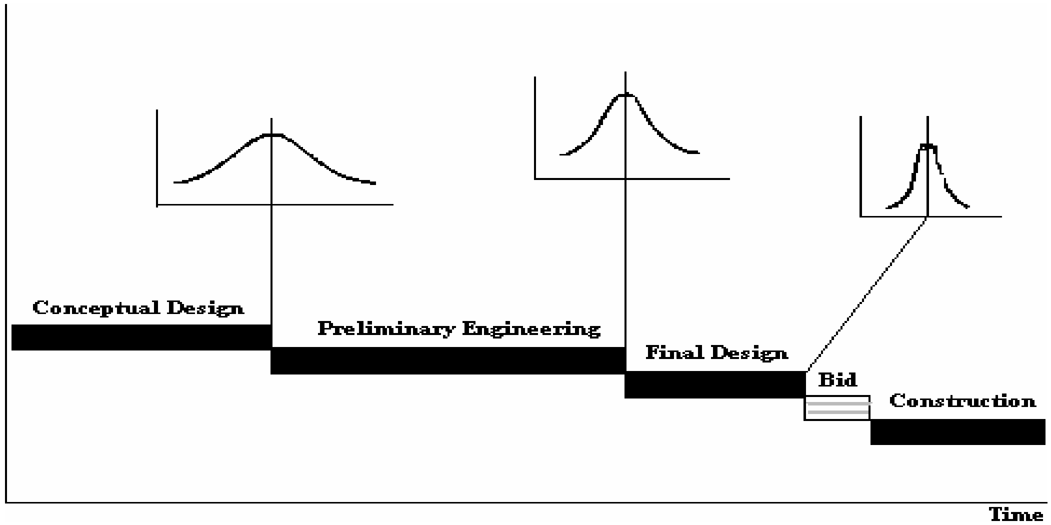

Figure 1 – The effect of level of information on cost uncertainty

Traditionally, project owners have accounted for the possible impacts of risks by establishing contingencies, or add-ons, to a base project cost and base project duration.

CONTINGENCIES

In order to cope with project uncertainties, the planner should include a reserve budget or contingency in the project budget. Contingencies typically are single-value allowances established using simple rules of thumb (e.g., 10 percent of the base cost when setting a budget). In contrast, risk analysis attempts to model the effect of project uncertainties and estimate their cost and schedule impact to a project; this way the allowances reflect defensible estimates of likely risk costs and durations. A probabilistic risk analysis uses concepts of probability to model uncertainties affecting project cost and schedule. It leads to a likely range of costs or durations that bracket potential risk cost or schedule impacts. The likelihood of a project being completed within budget and on time will depend upon the level of confidence that the owner needs with respect to project budget. As an example, if an owner is willing to accept a 50% chance of budget overrun, he or she would need a smaller contingency compared to accepting only a 25% chance of budget overrun.

Risk analysis has value at all phases of project development, regardless of project size. The objective of a probabilistic risk analysis is to establish the cost variance at various stages of project development (Figure 1). So it is clear that the outcome would depend on the stage when the analysis is performed (note the different cost distributions in Fig. 1). The preferred approach for risk analysis could vary depending upon phase or size; smaller projects usually do not justify extensive risk analysis procedures because of the cost of procedures. The approach, including analysis methods, should be based on the project owner's objectives, participants' attitude towards the process, available information, and the different types of risks potentially facing a project (Allen and Touran 2005).

2. AN OVERVIEW OF RISK ANALYSIS PROCESS

RISK ANALYSIS PROCESS

In order to provide an overview of the risk analysis process, we first need to establish some definitions. Risk analysis, risk assessment, and risk management are terms used by various entities and do not always refer to the same thing! As an example, until recently the term "risk management" for many programs basically referred to insurance program in a construction project.

Definitions

Risk in general is defined as *the possibility of loss or injury*. With this potentially negative connotation, risk modeling is generally used to estimate the effect of adverse events that can happen to the construction project. It is worth noting that a rigorous and comprehensive risk analysis should not limit its scope to only adverse events. *Opportunities* or the possibility of cost savings or project acceleration should also be considered and quantified during the analysis period.

With this basic definition of *risk* and *opportunity*, we can now establish a definition for *risk analysis*. Risk analysis is the systematic evaluation of uncertainty about the scope, cost, and duration of a project. This uncertainty is in the form of risks that a project could encounter during the course of its development. It can also be in the form of unknown opportunities for improving the cost and schedule prospects for a project (Allen and Touran 2005).

Risk Analysis Steps

The risk analysis process can be divided into several steps (Figure 2). The first step after the validation of project estimate/schedule (Step 0) is identification of risks/opportunities (Step 1). After risks are identified, their likelihood of occurrence and their magnitude (cost and delay potential), in case they occur, have to be quantified (Step 2).[1] In Step 3, using a ranked list of risks/opportunities that have already been quantified in Step 2, a Mitigation Plan is developed. The mitigation plan may affect insurance policies and contract clauses and terms. Step 4 is the implementation phase. Implementation is an on-going process; it is possible that during the implementation phase, visits to Steps 1 and 2 become necessary. Such cases

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[1] Step 2 (Risk Quantification) is sometimes called Risk Assessment. Some other sources use the term Risk Assessment for the whole process (called Risk Analysis here).

will usually lead to new mitigation procedures in the face of new information or risks. Steps 3 and 4 are sometimes referred to *risk management*.

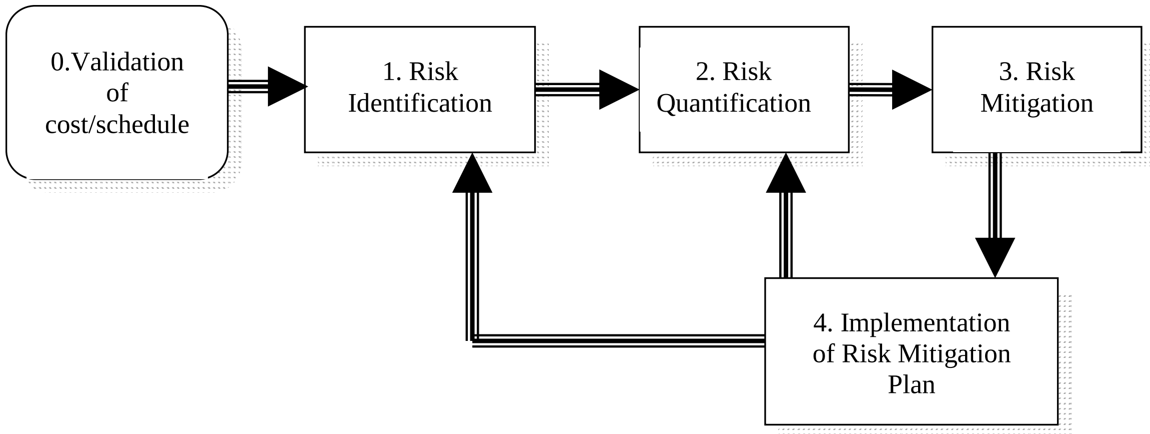

Figure 2 – Risk Analysis Process

In this report, the risk analysis process will be discussed following the framework outlined in Fig.2.

WHO SHOULD BE DOING THE RISK ANALYSIS?

The answer to this question depends on who is going to benefit from the exercise. Every member of the project team (designer, contractor, or the owner) can benefit from their own risk analysis. For example, a contractor in a traditional Design-Bid-Build (DBB) contract is anxious to ensure that he can complete the project with an acceptable profit margin. He knows the budget and the deadline and is interested in finding out what might go wrong within these constraints. Owner's risks on the other hand, are of a different nature. Many of the risks born by the contractor have been allocated to him by the owner through the construction contract. The owner however, has to deal with other types of risks during all phases of project development. In this report our main emphasis is the Agency CM, so we are interested in the analysis that benefits the project owner. The Agency CM represents the owner and is striving to make the project a success, while protecting owner's interests. Furthermore, depending on the project the CM may have been hired as early as during the conceptual design, so the CM could potentially be involved during all phases of project life-cycle. It should be pointed out that the framework described here is not designed to cope with CM's risks and liabilities. Rather, the report focuses on owner's risks. Following the guidelines however, will ensure that the CM's exposure remains limited.

It is the author's opinion that the CM is the entity who should be performing the risk analysis. The owner can benefit from an experienced construction manager that is present in the project since the beginning and understands the implications of various decisions regarding scope, budget, and schedule. An Agency CM is in a unique position to fulfill this role since the Agency CM's interest is in no point in conflict with the owner. Because the CM is not at risk, it can evaluate risky situations in an objective way and only consider owner's interest. Because of this characteristic, the Agency CM is in the best position to carry the owner's risk management program. Because of the CM's involvement during project development, he may have to conduct the analysis at various stages, *e.g.,* at the end of conceptual design, at the end of preliminary engineering, at the time of the bid, and during construction phase. This does not mean that the CM should do risk analysis during all these phases for each project. Rather, the decision to perform the analysis should be made on a case-by-case and as per need basis.

WHEN SHOULD THE RISK ANALYSIS BE DONE?

Timing of the risk analysis depends on the nature of the project and the project delivery system being used. As an example, in a Design-Build (DB) contract, the major analysis effort should be concentrated at the end of Preliminary Engineering (PE) and before the project is advertised for bid or negotiation. After the contract is signed, part of owner's control is transferred to the contractor and owner loses the freedom to take remedial actions. Parsons *et al* (2004) developed a guide for Project Management Oversight companies (PMOC) and suggested Figure 3 for the timing of risk analysis for various procurement methods. It should be noted that for cases where owners are interested to perform risk analyses at more than one point during project life-cycle, the level of effort drops considerably for consequent analyses. In many cases, if the original analysis has been done carefully (say, at the end of PE), the consequent analyses can be done quickly and efficiently with a fraction of effort. Performing multiple analyses ensures that the owner is not caught by surprise at any stage of the project development. In Figure 3, the comprehensive risk analysis (shown with solid circles) is more costly and extensive compared to the other three analysis types.

As part of this research we conducted a CM industry survey (Appendix B). In responding to the question: "At what stage of the project life-cycle do you perform risk analysis?" most participants responded: "at the end of Preliminary Engineering," followed by "at the end of Conceptual Design."

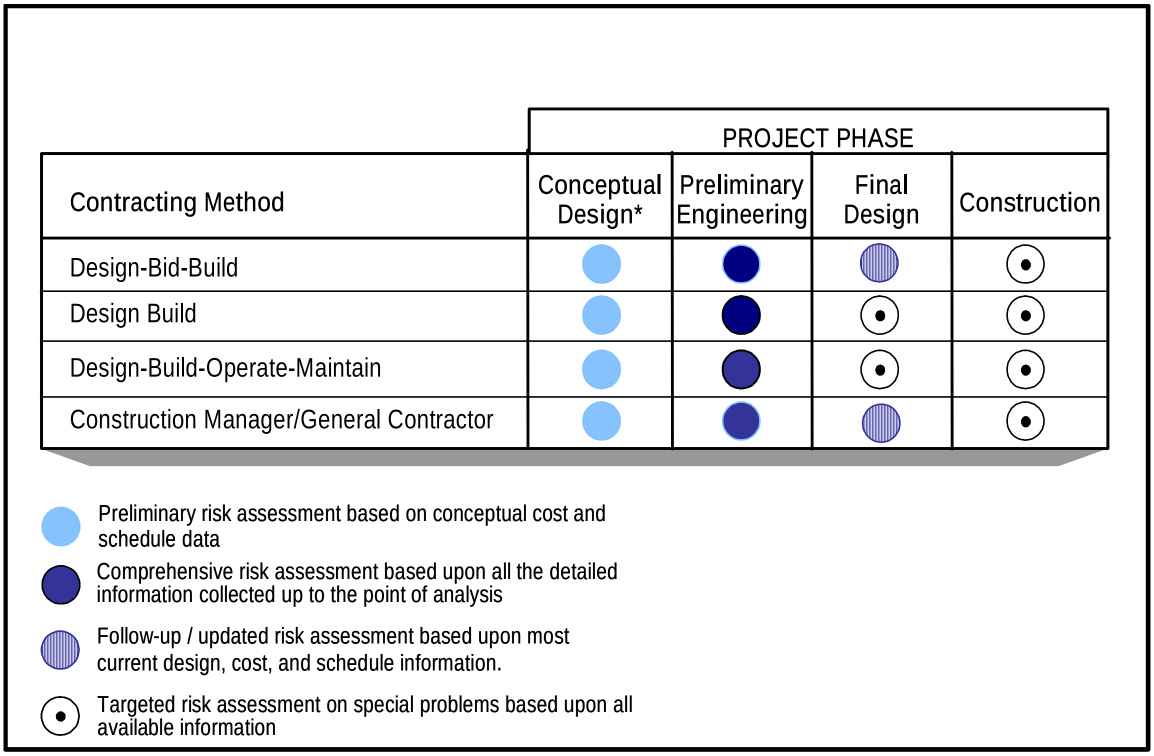

Figure 3 – Timing of risk analysis for various project delivery systems
(*Adapted from Parsons et al 2004*)

FORMAT AND PARTICIPANTS

As stated above, the owner's risk analysis program should be managed and implemented by the CM. There are various approaches to risk analyses. Sometimes a single individual with expertise in risk modeling helps and coaches the project cost estimating team to come up with a ranked list of risk factors and ranges of possible likely values for various cost items. However, this approach assumes that project scope, schedule, and estimate are complete and accurate.

