# Risk Assessment in Fixed Guideway Transit System Construction, Jan 1994

Click HERE for graphic.

Risk Assessment in Fixed
Guideway Transit System
Construction

Final Report
January 1994

Prepared by

Ali Touran, Paul J. Bolster,
and Scott W. Thayer
Northeastern University
Boston, MA 02115

Prepared for

University Research and Training Program
Federal Transit Administration
U.S. Department of Transportation
Washington, D.C. 20590

Distributed in Cooperation with

Technology Sharing Program
U.S. Department of Transportation
Washington, D.C. 20590

DOT-T-95-01

TABLE OF CONTENTS

| | Page |
|---|---|
| Chapter 1 - Overview | 1 |
| Chapter 2 - Risk identification | 7 |
| Chapter 3 - Understanding financial risk from the owner's perspective | 15 |
| Chapter 4 - Surety's risk assessment | 37 |
| Chapter 5 - Risk modeling and assessment | 53 |
| Chapter 6 - Risk allocation and mitigation | 87 |
| Appendix A - List of References | A1 |
| Appendix B - Supplementary comments on the risk checklist | B1 |
| Appendix C - List of contributing individuals | C1 |

Click HERE for graphic.

# CHAPTER 1 - OVERVIEW

## OBJECTIVE

The importance and urgency of risk analysis in today's complex projects, in face of financial constraints, has spurred several research efforts in this area. Cost overruns are commonplace in the design and construction of complex capital projects such as fixed guideway transit systems. One major reason for cost overruns is the uncertainty inherent in various aspects of the work. This uncertainty can result in a wide range of outcomes that in turn may impact project cost and schedule in unfavorable ways. Risk assessment is difficult in large capital transit projects. Yet, it is imperative that the owners or sponsors engage in a rigorous, systematic analysis of major sources of risk.

The objective of this report is to help the owner or sponsor in developing a framework for managing risk in the design and construction of fixed guideway transit projects. Risk, as used in the context of this report, is defined primarily as the potential for monetary loss resulting from uncertainty about the project. In order to develop the risk management framework, first the sources of risk must be identified and categorized. Then a measurement system should be used to quantify the risk. Finally, each risk

item should be allocated between the parties involved in an equitable manner. If the project risks can be identified in a timely manner, quantified in a logical way, and allocated properly between the project participants (sponsor, owner, contractor, and engineer), then the likelihood of significant cost and schedule overruns will be reduced considerably.

## INTRODUCTION

Large construction projects are generally prone to budget and schedule overruns. This may stem from the fact that construction projects are unlike the products of most manufacturing and industrial projects. Peculiarities of construction such as the uniqueness of every project, exposure to external elements, characteristics of the workforce and the industry have been documented in various sources (Gilly, et al, 1987). According to Thompson and Perry (1992), 63% out of 1,778 projects financed by the World Bank in the period 1974-1988 experienced cost overruns. In the United States, cost overruns in large complex projects such as powerplants have been common. Cost estimates for the Boston's Central Artery/Third Harbor Tunnel Project, currently the largest public works project in the United States, have been continuously adjusted upwards in the past six years. Major capital transit projects are not an exception in this regard. Pickrel (1990) studied



10 large U.S. transit projects and found out that nine out of ten of these projects suffered from budget overruns. The amount of overruns ranged from 13% to 106%.

Many parameters may be responsible for budget overruns in transit projects. Scope changes or optimistic scenarios yielding low estimates of costs and high estimates of benefits, incomplete information about the project objectives and features, estimation error, and delay in construction start date are some of the more important parameters contributing to the budget overruns. Some of these factors are of a technical nature and depend on the project complexity, location and size; others are financial issues and are affected by the state of economy, affordability, cost of funds, and the owner's creditworthiness. Still, other factors depend on the political atmosphere surrounding the decision-makers and the general public. Although these social and political factors are of utmost importance, they are not the primary subject of this report. We shall rather focus on design, construction and financial risks affecting the project budget and schedule.