A more costly, but effective approach is to use a workshop as a venue where project participants can identify and assess risks. Examples of workshop approach include the Cost Estimate Validation Process (CEVP) and the FTA risk assessments. In the CEVP approach, a risk assessment team collaborates with the project team in a workshop setting to help elicit risk and quantify the risk factors (Molenaar 2005; Reilly *et al* 2004). During the workshop a flowchart (similar to a summary-level CPM) is developed that portrays essential portions of the project and their logical interrelationships. Using this flowchart and ranged risk factors, the team's risk modeler can calculate the combined effects of risk factors on project cost and schedule. The FTA process is similar with the exception that the entity representing the FTA is the PMOC. The PMO contractor will be in charge of steering the risk assessment workshop, work with the owner agency and its representatives (either CM or design consultant) to identify and range the risks, and prepare the risk reports according to FTA's specifications. In FTA risk assessments, the PMO team consists of various experts (such as construction, systems, real estate, vehicles, cost, and schedule). The owner agency will also have its team of experts and the workshop participants examine every important aspect of the project under consideration.

The workshop approach has many benefits. It allows all the stakeholders to meet face to face and discuss potential risk factors and contribute to resolving any issues. The workshop also improves the communication among project members and their understanding of impediments. Indeed, one of the major benefits of the risk analysis process is to promote the understanding of project issues among all project team members. Another major benefit is the creation of a ranked risk checklist that can serve as a means for the mitigation effort.

WHO SHOULD BE INCLUDED IN THE WORKSHOP?

Assuming that the project is sufficiently large to justify a significant risk analysis effort, it is important to include representatives of various disciplines in the process (workshop), depending on the timing of the analysis. If the analysis is done during planning and Conceptual Design, expertise is needed in the overall project implementation, cost/benefits analysis, funding, environmental, and conceptual design issues. For projects with completed P.E. or Final Design, expertise should include project and construction management, cost estimating, scheduling, real estate (if right of way or other property acquisition is necessary), and engineering.

During the analysis, the owner should remain fully involved, although the technical details should be coordinated and managed by the CM. The CM is the party that plans the whole process, ensures that various key disciplines are present, and that appropriate data and information is available during the workshop. Further, the CM should be setting the agenda and try to keep the process on time; there is a possibility for the discussions to get bogged down and the process to get derailed from the main objectives, hence wasting valuable time. There is a need for a facilitator during these workshops. The facilitator coordinates the workshop, elicits comments from the relevant participants, and provides expert advice on technical matters related to risk modeling. He or she should be able to explain the basis and background of needed data clearly. As an example, the facilitator should explain the general modeling approach, the type of distribution to be used for risk modeling, the effect and meaning of correlation and its impact on the final result. The facilitator can be an independent consultant or may be an employee of the CM.[2]

[2] Parsons et al (2004) recommend the following to strengthen the risk analysis team: "Based upon lessons learned from recent transit risk assessments, one of the most important of other technical resources to include is an experienced project developer. Someone who has put together a complex project and preferably seen it into or through the construction period is invaluable for understanding project risks that technical staff or policy people may not appreciate. This individual has the "picture window" view of the world, which allows the sorting out of significant issues from the myriad details of project implementation." (Parsons *et al* 2004).

3. RISK ANALYSIS PHASES

As discussed earlier (Fig. 1), a systematic risk analysis can be planned as a sequence of four steps plus a prelude. The first phase, "Validation of scope, cost, and schedule" is labeled Step 0 because this phase has to be completed before the risk assessment workshop. While this step precedes the formal activities involved in a risk assessment (*i.e.,* identifying and quantifying risks), it is a very important pre-cursor.

STEP 0 – VALIDATION OF SCOPE, COST ESTIMATE AND SCHEDULE

The risk analysis team should first review the project documents and clearly delineate project scope. The review of scope ensures that project documents are consistent with project objectives and the owner's needs are met. For large complex projects, it would be important to have an independent party perform this review. This will ensure that items inadvertently missing from the scope will be identified. The validated scope will then be the basis for the validation of cost and schedule. Again, an independent estimator and scheduler are desirable. If for practical reasons, the reviewer is employed by one of the project teams, it is suggested that they are selected from outside the regular project team. This fresh outlook is important for identifying any discrepancies and errors and omissions in estimate and schedule[3].

The cost review should ensure that estimating assumptions are reasonable and that the estimate is compatible with the scope. Typical checks include:

- Accuracy of quantities, availability of material and equipment
- Productivity assumptions, availability of labor
- Cost escalation assumptions in longer projects or during periods of high inflation
- Project soft costs
- General conditions costs
- Bidding competition and its potential impact on fixed price projects
- Identification of project contingency line items

If the estimate contains any contingencies, the total estimate should be stripped of contingencies. The *base cost* is the cost of project without contingencies (Eq.1). These are more or less certain cost items that are defined by project scope. Contingency budget is

[3] It is understood that the CM may be in charge of preparing project cost estimate and schedule. We are suggesting that the CM team should be conducting the risk assessment. If the cost estimate and schedule has been prepared by the CM, it would be desirable to have an independent party review these documents for the workshop. As a minimum, the review personnel should not be directly involved with the project in question. Often, a fresh outlook can identify many errors or omissions that people too close to the project may not have observed. The size and complexity of the project will play a key role in some of these decisions. For most projects, a much simpler structure suffices. For projects where the sponsor is different than the owner, the approach may be different. The sponsor may insist on having an independent party conduct the risk assessment.

established to deal with uncertainties. The objective of the risk analysis exercise (to follow this validation process) is to quantify the cost of project uncertainties.

$$\text{Total project estimate} = \text{Base cost} + \text{Contingencies} \tag{1}$$

Care should be taken to identify the contingencies that are buried among other cost line items. Also, it is important to distinguish project allowances from contingencies. Project allowances are those estimates or *plug numbers* used by the estimator to account for project components that are hard to estimate either because the design is not complete or because based on available information an accurate estimate is not feasible. These allowances are clearly part of project scope and hence should be included in the *base cost*. As an example, the estimator may allow a budget based on $/acre of land needed for the project. While this $/acre may be based on some previous experience with the price of land in that area, an appropriate estimate should be based on identification of property owners, proper real estate research, and a study of recent transactions on similar properties in the area. This detailed approach may be left for later phases of project development.

The reviewer should also review the schedule and validate it. Typical checks include:

- Given the level of design, the number of activities are adequate
- Activity relationships are properly established
- Critical activities are reasonable
- There are sufficient link between activities; often, a schedule is developed with a large number of activities that are not properly tied (logically) to other components. This will result in faulty *critical paths* or in ignoring some potential critical paths.

STEP 1 – RISK IDENTIFICATION

If it is decided to utilize a workshop approach, Step 0 should be accomplished before the workshop. Furthermore, in order to expedite the workshop, it is advisable that project team members arrive with a list of identified risks. Obviously various experts participating would concentrate on their own area of specialization. As an example, on a highway project, an expert (most probably a non-engineer) might be present to evaluate the right-of-way acquisition issues. This will ensure that the workshop can proceed expeditiously.

The workshop facilitator should begin the workshop by explaining the objectives and providing an overview of the approach that is to be taken. There are a whole range of alternative approaches to conduct the quantification and modeling. Some will be quite simplistic and consist of deterministic estimates of cost and schedule impact of major risk factors. At the other end of the spectrum, the modeling may consist of more sophisticated probabilistic modeling which includes risk distributions, correlations among risk factors, and how these are combined to calculate the overall effect of risks on project cost and schedule. The method chosen may have an effect on the process of risk identification. We will cover these various techniques later under Step 2.

Risk identification is the process of identifying risks that can adversely affect the project cost and schedule and also the opportunities that can reduce project costs or result in a reduction in project duration. An effective aid in the identification process is a risk catalog or risk checklist. A risk catalog ensures that the team has not forgotten any major risk factors. We have developed a standard risk catalog using various sources (Appendix A). The format used in this catalog is similar to the format used in Touran, *et al* (1994). During our discussions with industry experts it was noted that Agency CM is usually involved with public projects and public owners. Because of this, more emphasis is placed on risks facing public owners; however, many of the risks identified affect private owners also. Similar or related risks are grouped according to their general theme or source and are arranged in a roughly chronological order. The project life cycle is divided into the following phases:

i- Pre-design phase
ii- Design phase
iii- Bid and award phase
iv- Construction phase
v- Post-construction phase

The risk checklist provides a listing of the typical factors affecting the risks associated with a project. Although such a checklist can never be complete, it can be used by owners, agency CMs, and other project participants as a basic checklist and guideline for identifying project risks. The checklist is prepared according to the Construction Management Association of America (CMAA) life-cycle breakdown. At a risk workshop, the list of risks (or *risk register*) should include a list of opportunities as well. Opportunities are potential cost and duration savings. No specific effort has been made to identify project opportunities and include them in the list in Appendix A.

STEP 2 – RISK QUANTIFICATION

After risk identification, it is time to quantify the effect of each risk factor (Fig.2). Risk quantification involves eliciting expert opinion from the risk assessment team about the potential impact of each major risk factor. It is understood that some uncertainty is involved with the cost and duration estimates of the risk factors. Because of this uncertainty it is prudent to estimate the risk impact by specifying a range of values rather than a single number. These estimated values are documented in the *risk register*.

Risk Register

The risk register is an important product of the risk identification process. The register is a listing of risks/opportunities identified for the project along with their impact on cost and/or schedule. In order to quantify the effect of risk, one needs to consider the *probability of occurrence of each risk event* and the range of cost or schedule impact if the event occurs (Fig.4). Combining the probability of each risk event and the cost range will result in the expected value of the risk. The expected value of the risk is the average cost (duration) of the risk factor.

Expected cost or duration impact = (Probability of occurrence) X (Estimate of cost or duration impact) Eq. (2)

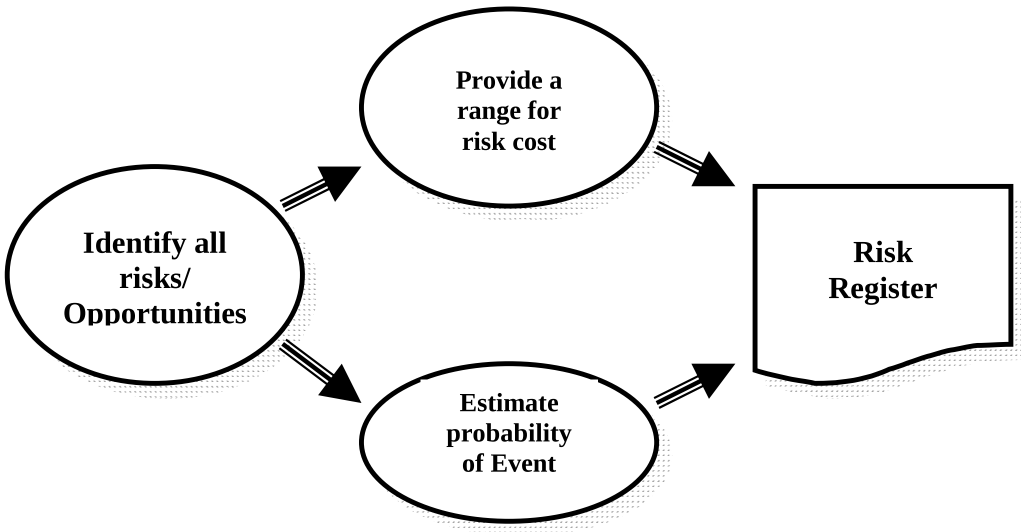

Figure 4 – Development of *Risk Register*

A simple example of a risk register is shown in Table 1. Note that depending on the project this table can be expanded. As an example, an additional column can link the risk factor to a certain project component, or another column can be added to show the effect of risk on schedule. The last column in Table 1 is the range that describes the cost impact of the risk. For example, the first risk factor (Utility relocation) can have an additional cost for the project ranging from \$1 million to \$3 million, with a most probable cost of \$2 million. Further, this cost will follow a triangular distribution (Fig.5). The choice of the distribution depends on the risk modeler's preference, previous experience with similar projects, and mathematical convenience. It is also possible that the situation in the field turns out to be as predicted by design documents and hence no extra budget may be needed. This is estimated by assessing a 50% probability of risk event in the risk register.

Table 1 – Example of a partial *Risk Register*

Risk ID	Risk/Opportunity	Description of Risk	Prob. Of Risk Event	Risk Cost/Range
xyz	Utility relocation	Location of certain utilities is unknown due to lack of data; may result in extra costs	50%	Triangular dist.: $1m,$2m,$3m
yxz	Price of copper	The current trend in escalation can extend into construction phase	75%	Triangular dist.: $0.5m,$0.75m, $1m

There is a wide range of statistical distributions that can be used to model almost any cost pattern. Much has been done and presented in the literature that can help the modeler choose appropriate cost and schedule distributions.

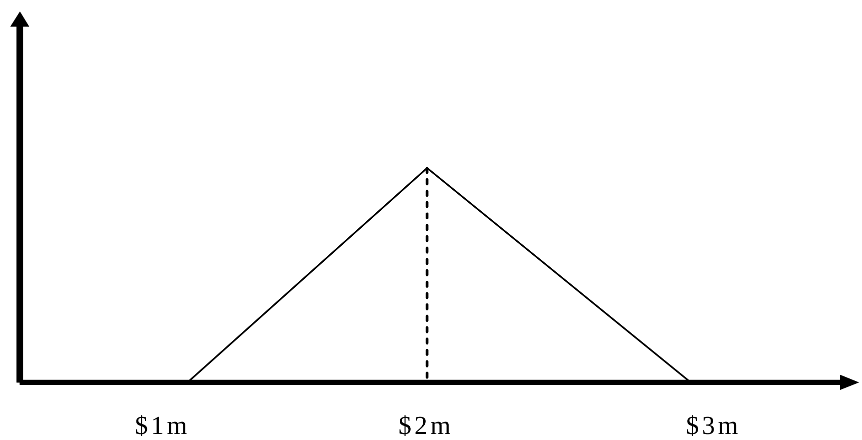

Figure 5 – Triangular Distribution for the Risk Factor "Utility Relocation" of Table 1

Usually the risk modeler (that could be the same as the facilitator in the workshop) has already selected the type of distribution for risk. He or she then has to be able to clearly explain the implications of the type of distribution to the workshop participants. It is important that the participants have a general understanding of the underlying assumptions. As an example, triangular distribution is used to model cost (or duration) where it is possible to estimate the most likely value along with optimistic and pessimistic cases. If the participants cannot estimate the most likely value, then the modeler may select a uniform distribution. This distribution will assume that any value between the optimistic and pessimistic values is equally likely.

Sometimes it is advisable to assign ranking to risk factors and only consider those risks that meet certain criteria. A typical approach is to consider two main risk characteristics: *severity* and *frequency*. *Severity* is a measure of the negative magnitude of the risk event if it occurs. As an example, a risk that can cause fatalities would have the largest severity rating. Frequency is an indication of how often one expects the risk event to occur. Instead of frequency, sometimes *probability* or likelihood of occurrence of risk event is used. Fig.6 gives a typical matrix that can be used in ranking a risk. *Probability* is measured with a scale of 1 (improbable) to 4 (very probable); *severity* is measured with a scale of 1 (minor) to 4 (catastrophic). The product of severity and probability will be used to rate the risk factor. Depending on the value of this rating, a mitigation strategy may be adapted.

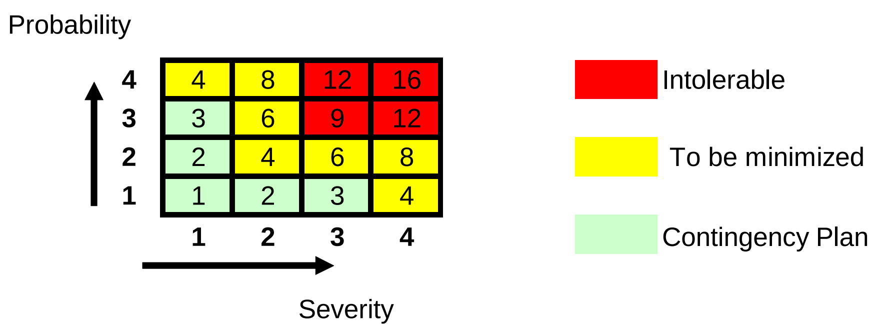

Figure 6 – Ranking of risk factors (Adapted from Richards 1999)

Another way to filter risks is to only consider those risks that meet a certain $ threshold. As an example, in a $100 million project, the participants may decide to ignore risk factors with a most likely value of less than $200,000 (or say a pessimistic value of less than $500,000).

Alternative Methods of Risk Quantification

Sometimes a more aggregate approach may be used in quantifying the effect of risks. Instead of considering the risks individually and trying to estimate their impact, sometimes various project components are ranged. As an example, the management may feel that the cost of earthwork (which may be the source of many risk factors) may range between $1 million and $1.5 million in a project. So this cost will be modeled as a variable that may take values between these two limits. This can be repeated for other project components (such as the cost of steel structure in a high-rise building) and these ranges summed up. This approach has sometimes been termed *range estimating* in the industry and provides an approximate envelope for project costs. Variations of this approach have been called *top-down* approach (Hopkinson 2006). The main emphasis here is to capture cost variability in major project components. The results can alert the management to where the main risk centers are in the project, and the extent of exposure.

Risk Measurement Methods

There is a range of options for measurement of risks in construction projects. In very preliminary stages of project development, when project data is lacking, a qualitative approach might be employed. We have already discussed some of these approaches under Step 1. Brainstorming, risk checklist, risk register, rating major risks according to their perceived impact on budget or schedule (such as *High, Moderate, Low*) are examples of qualitative risk measurement (Akintoye *etal* 2001). Even if numbers are assigned to these risks, the reliability of the numbers would be low. Despite this, qualitative methods are effective in identifying major problems early on. Their major contribution is to bring all the project members together and force them to think collectively and collaboratively for risk identification. Quantitative methods of risk measurement take more time and will provide more precise results. A whole range of concepts and tools can be used including sensitivity analysis, deterministic and probabilistic assessment methods. Probabilistic risk assessment may use an assortment of tools such as fault tree, probability tree, decision analysis, and Monte Carlo simulation. Figure 7 provides a general overview of various approaches to measurement of risk using a probabilistic approach. Both deterministic and probabilistic estimates follow the same basic approach. The risk is estimated by estimating cost of various risk factors and combining these costs in an appropriate way (either by adding them up or combining the costs using other mathematical relationships as appropriate). The main difference in a probabilistic estimate is that it explicitly considers the fact that some cost components are not single values but a range of values modeled using appropriate statistical distributions. The mathematics of combining these components consists of dealing with ranges of data rather than single data values. Addition, subtraction, multiplication, and other mathematical operations have to be performed on data ranges, and require the use of probability theory.

Figure 7 divides probabilistic approach into simulation and non-simulation methods. In many cases mathematical manipulation of distributions becomes unwieldy and intractable due to the complexity of the problem. Indeed in most cases, as soon as manipulation involves anything but the simple addition or subtraction of variables, calculation of the total cost becomes difficult. The only logical way to perform the analysis is to *simulate* the data according to statistical distributions specified in the model and combine these sampled values. Each time that the distributions are sampled, a total cost and schedule are calculated deterministically. By repeating the process of sampling the distributions and calculating the total cost and schedule a sufficient number of times (usually a few thousand times), a distribution for cost or schedule can be obtained. This distribution then provides possible values of total project cost or duration and identifies their probabilities (Parsons *et al* 2004). This method of repeatedly sampling various statistical distributions and calculating their combined effect is called Monte Carlo simulation. As the number of samples increases, the final outcome approaches the true distribution.

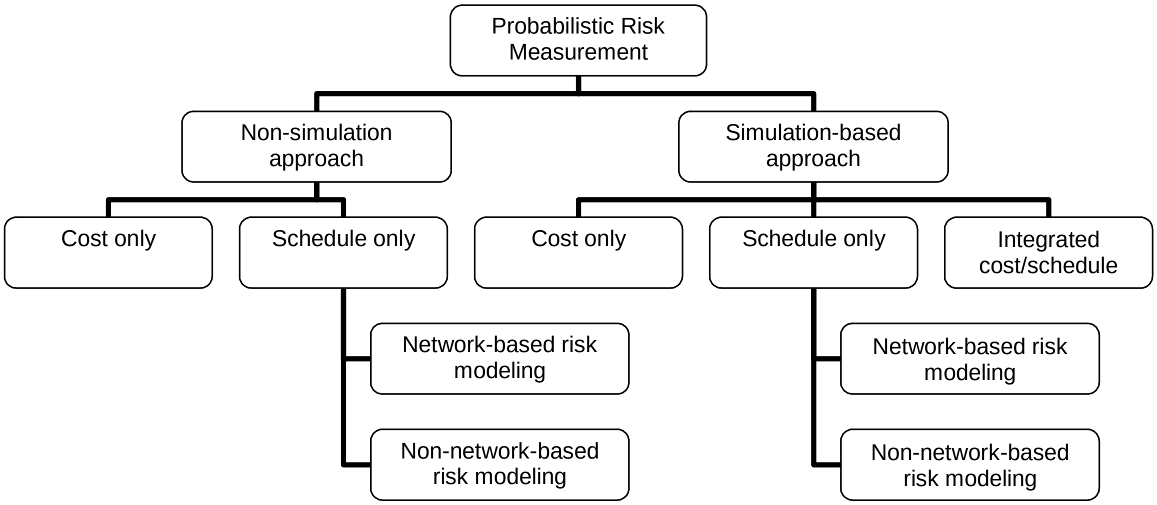

Figure 7 - An overview of risk measurement approaches

With the advent of economical and powerful personal computers, Monte Carlo simulation has become a viable alternative to exact analytical solutions for most risk assessment exercises. It should be emphasized that simulation is just a tool for facilitating the process of probabilistic risk quantification. Simulation in and by itself will not improve our understanding of risk and the extent of exposure but it allows the analyst to consider the most complex situation and arrive at a solution. Some people may distrust simulation because simulation *always works!* Even if the model is unrealistic, one can simulate the model and get some results (which could be equally unrealistic). Because of this characteristic, it is essential that care should be taken to develop realistic models of cost and schedule. In general it is a good practice to evaluate the reasonableness of simulation outcome with some approximate analytical method. When the results are corroborating, then the analyst can be ensured that the mathematical model is sound.

Another issue is to consider the effect of delay on project cost. Traditionally, risk assessments have concentrated on either cost or schedule. While schedule risk assessment can be performed without regards to cost in most cases, calculation of risk costs has to be tied to schedule. If the project is delayed it may have a negative impact on the budget. Despite this, many assessment approaches deal with cost and schedule separately in order to simplify the process. The CEVP process (Molenaar 2006) considers both cost and schedule, although schedule modeling tends to be at the aggregate level. Other approaches calculate the distribution of schedule (from a probabilistic network analysis) and then adjust the cost distribution according to the distribution of schedule (which includes the effect of delay).

Figure 7 also divides schedule risk assessment into two categories: network-based and non-network-based. The network-based risk assessment consists of starting with a CPM network of the project schedule and range activity durations that are prone to variation. The network is then simulated and the total project duration will consist of a distribution showing the possible range of durations for the project. A *Criticality Index* is calculated for each activity that represents the likelihood that the activity will fall on the critical path(s). Due to uncertainty in activity durations, the critical path may change constantly. Several software products are available that work with popular scheduling software and let the analyst range activity durations and simulate the duration. Examples include @Risk for Project™ and Pertmaster™.

It is also possible to perform the probabilistic schedule analysis without resorting to simulation. PERT (Project Evaluation and Review Technique), a non-simulation network-based approach has been around since late 1950s, and is sometimes used in schedule risk assessment. The non-network-based scheduling risk assessment analyses are sometimes conducted by modeling specific aspects of the project that is crucial to the schedule. As an example, a tunneling progress rate can be modeled as a function of TBM penetration rate and TBM utilization rate. These parameters in turn can be affected by rock type, water inflow, management and labor conditions. A realistic model should consider all important factors without being overly cumbersome. The developed model can then be solved using a simulation or non-simulation approach. These approaches are custom-built to each project and would require a higher level of expertise by the modeler. A more detailed description of some of these approaches is given in Touran (1989) and Parsons *etal* (2004).

Outcome of Risk Measurement

The typical outcome of a risk measurement analysis is a histogram and a cumulative curve for project cost and schedule. As an example, assume that a development project has an estimated *base* cost of $200 million. This estimate excludes any contingencies. This means that in the most optimistic scenario, the project developer does not expect the cost to go below this value. During a two-day workshop all project risks have been identified, ranged, and combined. Figure 8 shows the range of possible outcomes by giving the distribution of risk costs. In other words, the combined effect of project risk factors can be anywhere from -$5m to +$35m with an expected value of $15m. As the shape of histogram suggests, values less than $5m and values larger than $25m are not likely to happen as their probability is much less than 5%.