Based on our research and discussions with FTA experts, we have divided project uncertainties into two main categories: design/construction risks and financial risks. Design/construction

risks pertain to the process of construction and technical factors that affect the construction cost and schedule. Examples include unusual inclement weather, unfavorable underground conditions especially in projects where tunneling comprises a major portion of the work, and possibility of contractor's inability to meet project deadlines and/or quality standards. Financial risks relate to all aspects of project financing and budgeting and may include unfavorable changes in interest rate, shortfall in the estimated revenues, and uncertainty in construction budget cash flows.

In addition to evaluating these risks, one has to consider the interaction between financial and construction risks. For example, a shortfall in revenues dedicated to the project may delay construction. Conversely, a delay because of construction difficulties may increase financial burden on project sponsors.

## STEPS IN PROJECT RISK MANAGEMENT1

The risk management program has three phases as depicted in Figure 1. 1. The first step in a risk management program is to identify risk prone areas in a project. After the risk identification process, a methodology for measuring design, construction and financial risks should be devised. The methodology, though based on sound theoretical principles, must be practicable and convenient to apply to real life problems. After risks are appropriately identified and measured, they should be allocated to various parties involved in the project in a fair and equitable way. This should be done in a way that ensures the prudent expenditure of public funds

---

1Traditionally, the term "Risk Management" is used in conjunction with an insurance program. Here, "Risk Management" consists of dealing with all types of construction and financial risks.



and at the same time provides reasonable compensation to the providers of construction and financial services.

The importance and urgency of risk analysis in today's complex projects, in face of financial constraints, have spurred several research efforts in this area resulting in many publications. In preparing this report, we have reviewed, discussed, and elaborated on many of these

Click HERE for graphic.

publications. Depending on who is doing the risk analysis, the process may vary. The contractor's interest and emphasis will be somewhat different from the owner's. In this report, most of the discussion proceeds under the assumption that the end user of the report will be either the sponsor of a transit capital project (such as FTA) or the local owner (transit agency). Furthermore, most of the examples and cases cited are relevant to transit projects or those with components similar to major transit projects. We believe that the document in its present form contains a wealth of information about the state-of-the-art in the practice of risk analysis and mitigation.

## ORGANIZATION OF REPORT

We address each of the steps of risk management mentioned earlier, in an independent chapter. Chapter 2 covers risk identification. Chapter 3 discusses different types of financial risks affecting the project. Although elements of financial risk are identified in Chapter 2, we include this chapter to further highlight and elaborate on various aspects of financial risks. This chapter could be very useful to construction experts. While these experts are proficient in technical aspects of the project, they may lack the detailed knowledge about financial issues.

Chapter 4 describes the process of risk assessment by the surety industry. The surety, in effect, indemnifies the owner in case of contractor default. Because of the nature of its responsibility, surety has to perform a thorough risk evaluation before bonding a contractor. We included this chapter because we feel that it is useful to consider the surety's unique perspective on risk Clearly, virtually all risk analysis carried out by the surety is relevant to this research. Furthermore, FTA experts felt that the agency would benefit from a better understanding of the surety's function and procedures.



Chapter 5 addresses risk modeling and measurement and Chapter 6 covers risk allocation and mitigation. An extensive reference list is included as Appendix A. This will help the reader to locate sources of information in related areas. Appendix B contains a detailed set of comments about the risk checklist presented in Chapter 2. Appendix C provides a list of names of the individuals who contributed to this research. The following is a brief summary of each chapter's contents.

## Chapter 2 - Risk Identification

This chapter describes various types of risk (especially the ones related to construction and design) that may impact a capital transit project. Several methods of risk classification are described and a suitable classification method is recommended. A detailed risk checklist is developed. This list breaks down construction and financial risks into fifteen broad categories. Each category is subdivided into important risk items. Important items in the risk checklist are described and highlighted in the commentary section provided in Appendix B. Development of the risk checklist helps the project owner to focus on risk elements and develop an appreciation for what may go wrong during the course of project implementation.

## Chapter 3 - Understanding Financial Risk from Owner's Perspective

Broad sources of financial risk such as the cost of capital and inflation are described and then financial risks that directly affect the owner (or sponsor) of transit projects are analyzed. Issues such as sources of revenue, bonds, bond rating, exchange rate risk, and project-specific parameters are discussed. Operating risk factors are covered also because they may impact the project feasibility at the conceptual level. In addition, the contractor's exposure to financial risk is discussed.