Figure 9 shows the cumulative risk costs for the project. This curve can be constructed by developing a cumulative function of the cost values in Fig.8. This cumulative curve can be used to set a contingency budget for the project. The values along y-axis give the probability of sufficiency of contingency. It is seen that if a contingency of $15m is considered (the

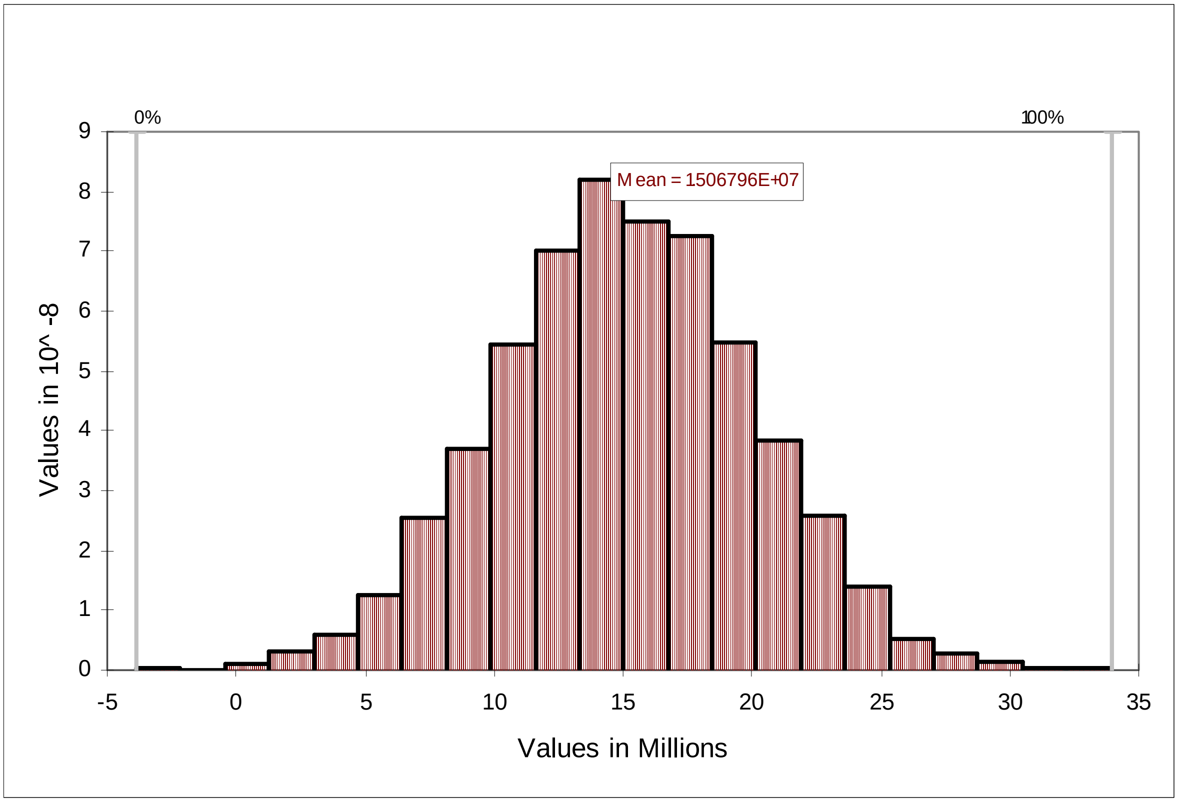

Figure 8 – Histogram of Risk Costs

expected risks cost), then there is a 50% chance (the value on the y- axis of Fig. 9) that the contingency would be sufficient. This confidence level is usually not sufficient from the owner's point of view. If the owner requires at least an 80% confidence that the budget would not run over, then referring to Fig.9, he would need a contingency budget of about \$20m. That would set the project budget at \$200 + \$20 = \$220m. This method of establishing contingency is vastly superior to the traditional rule-of-thumbs that add a fixed percentage point to the estimated cost. It further allows the owner to see the effect of increasing or decreasing contingency budget on the probability of cost overrun.

Similar curves can be developed for project schedule. For each important *milestone* or for the project *finish date* a range of dates along with their likelihood can be generated. Using these curves, a reasonable duration contingency can be established for the project.

Another common format is to add project base cost (cost of the project excluding contingency) to the risk distribution. In such a case, a histogram and a cumulative curve similar to Figs. 8 and 9 are developed where the x-axis will give total project costs (rather than just risk costs). It would be equivalent to adding \$200m (the base cost) to each value along the x-axis in Figs. 8 and 9 to arrive at the range of possible total costs.

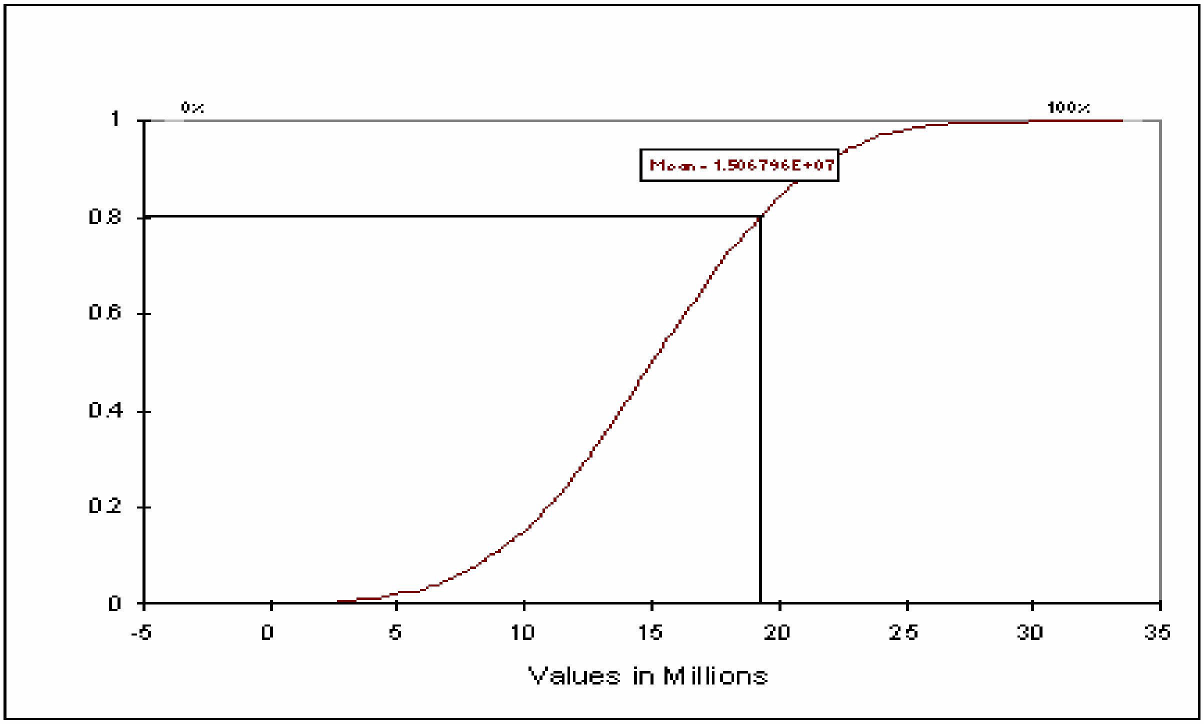

Figure 9 – Cumulative Distribution Function for the Risk Cost

Potential Issues in Risk Assessment

The process of risk assessment can be costly. Several people with varying degrees of expertise get involved in reviewing project estimate and schedule, identifying risks, and quantifying them. Some recent risk workshops for major projects have taken two to three days and included more than thirty individuals. Because of the time and expense involved, it is important that the whole process be planned carefully in order for the outcome to be worth the expenditure. Our suggestion is that the CM should conduct the risk assessment for the owner. This is assuming that the CM is not acting as a GC (*i.e.,* it is not at risk). Here are some of the more important issues that should be carefully considered for risk assessment.

- A common pitfall is not validating whether the base project scope, cost and schedule are reasonable. It is suggested that if the CM prepared the original estimate and schedule, an independent party review the estimate and schedule.
- Using an inappropriate or error prone analytical method is another major problem. The saying "moving pebbles with a dozer" applies to cases when the risk analyst is using sophisticated tools and techniques where a much simpler method is all that is

needed. In many instances, using sophisticated tools require information and data (such as various distributions and correlations) that are nonexistent. Using such tools will force the risk team to make wild guesses with regard to a variety of issues in order to satisfy model requirements. The result is a loss of confidence among risk team members and loss of credibility for the analyst and/or facilitator.

- An underlying problem is that both the CM and the owner may be inclined to think that the project is more meritorious than it really is. This attitude is necessary to a certain extent in any endeavor. The project owner and champions should feel excited about the project and its prospects. The problem is that the accuracy of risk assessment depends on the objectivity of the risk assessment team. This could be the most difficult hurdle to overcome. The problem gets more complicated in projects where the sponsor is conducting the risk analysis (as an example, a federal agency that is funding the project). Usually the owner or his representative (maybe CM) finds himself in a position to defend the project budget and schedule. Especially, if federal funding is tied to the outcome of risk assessment, objectivity of the team members may be in doubt. Often, this leads to an underestimation of various risk factors by some on the project team, while genuinely believing that they are objective! For these cases (where the owner agency is different from the sponsor) a fully independent risk analysis will largely avoid the potential for bias among project advocates but has several drawbacks. Project owner buy-in may be difficult. Without being a close participant, the owner will not fully understand how project information has been used to establish risks and their impacts; understandably, the owner will be less accepting of findings (Parsons *et al* 2004). Further, without genuine cooperation of the owner, the independent consultant may have difficulty in obtaining reliable data and information. Because of these concerns, it would be imperative to include the owner's team in the risk assessment process; having independent reviewers and an objective facilitator as part of the risk assessment team (similar to value engineering), complementing the project owner's resources, is the recommended option

- For privately-owned projects the process is simpler. The owner is genuinely interested in identifying project risks and wants to make sure that the project can be completed within the established budget. The CM will be in the best position to accomplish the risk assessment. The risk team will consist of CM and the A/E's staff as well as the GC (in case the project is a phased development where construction and design is proceeding concurrently).
- As part of this research we conducted a survey among the CM firms. One of the questions was to ask participants what they considered to be obstacles in conducting a risk assessment. According to survey participants (who all were CMs), the most important impediment was the unrealistic expectations of the client (Appendix B). This was followed by the reluctance of the risk assessment participants to consider pessimistic scenarios. Lack of reliable data and lack of risk analysis experience and expertise are other significant impediment factors. Interesting enough, lack of know-how in advanced mathematical modeling was not perceived as a major impediment.

- "As important as the analysis steps and proper analytical methods are, the process itself has value. It provides a powerful means for communicating to project's participants the effects of potential adverse events. It can serve in educating the project sponsors and other stakeholders on what can go wrong. Project sponsors are able to better understand the potential difficulties of project implementation and the critical interrelationships among project components." (Parsons *et al* 2004)

STEP 3 – RISK MITIGATION

The outcome of risk assessment is a quantified risk register and the histogram of possible project costs accompanied with a contingency analysis. As explained before, based on the owner's degree of comfort (his risk proneness or risk averseness) a contingency budget is selected to provide a certain probability of sufficiency of budget. Some risk assessment exercises are considered complete at this stage. The risk team is now aware of the major risk factors and they embark on the execution of project with that knowledge. It is strongly recommended however that the risk analysis process be a continuous process during the project life cycle. As a minimum, a formal risk mitigation effort should be administered and implemented so as to make the earlier effort worthwhile. In some ways this effort is like a value engineering exercise.

The team members are the same individuals that took part in the assessment process. It is possible that because of the insight gained during the assessment, new individuals are added to the mitigation team. Likewise, some members may not be invited to mitigation if their area is sufficiently covered by others. Risk mitigation can be accomplished using a workshop format, much like the assessment process, and is usually scheduled a few weeks after the assessment workshop.

Figure 10 shows the steps in the mitigation process. The first step is prioritization of risk factors listed in the risk register. Dealing with a large number of risk factors is not efficient and the team's effort should be concentrated on tackling major issues facing the project. The risk assessment exercise has quantified each risk, so it would be easy to rank the risks in terms of their effect on cost and schedule. One approach is to rank the risks according to their expected values (average values). Another approach gives more weight to the ability of each risk factor to vary the total cost and hence may rank the risks according to their standard deviations (or variances). Still, other software packages use more sophisticated sensitivity analysis approaches to rank risks according to their potential to change the total cost or schedule. Most of the time analysts find that the larger risks also have the larger variances. As a rule of thumb, some teams decide to consider only the top 10 or the top 15 risk factors. Others might use other criteria. One such criterion is the Pareto's Law: *i.e.,* 20% of risk items are responsible for 80% of cost increase, so those are the risks that need to be considered. The same process can be applied for ranking *opportunities*. Opportunities are those factors that have the potential to save costs or expedite the project.

After the most important risks and opportunities are ranked, each risk factor should be carefully evaluated and mitigation measures should be planned. Often, a mitigation measure has a price. This will mean that deflecting a risk or realizing an opportunity may have upfront costs. These should be carefully calculated. Also, sometimes there is uncertainty associated with some mitigation measures. Because of this, a *probability of success* should be considered for the realization of a mitigation measure. The following range of options is available to the owner according to risk literature (Wideman 1992; Touran *et al* 1994):

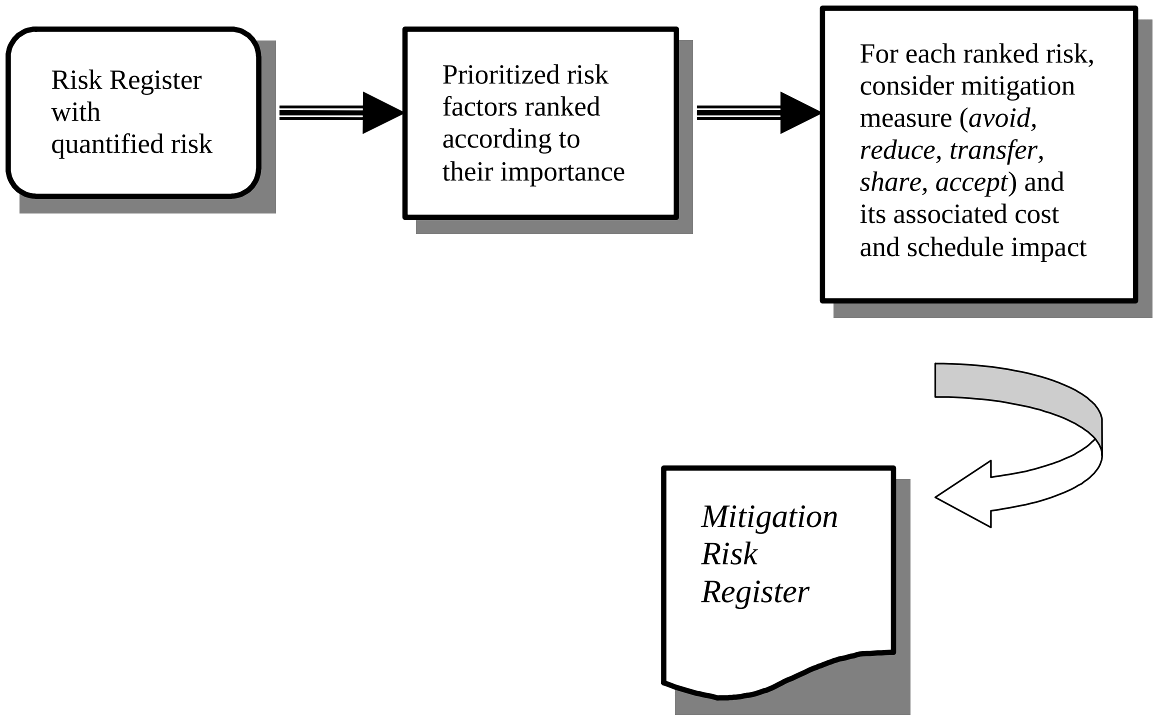

Figure 10 – Risk Mitigation Process

- *Accept the risk* – Sometimes the nature of the risk is such that the most effective way is to accept its existence and absorb the consequences. As an example, project contingency is meant to counter some of these risks.
- *Reduce the risk* – Often, while it is impossible to eliminate a risk factor, the owner can reduce (or mitigate) the adverse effect of risk. As an example, if ground conditions are critical to a project, the owner may spend money to treat the ground before starting the construction. There is some upfront cost but it is hoped that the money spent is more than justified in the face of larger risk of constructing in untreated ground. Despite the implementation of the mitigation measure, there still may be some chance that the treating does not work, hence *probability of success* of the mitigation measure should be estimated and considered also.
- *Share the risk* – Sharing the risk could be considered in a variety of situations. As an example, in dealing with utility companies for utility relocation in infrastructure projects, the owner may be able to negotiate a cap for the cost of utility relocations. The classical example of risk sharing among contractors is the joint venture.
- *Transferring the risk* – Insurance is the typical risk transfer mechanism.
- *Avoiding the risk* – Sometimes a risk is of such magnitude that the owner would be prudent to avoid it at all costs, even at the cost of not pursuing the project. This

would be an extreme case though. A less dramatic example could be avoiding the risk of errors and omissions in design by utilizing a Design-Build approach.

In summary, the aim of risk mitigation exercise should be to reduce the uncertainty in project cost and schedule and to reduce the magnitude of risk effects. Figure 11 provides the overview. The curve titled "Project cost, unmitigated," shows the total cost distribution before mitigation. This curve is the same as the histogram shown in Fig.8. The curve titled "Project costs, mitigated and opportunities realized," shows the distribution for total costs after mitigation, assuming that the mitigation measures are successful. It shows the range of costs to the left of the range of costs of unmitigated costs (indicating overall lower total costs). Moreover, the spread is smaller for the mitigated case, showing that because of mitigation measures, the cost uncertainty has been reduced.

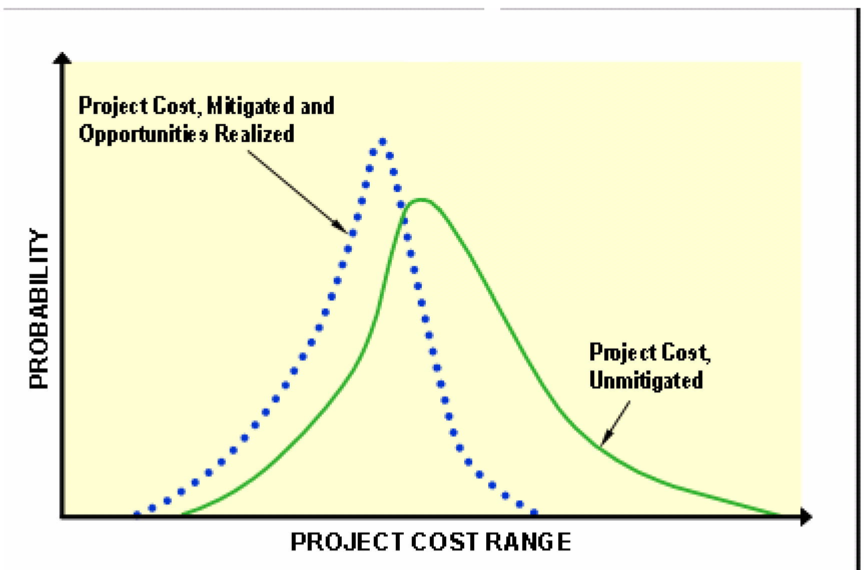

Figure 11 – The Effect of Mitigation on Project Cost (adapted from *Parsons et al 2004*)

A reasonable approach for documenting risk mitigation strategies and their estimated impacts is to develop a *risk mitigation register*. The format is similar to the risk register described before, but the list is much shorter. The mitigation register will only contain ranked risks that can be mitigated. Mitigation strategies formulated by the team members should be documented in the register. Other information that should be included:

- Cost of mitigation strategy
- Probability of success of mitigation
- Party responsible for mitigation

- Possible unintended consequences

Risk Allocation

Some of the risk management strategies listed above may fall outside the realm of authority of the risk assessment team. Decisions regarding *risk transfer* and *risk acceptance* usually require executive management approval or legal counsel advice. The risk team will usually provide technical support in these areas. It is clear that a major part of risk management/mitigation is allocation of risks to various parties. Allocation of risks is usually implemented through a construction contract. Because of this, mitigation workshops conducted after bid opening are usually more limited in terms of options available to cope with risks. On the other hand, the results of risk mitigation workshops before the completion of design documents may be invaluable in developing contract clauses that support the risk mitigation policies recommended.

The owner controls the contract and because of this the owner is generally in charge of assigning risks to designers and contractors. Despite this authority, the owner has to deal with many restrictions in preparing the contract. A contract that tries to protect the owner against all risks could have many negative consequences and eventually be more costly to the owner. Information about the principles and practice of risk allocation is available in published literature from academic researchers, the construction industry, and other organizations (Touran *et al* 1994; "*Contractual Sharing …*" 1995). The broad doctrines of risk allocation according to the relevant literature are as follows.

- Allocate risk to the party in the best position to control it.
- Consider the consequences to the receiving party.
- Consider whether the cost incurred or charged by the receiving party is acceptable.
- Evaluate the potential for new risks being transferred back to the project owner.

Apart from the contract clauses, the owner can select the project procurement method and the contract type to mitigate and manage risks. The advice of legal counsel and the Agency CM are invaluable in this respect. As an example, the Design-Build (DB) method reduces the delivery time, reduces the contractor's claims regarding the engineer's error and omissions, and creates a single point of responsibility: all positive for the owner. However, DB may reduce the competition during the bidding, and open up the door for future claims due to lack of clarity of scope. The CM/General Contractor (CMGC) procurement method assigns subcontracting and overall construction management responsibilities to the contractor. However, the owner would still benefit from having an Agency CM representing him or her in all matters regarding the project construction. The traditional Design-Bid-Build (DBB) approach would require complete design documents; in larger projects, the owner may use several prime contractors to optimize the competition and get the best price. Also, in some public projects, the owner has no choice but to use several primes.[4] Multi-prime projects are

[4] As an example, in the State of New York, the General Municipal Law requires separate bids for three categories of work: 1) Heating and ventilating, 2) Plumbing and gas-fitting, and 3) Electrical. So, as a minimum, each major public construction project in New York will have four prime contracts.

another area where the services of CM Agency can be quite beneficial. The CM is in an excellent position to help the owner break down the project into optimal packages. After the start of the project, the CM can be instrumental in ensuring effective communication among contractors and other stakeholders. Furthermore, the CM's role in coordinating various primes is crucial in a project's success.

In a CM Industry survey conducted as part of this research, participants overwhelmingly stated that it is imperative that the owner brings the CM on board very early in the project. Specifically, many suggested that the CM should be brought on board at the beginning or certainly before the end of design phase. They also noted that the best time to do the risk analysis is at the end of Preliminary Engineering. It is clear that as the project advances it would be harder to implement changes (such as those prescribed by a risk mitigation exercise).

STEP 4 – IMPLEMENTATION OF RISK MITIGATION MEASURES

The last step in the risk analysis process is the implementation of mitigation measures listed in the risk mitigation register (Fig.10). In simpler projects, a complete risk mitigation register may serve as a *Risk Management Plan* (RMP). In larger, more complex projects, the CM should prepare a more detailed version of register to serve as a Risk Management Plan. After the RMP is approved by the owner, it should be incorporated into the Project Management Plan (PMP). The RMP should describe in sufficient detail all the steps necessary to implement each major mitigation measure, its intended consequences, and the cost and schedule impacts of the mitigation measures. The implementation of the Risk Management Plan should be carefully monitored by the CM. The plan should include the following (see "Guidelines for Tunneling Risk Management" 2003):

- "Objectives of the risk management plan
- Prioritized listing and description of risks targeted for mitigation
- Technical and other requirements to mitigate risks (assessment of risk management competence)
- Risk mitigation measures, their costs and benefits
- Description of risk management responsibilities, project owner versus contractor versus others
- Description of actions to be implemented by each responsible party
- Monitoring program and process for follow-up or additional corrective actions. The program should also ensure information is obtained to evaluate the actual benefits of implemented mitigation.
- Implementation schedule; overall time and cost impact of the risk mitigation plan."[5]

[5] Parsons *et al* 2004.

It may be necessary to re-visit the RMP during the construction phase and adjust some of the measures based on the information available. Again, the CM is the best party to be in charge of monitoring, evaluating, and updating the Risk Management Plan. Managing the RMP is an on-going process including tracking each item in the register, tracking actions taken by the responsible party with regard to each item, and evaluating and reporting the results of mitigation action to all relevant parties. In a simple project, this can be accomplished by documenting all actions in a special log and providing periodic updates to owner, sponsor, designer and the contractor. In complex projects, the RMP should include a comprehensive and clear pathway for the implementation of the mitigation process by considering all the steps mentioned above.

4. SUMMARY AND CONCLUSIONS

In this report we described a framework for performing risk analysis for construction capital projects. Emphasis is placed on the role of CM and how best CM can conduct the risk analysis process. The objective of risk analysis in the context of this report is to identify, quantify, and mitigate factors that have the potential for driving up project cost and/or delay the project or its milestones. In each step the role of CM is explained and suggestions are made as to the most effective way of conducting the risk analysis. The purpose of the report is not to provide a mathematical treatise on the subject of risk assessment; rather, it has been written in such a way to be of use to a wide variety of project participants.

A complete risk analysis cycle starts with a thorough project budget and cost characterization. This review allows the owner to assess the validity of project estimated cost and schedule and critically evaluate the appropriateness of the methods and assumptions used in cost and duration estimate. Based on this characterization, the stage is set for identifying major risk factors. The risk analysis team will then identify all potential risks and opportunities that may affect the project. As part of this report, a risk catalog was developed that can be used as a checklist for the identification process. After risks are identified by the risk analysis team, each risk is ranged (cost and/or schedule). Using appropriate mathematical procedures, the combined effect of risks on cost and schedule is calculated and represented in the form of a statistical distribution. Using this distribution, one can establish a reasonable and defensible contingency budget for the project.

Project risk management consists of planning for, and implementing a systematic approach for risk mitigation and implementation. Risk factors that are quantified will be used to develop strategies for mitigation. For each major risk factor, a remedial action with its associated cost will be devised and incorporated into the project's Risk Management Plan (RMP). The Risk Management Plan is the road map for the implementation phase where the owner's representative will be responsible for follow up and documentation of actions taken.

The report also covers some related but important issues such as who is in the best position to conduct the risk analysis, who should be included in the analysis team, at what stage of project life cycle should the analysis be conducted, and what is an effective format for conducting the analysis.

It is concluded that the risk analysis is a valuable source of information for the owner, and that the Agency CM is the natural choice for conducting the analysis. Both the CM and the owner can benefit from a carefully developed Risk Management Plan.

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APPENDIX A

A RISK CHECKLIST FOR PROJECTS USING AGENCY CM

The Agency CM's role is to support the owner and represent him (with owner's consent) in all aspects of managing and executing the project. Because of this the CM will have to deal with risks that affect the owner. These risks may be different from the risks that face the contractor (or CM-at-risk) or the design consultant. The following risk catalog is prepared based on several sources. These sources include:

1- "Management of project risks and uncertainties," *CII Publication 6-8,* 1989.
2- Touran, A., P. Bolster, and S. Thayer, "Risk assessment in fixed guideway construction," *FTA-MA-26-0022*, U.S.D.o.T., 1994.
3- Akintoye, *et al,* "Framework for risk assessment and management of private finance initiative projects," Glasgow Caledonian University, 2001.
4- Parsons, Inc., "Risk assessment methodologies and procedures," report prepared for Federal Transit Admin., 2004.
5- Several actual risk assessment workshops for transit projects where the PI was present.
6- Feedback from a group of experts that served as an advisory board for preparation of this checklist.[6]

The format used in this catalog is similar to the format used in Ref [2]. During our discussions with industry experts it was noted that Agency CM is usually involved with public projects and public owners. Because of this, more emphasis is placed on risks facing public owners; however, many of the risks identified affect private owners also. Similar or related risks are grouped according to their general theme or source and are arranged in a roughly chronological order. The project life cycle is divided into the following phases:

i- Pre-design phase
ii- Design phase
iii- Bid and award phase
iv- Construction phase
v- Post-construction phase

The risk checklist provides a listing of the typical factors affecting the risks associated with a project. Although such a checklist can never be complete, it can be used by owners, agency CMs, and other project participants as a basic checklist and guideline for identifying project risks. The checklist is prepared according to the CMAA life-cycle breakdown. Please note that at a risk workshop, the list of risks (or *risk register*) should include a list of opportunities as well. Opportunities are potential cost and duration savings. No specific effort has been made to identify project opportunities and include them in the following list.

---

[6] Contributors include: J. Allen, Parsons Transportation Group; B. Brenner, Tufts University; N. Corcoran, Attorney at Law; DJ Mason, Keville Enterprises; T. McManus, DMJM Harris; C. Sciple, Massport.

i – PRE-DESIGN PHASE

Project justification/value

- Technical feasibility
- Economical feasibility/value
- Political circumstances/pressures
- Delay in various approvals
- Competing projects
- Statutory/regulatory (local, state, federal) constraints
- Public acceptance

Funding/financial

- Sources of funding
- Political climate and public support (especially public projects)
- Potential opportunities and timeliness
- Bond market and rates
- Exchange rate
- Inflation rate
- Cash flow uncertainties
- Authorization / appropriation risk(congressional)
- Underestimation of budget and duration
- Overestimation of project benefits
- Adequacy of marketplace supply (vendors, subs, labor, *etc.*)

Scope

- Management of the scope
- Clarity of owner's objectives
- Effect of interaction with constituents on the scope (*e.g.,* scope creep)
- Complexity and size of the project
- Sole source equipment and service providers
- Opportunity for equipment discounts (concurrent projects/clients)
- Design and performance criteria
- Constructability
- Omissions
- Selection of preferred alternatives based on limited design information

ii - DESIGN PHASE

Design consultants

- Designer's qualifications, availability, teamwork spirit
- Designer's understanding of cost/schedule management
- Incomplete design

- Errors and omissions
- Design QA/QC
- Accountability for design
- System integration
- Coordination between section designers
- Liability insurance (e.g., for errors and omissions)
- Quality of design (proven vs. unproven design, constructable, biddable[multiple bidders])
- Delays in design deliverables

Project/site
- Design and performance criteria
- Complexity
- Subsurface conditions/hazardous materials
- Unreliable data and test results (geotechnical, hazardous materials, cultural resources, other environmental conditions)
- Inaccurate or inadequate surveys
- Design changes
- Scope changes
- Scope creep
- Impacts from abutters

Cost estimate and schedule
- Soundness of engineer's estimate
- Omitted quantities
- Financial costs risk/opportunity
- Escalation assumptions
- Underestimation of design effort/costs
- Completeness and reasonableness of schedule
- Schedule consistency with project scope
- Level of schedule detail/integration
- Inadequate contingency
- Inadequate force account budget

Right of way acquisition
- Right-of-way appraisal and acquisition
- Delay in property acquisition/ court injunction preventing property taking

Regulatory conditions
- Licenses, permits, approvals
- Environmental regulations and requirements
- ADA requirements for public facilities
- Delay in various approvals

- Patent infringements
- Buy America and other procurement requirements

iii – BID AND AWARD PHASE

Project delivery[7]

- Turnkey, design-build
- Design-bid-build
- DBOM
- Joint venture
- Single prime
- Multi-prime
- Public-private partnerships
- Guaranteed Max/ Gen Contractor (GM/GC)
- CM @ Risk

Contract

- Fixed price
- Unit price
- Cost reimbursable (even in fixed price contracts, parts can be cost reimbursable, for example, work done by utility companies or some railroads)
- Dated or stale contract documents
- Contract package size (too big and it may limit the number and type of bidders)

Contractor

- Experience and performance on similar projects
- Character, capacity, capital, continuity (criteria used by surety)
- Safety record
- Need for bonds, bond limits, surety's reputation
- Familiarity with the area
- Cost, schedule, and document control practices
- History regarding claims and change orders
- History of delivering on-time and on-budget
- Subcontractor qualifications and capacity
- Subcontractor roles and responsibilities
- QA/QC program (contractor and subcontractors)

[7] There may be some inconsistency in listing all the factors. While many risks are listed as a potentially negative event, some risks are listed in a more general sense. As an example, while the type of project delivery system, or type of contract, in and by itself may not be a risk issue (assuming everything goes well), we have listed these as a reminder that the choice of project delivery (or choice of contract type) may lead to various risks specific to the delivery method (or the contract type).

Market conditions

- Number of bidders
- Availability of supplies and subs
- Unemployment rate in construction trades
- Workload of regional contractors
- General economic climate that can affect bidding behavior
- Material and energy prices
- Inflation rate, interest rate

Regulatory conditions

- Environmental and ADA requirements
- DBE requirements and (local) workforce participation
- Taxes and duties
- Limitations on the use of overseas materials and equipment

Owner/CM involvement

- Clear definition of CM (Agency) scope and authority
- Underestimation of the level of effort (soft costs)
- Supplying of material
- Testing, inspection, safety
- Start-up and providing clear access to the site
- MOUs and coordination with local agencies, companies, and community groups
- Communication channels/MIS

Guarantees

- Contractors' bonds or letters of credit
- Designer's liability insurance
- Consequential damages
- Liquidated damages
- Performance/quality
- Cost/schedule

iv – CONSTRUCTION PHASE

Insurance

- Coverage and requirements
- Wrap-up insurance
- Owner purchased insurance program

Site

- Access
- Congestion
- Differing Site Conditions including but not limited to:

    - Soil and rock conditions
    - Water table and flow (underground work)
    - Hazardous waste
- Archeological finds, sites
- Endangered species and other environmental concerns
- Environmental mitigation and remediation
- Noise mitigation: supplemental structures, schedule restrictions
- Security
- New security concerns leading to shutdowns, *etc*.
- Abutting structures and their conditions
- Unanticipated settlements

Work schedule
- Abutting contractors
- Limited work hours, restrictions on some construction activities such as blasting, trucking
- Maintenance of traffic, restrictions on traffic flow and access to site
- Disruption to public and businesses
- Coordination with utilities and other agencies
- Coordination with suppliers (long-lead orders)
- Subcontractors' delay, contractor's failure to effectively manage subs
- Weather effects on schedule
- Cash flow and contractor payments

Means and methods
- New, untried techniques
- Noise, dust, fumes, excessive vibrations
- Utility relocation
- Errors in the design of temporary facilities
- Construction errors
- Accidents
- Material shortages and large price increases
- Delays in mobilization (equipment and manpower)
- Failure of major equipment
- Hardware/software problems (control systems, integration, *etc*)

Acts of God/force majeure, including but not limited to
- Inclement weather
- Earthquake
- Flood
- Fire
- Terrorism

Labor
Most of the risks involving labor is transferred to contractor; however, owner or CM could benefit by being aware of these, as these factors can adversely affect project schedule. Also, on Force Account contracts, labor cost can be a major risk to the owner.

- Strikes
- Accidents
- Large wage fluctuations
- Sabotage, theft
- Substance abuse
- Unions
- Material wastes
- Insurance
- Productivity (especially in Force Account contracts this can directly affect the owner)

v – POST-CONSTRUCTION PHASE

- Individual systems and full integrated testing
- Owner training
- Full commissioning
- Occupancy permit (building projects)
- Warranty issues
- Complete close-out of all financing, funding, and permitting agreements and conditions

APPENDIX B

RISK ASSESSMENT SURVEY

The main objective of this research is to develop guidelines for the CM firms for the conduct of risk assessments. Because of this it was important to know what the CM firms are doing in the area of risk assessment. In order to obtain this information, it was decided to conduct an industry-wide survey among the CM firms. The CMAA's help in this survey was pivotal because they supplied the list of potential survey participants using their membership directory. They made sure that each CM firm received only one survey. Also, CMAA allowed us to use their online survey software, Zoomerang™. The survey was designed using the Zoomerang ™software and emailed to more than 200 potential participants in late February 2006. The survey was closed on March 24, 2006, after we had received 58 completed responses. The participation level was about 25% which provides a reasonable and representative sample of the total population. Fig. B1 shows the introduction screen of the survey.

> This survey is prepared as part of a research project sponsored by the CMAA Foundation. The purpose of this survey is to get an overall impression of how prevalent the use of formal/systematic risk assessment in the CM industry. While some clients require that the CM or PMO conduct a risk assessment on their projects, others have no specific policies as such. The main emphasis in this research is the CM as an agency.
>
> This survey is designed in such a way to require only a few minutes of your time. We value your time and contribution and welcome your feedback.
>
> Thank you for participating in our RISK ASSESSMENT survey. We will share the findings of the survey will all the participants.
>
> Sincerely,
>
> Ali Touran
> Northeastern University

Figure B1 – Introduction screen for the Risk Assessment Survey

The survey consisted of 14 questions. The survey results are presented and discussed in the following sections.

General profile of responding firms

58 companies participated in the survey. 40% of the survey participants have an estimated annual CM work volume of more than $50 million (Fig. B2)[8]. All the companies responding were based in the United States. Geographical areas of companies' operations were distributed throughout the U.S. with no significant concentration in a specific region (Fig. B3).

Also, 21 of 55 companies responded that they had international work. The most common types of projects were public buildings, schools, academic, and transportation projects (Fig. B4). It was noted that the share of public projects far exceeded the private work. This was probably due to the fact that our main target was CM Agency firms. These firms tend to mostly work with public owners, while private owners tend to use the CM-at-risk approach.

Survey Results
Risk Assessment by CM (Agency)

1. What is the estimated annual volume of CM work performed by your company?

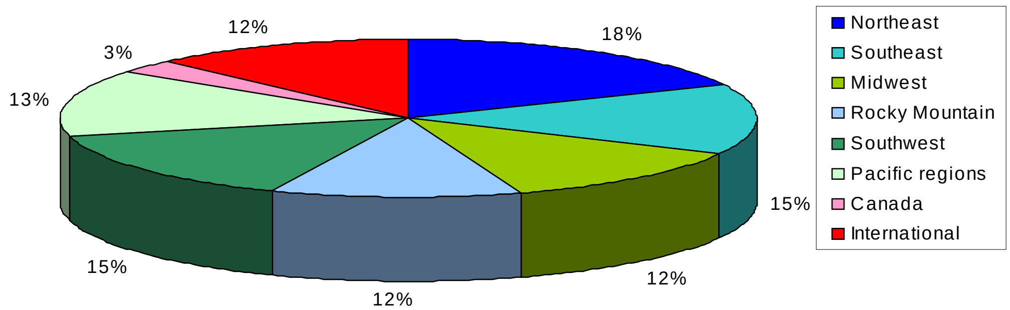
$1-10 million		15	27%
$11-50 million		18	33%
$51-100 million		8	15%
$101-500 million		9	16%
over $500 million		5	9%
	Total	55	100%

Figure B2 – CM Survey - Question 1

[8] In each of survey result figures, the column immediately to the right of the choice/category is the total number of participants that checked that choice/category. If multiple answers were allowed, then the sum of percentage points would not add up to 100%. The column in the far right (with percentage values) shows the ratio of the number of answers received for that choice divided by the number of responses to that specific question. Note that the number of responses to different questions varied widely.

Survey Results
Risk Assessment by CM (Agency)

2. The general geographical area of company's operations?



Northeast Region: Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Delaware, and Maryland
Southeast Region: Virginia, West Virginia, North and South Carolina, Georgia, Kentucky, Tennessee, Alabama, Mississippi, Florida, Louisiana, and Arkansas
Midwest Region: North and South Dakota, Nebraska, Indiana, Michigan, Wisconsin, Missouri, Kansas, Iowa, Illinois, Ohio, and Minnesota
Southwest Region: Texas, Oklahoma, New Mexico, and Arizona
Rocky Mountain Region: Montana, Wyoming, Colorado, Idaho, Utah, and Nevada
Pacific Region: Alaska, Hawaii, Washington, Oregon, and California

Figure B3- CM Survey – Question 2

Survey Results
Risk Assessment by CM (Agency)

3. What are the main types of projects that your company is involved in?

Transportation (highway, transit)		21	38%
School		26	47%
Academic (college, university)		21	38%
Institutional (churches, non-profits)		18	33%
Pharmaceuticals		5	9%
Process plants		9	16%
Other building (public)		30	55%
Other building (private)		20	36%
Other, Please Specify		27	49%

Figure B4. CM Survey - Question 3

Risk Assessment in CM Firms

Most participants, 37 of 55 companies (66%), perform a systematic risk assessment for the clients. Only 8 of the 37 (15%) do the risk assessment for all clients and projects, while 29 of 37 do for some clients and projects. 18 of 55 (33%) do not perform a formal risk assessment (Fig. B5).

Survey Results
Risk Assessment by CM (Agency)

4. Do you perform a systematic risk assessment for your clients consisting of risk identification, risk quantification and mitigation?

We do for all clients and projects		8	15%
We do for some clients and projects		29	53%
We do not perform formal risk assessment on any project		18	33%
	Total	55	100%

Figure B5. CM Survey – Question 4

It appears that most of the risk assessments are done because the CM firms advocate those. According to Fig. B6, 59% of the participants advocate a risk assessment for a client, while 9% of the participants do not. In most cases, the CM may advocate the risk assessment because the owner may not be aware of its benefits. In other cases, the CM advocates the risk assessment as part of their standard services.

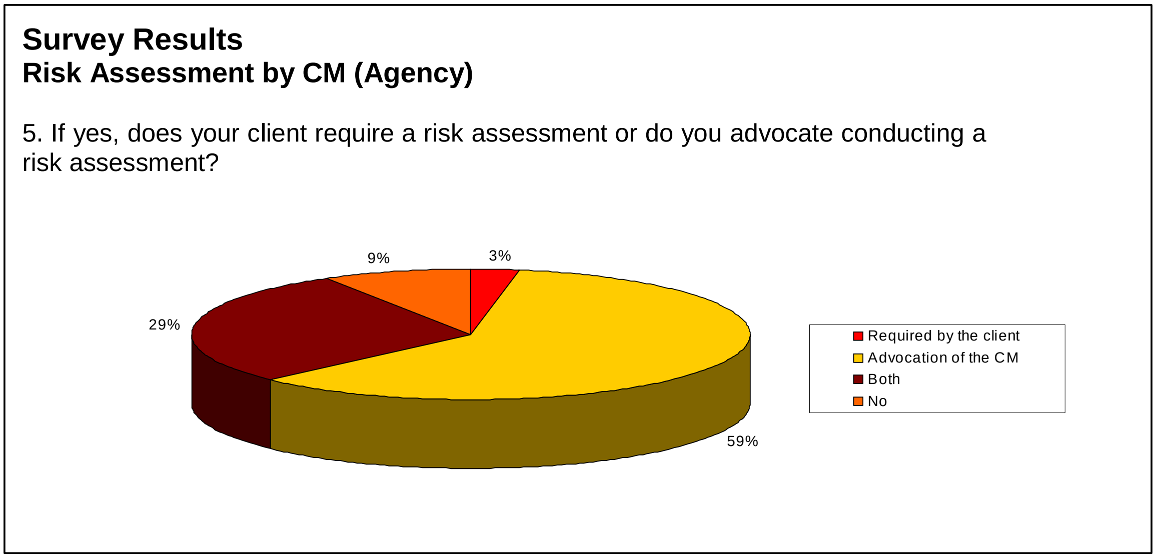


Figure B6. CM Survey – Question 5

The respondents were generally reluctant to identify the owners requiring risk assessment in the survey. The significance of this question was that it would have helped to identify potential clients with interest in risk assessment. The clients who require the risk assessments are usually governmental organizations such as Federal and municipal agencies. One respondent noted that the bank that provided the loans required risk assessment. In one instance a private developer required the risk assessment (Fig. B7). From the information gathered it seems that the driving force behind the owner required risk assessment is the federal government, and for large complex projects. Again, because the emphasis of this research is CM-Agency, it is plausible that larger private owners procure construction services using CM-at-risk.

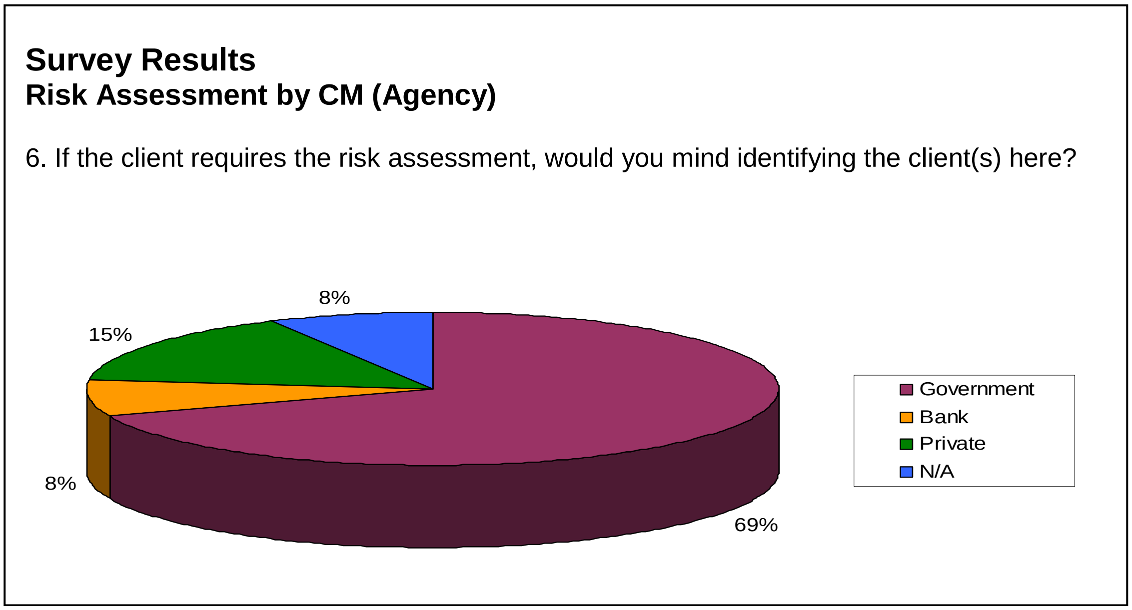


Figure B7. CM Survey – Question 6

Timing of Risk Assessment

An important issue in risk assessment is the timing. When should the risk assessment be conducted to be most beneficial? Questions 7 and 8 dealt with these questions. The chart in Fig. B8 gives a breakdown of when risk assessments are conducted by the CM firms. It is evident that most of risk assessments are performed during Preliminary Engineering and Conceptual Design. Clearly, the risk assessment should be done at an early stage, when it would be possible to make changes to project plans without incurring huge expense and delay. However, the risk assessment can be performed at every stage of project life-cycle. Please note that as multiple answers were acceptable or this question, the sum of responses does not add up to 100%.

Question 8 asked the respondents to choose the optimal time for conducting risk assessment. According to survey results, the majority of respondents felt that the best time to conduct the assessment is at the end of Conceptual Design (37%), at the end of Preliminary Engineering (19%), and at the end of final design (23%). It appears that for the traditional DBB projects, a risk assessment at the end of final design is recommended, while for the DB projects, a risk assessment at the end of preliminary engineering is preferred. It is evident that many respondents feel that risk assessment can benefit the project at almost every stage of the project life-cycle, but the opportunities for risk mitigation is reduced as the project advances in design and development. The participants overwhelmingly emphasized the importance of early risk assessment and mitigation. Only 11% of the companies think that risk assessment should be performed during the construction phase (Fig. B9). These cases could be targeted risk assessments designed to cope with specific issues that arises during construction. Several participants were of the opinion that risk assessment should be done at more than one stage during project life-cycle so that risks can be properly tracked and mitigated. Question 8 had a second component that asked the participants about who would they include in their risk assessment exercise. Most participants responded that they would include the designer and owner, with a lower percentage suggesting that including the contractor can be helpful.

Survey Results
Risk Assessment by CM (Agency)

7. At what stage of project life-cycle do you perform the risk assessment?

At the end of Conceptual Design		20	48%
At the end of Preliminary Engineering		23	55%
At the end of Final Design		17	40%
During Construction phase		14	33%
Other, Please Specify		6	14%

Figure B8. CM Survey – Question 7

Survey Results
Risk Assessment by CM (Agency)

8. At what phase of the project life-cycle do you think the risk assessment is most effective?

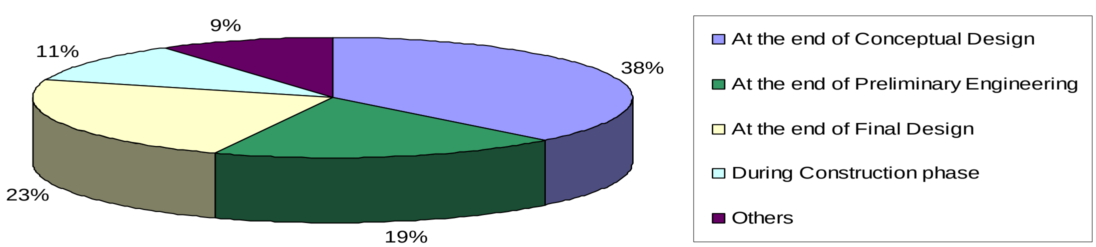


Figure B9. CM Survey – Question 8

Risk Assessment approaches and impediments

The next set of questions was designed to elicit information about risk assessment procedures used by the industry and potential impediments. As various CM firms may have a different understanding of what constitutes a risk assessment, several approaches to risk assessment were mentioned in Question 9. The response clearly shows that in general, CM firms are knowledgeable about risk assessment process. While the most common approach is to qualitatively assess the impact of identified risk factors (which is an effective method in its own right and can be sufficient in many situations), many CM firms are familiar with approaches that use probability of occurrence, range estimating, and simulation to quantify the effect of various risks (Fig. B10).

Question 10 dealt with the types of risks that are considered by CM during risk assessment. According to survey results, Construction phase and its associated risks receive the most attention by the CM. Financial, design, and escalation risks are deemed very important too. The respondents have also identified political, country, and security risks as significant also, although these may be more applicable to international projects (Fig. B11).

Question 11 asked about the impediments to a successful risk assessment. Again, because multiple answers were allowed, the sum of percentage points does not add to 100%. It is interesting to see that the most important impediment according to survey is the unrealistic expectations of the client (Fig. B12). This is followed by the reluctance of the risk assessment participants to consider pessimistic scenarios. Lack of reliable data and lack of risk analysis experience and expertise are other significant impediment factors. Interestingly enough, lack of know-how in advanced mathematical modeling was not perceived as a major impediment. In order to capture other factors that could be important impediments, the respondents identified other factors in response to Question 12 (Fig. B13).

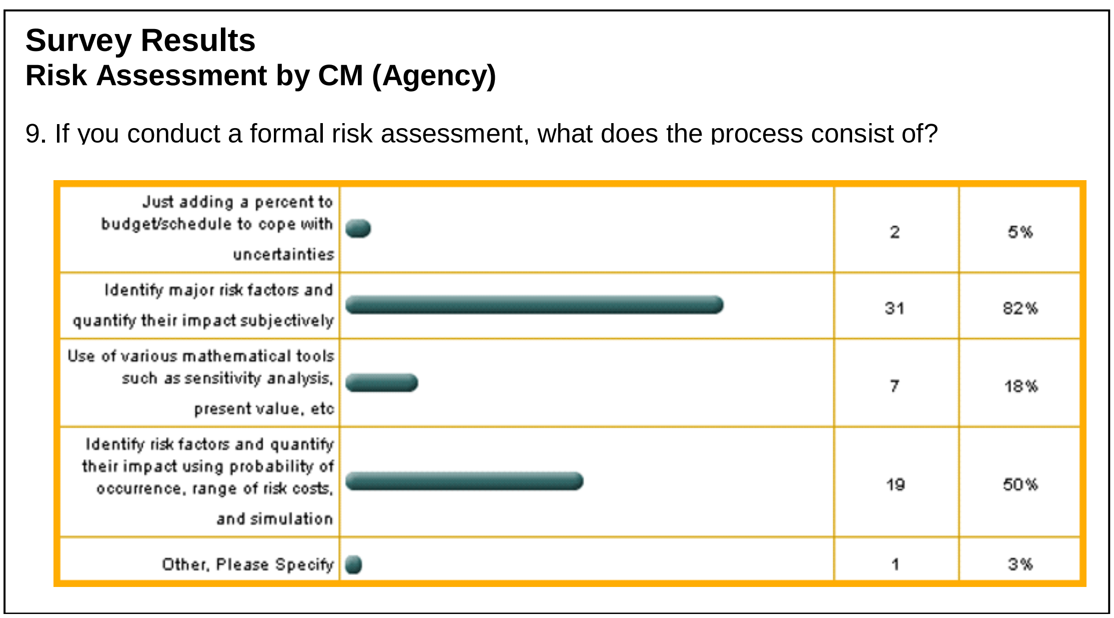
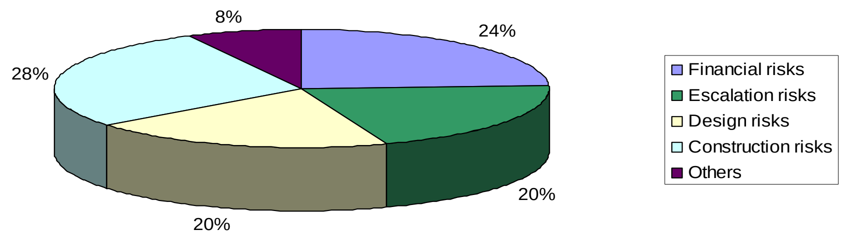


Figure B10. CM Survey – Question 9

Survey Results
Risk Assessment by CM (Agency)

10. What types of risks do you concentrate on?



Others: Legislative or regulatory changes, Country, Security, Environmental, Political, Public impacts, Operational Risks, Flexibility of building to be remodeled, Only those related to our CM firms, Political and stakeholder risks, Availability of material & labor, Third party, all associated risks

Figure B11. CM Survey – Question 10

Survey Results
Risk Assessment by CM (Agency)

11. What are the main impediments in conducting an effective and successful risk assessment?

Lack of reliable data		20	48%
Lack of experience of risk assessment teams		18	43%
Lack of know-how in mathematical modeling needed for the more advanced techniques		9	21%
Unrealistic expectations of the client (owner)		28	67%
Reluctance of various parties to consider pessimistic scenarios		23	55%
Other - please specify in the following question		7	17%

Figure B12. CM Survey – Question 11

Survey Results
Risk Assessment by CM (Agency)

12. What are the main impediments (other factors) in conducting an effective and successful risk assessment?

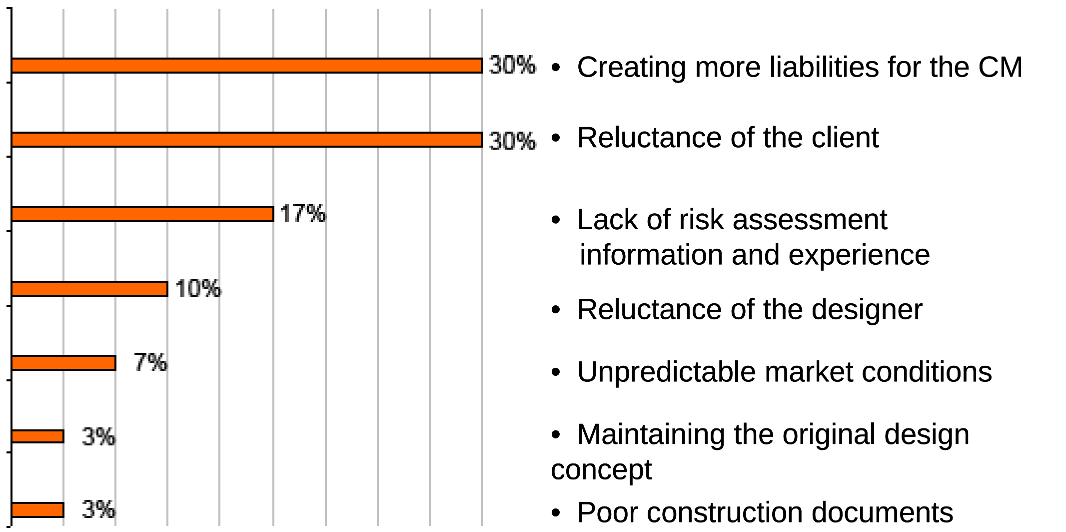


Figure B13. CM Survey – Question 12

Other impediments include more liabilities to construction manager, reluctance of the client and designer, lack of the risk assessment information and experience, unpredictable market conditions, maintaining the design concept, and poor construction documents (Fig. B13). There is some inconsistency in responses. For example, many responded that risk assessment could be a source of liability for the CM. While there may be some merit in this perception, this factor can work as an impediment to the CM and not to the risk assessment process. Reluctance of the client is largely because the client may not be convinced that risk assessment would be cost-effective; further, owners sometimes try to transfer risk to contractor rather than to quantify it.

General Evaluation of Risk Assessment

The next question dealt with the contracting arrangement and the role of CM in helping the owner with project risks. In general, the respondents felt that regardless of contracting arrangement, the CM (Agency) can help the owner cope with risks, especially if the CM is brought on board early in the development phase. There was a fair amount of discussion regarding multiple-prime contracts. Several participants claimed that multi-prime approach is an effective way to manage project risks and the CM can be instrumental in helping the owner manage this arrangement. Also, constructability analysis and value engineering were mentioned as effective means in risk mitigation.

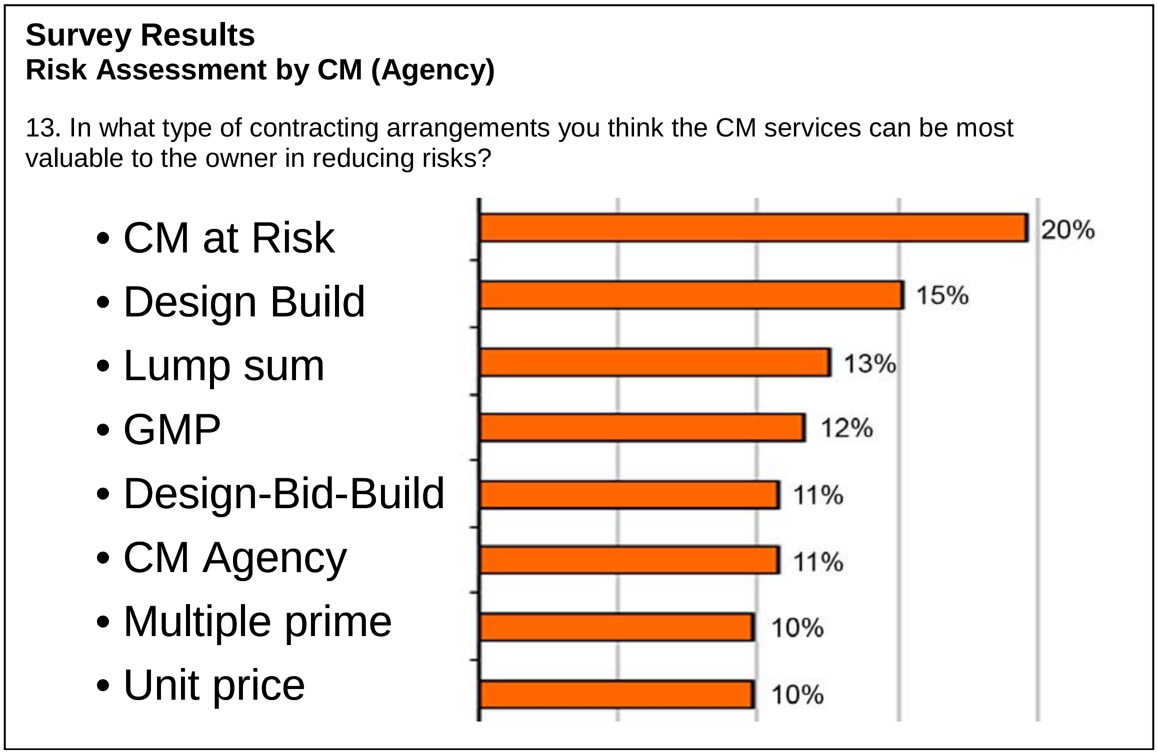


Figure B14. CM Survey – Question 13

Question 13 was an open-ended question where the participants wrote down their responses. There is a little ambiguity in interpreting some of the responses. As can be seen in Fig. B14, some respondents have identified CM (Agency) as the contracting arrangement where CM services can be most effective! The purpose of the question on the other hand, was to evaluate the effect of CM (Agency) on other types of contracting arrangements.

90% of the participants agree that a formal risk assessment is useful (Fig.B15). According to participants, the highest rated benefit from a risk assessment is the mitigation plan. The other benefits are risk identification, improved quality, confidence in scope, cost, and schedule control. Other items listed included improvements in contracting and legal issues, insurance, value engineering, design, financial planning, safety, and peace of mind for the client.
Other impediments include more liabilities to construction manager, reluctance of the client and designer, lack of the risk assessment information and experience, unpredictable market conditions, maintaining the design concept, and poor construction documents (Fig. 13).

Summary

A survey was conducted to obtain information about the state of risk assessments in the CM industry. 58 responses were received from CM firms. 90% of the participants agree that a formal risk assessment is useful. They see a range of benefits resulting from risk assessment including a mitigation plan for containing project risks and reducing them, improved quality, better control in project cost and schedule, better financial planning, and improved safety.

Most of the companies perform a systematic risk assessment for the clients however, 33% of the participants stated that their firms do not perform a systematic risk assessment on any project.

Survey Results
Risk Assessment by CM (Agency)

14. Do you think a formal risk assessment is useful? If yes, what are the main benefits?

Yes		47	90 %
N/A		1	2 %
No		4	8 %
	Total	52	100 %

Figure B15. CM Survey – Question 14

Thirty-six percent (29%+9% in Fig. B6) responded that the risk assessments are done because the owners require them. Many responded that they do the risk assessment as part of their standard services provided to the owner. The large majority of the owners who require risk assessments are public agencies (69%).

It was found out that most risk assessments are conducted at the end of conceptual design or preliminary engineering phases. Despite this, many responded that they had also conducted risk assessments at the end of final design and during construction (to a lesser extent). Most participants felt that the best times to conduct the risk assessment are at the end of conceptual design, preliminary engineering, and final design. Participants stressed the importance of early risk assessment and decision-making.

Based on responses it became evident that many CM firms are familiar with common methodologies used in risk assessments. These methodologies include identification of risks, estimating their impact qualitatively and finding ways to mitigate them. Alternatively, quantitative approaches using probability and simulation have been used by the CM firms. Some of the more important impediments in the success of risk assessments include unrealistic expectations of the client, reluctance of various parties to consider pessimistic scenarios, and lack of reliable data which is needed for performing an effective risk assessment.