## Chapter 4 - Surety's Risk Assessment

This chapter provides an overview of the surety industry and the procedures used by the surety for evaluating contractor's risk. The surety is exposed to huge losses in case of contractor's failure. Because of this, the surety has to perform a careful analysis before deciding to bond a contractor for a particular project. Therefore, studying the surety's methods of risk evaluation can be useful to the owner in contractor prequalification and also result in a better understanding of the parameters contributing to a project's risks.

## Chapter 5 - Risk Modeling and Assessment

This chapter builds upon the material covered thus far and explains owner's and contractor's risks and levels of contingency. Deterministic and probabilistic approaches in estimating the

potential for cost and schedule overruns are covered, with more emphasis placed on probabilistic approaches. Both analytical methods and simulation approaches are introduced and explained. Several elaborate examples and case studies are used to illustrate the process of quantifying the level of uncertainty in budget and schedule and to calculate contingency. Furthermore, conceptual and computer software tools available for risk measurement are described and their strengths and weaknesses elaborated. Areas of research and development in this field are identified. A realistic risk picture for a transit project is only possible by evaluating the impact of financial and construction risks and considering the interaction between these risks.

Chapter 6 - Risk Allocation and Mitigation

This chapter reviews various methods proposed for risk allocation and mitigation. Based on the work done by others and research conducted by the authors, a method for classifying risk mitigation measures is proposed. A well thought out and fair contract is an excellent vehicle for allocating risk to various parties. Ideally, there should be a set of circumstances where the owner and the contractor assume their fair share of responsibility and the owner does not have to pay for some contingency that will never be utilized. To foster this process, a set of guidelines should be prepared to help the owner in developing an effective contract. A detailed table is developed that incorporates the experiences gained in the past two decades in risk allocation in construction contracts. This Table is based on the risk items in the Risk Checklist presented in Chapter 2. The material in the Table is cross-referenced to various publications and augmented by explanatory remarks and comments. We believe that this Table is a convenient tool for checking the contract's effectiveness. Further, it brings together various aspects of this project by providing recommended solutions to most of the risk items identified in Chapter 2 and measured in Chapter 5.

ACKNOWLEDGMENT

Several people from engineering firms, construction companies, insurance companies, Federal and State agencies have contributed to this effort by providing information and reviewing earlier drafts of portions of this report. We have included a list of the names of these individuals in Appendix C. The authors would like to express their appreciation to those who helped, and apologize to anyone inadvertently not included in the list.

The authors accept full responsibility for any errors and would appreciate it if readers comment on those.

Ali Touran, Department of Civil Engineering
Paul J. Bolster, College of Business Administration
Scott W. Thayer, Department of Civil Engineering

Northeastern University, January, 1994.



# CHAPTER 2 - RISK IDENTIFICATION

Every technique for risk analysis must begin with the development of a method for the identification and classification of individual risks inherent in a particular projecT. While every construction project has its own unique set of risks, there are many risks that are common to all projects. Examples include unknown underground conditions, severe weather possibilities, contractor reliability, and the risk of maintaining adequate funding. One of the most adaptable methods for risk identification and classification is the development of a risk checklist. This technique allows the user to list common project risks, and then to append the list with those risks peculiar to the project at hand. Virtually every method studied in this research included the use of a risk checklist

The current planning process employed by the Federal Transit Administration (FTA) for Environmental Impact Statements (EIS) contains many of the risks common to all transit projects. The significant risks delineated by EIS process include capital cost, land use and economic development, air quality, noise and vibration, ecosystems, water resources, energy, utilities, historical/archaeological, safety and security. These items and others were used to develop a risk checklist for this report (Table 2.1).

Risk identification is heavily dependent upon the experience and perceptivity of project management. In order for a checklist to be effective, there must be a concentrated effort during the development stage to identify all relevant risks by all members of the management team. This process can be particularly arduous because humans are not predisposed to identify more risks and thereby creating more things to worry about. By identifying risks and developing appropriate courses of action should such events occur, management will trandescend the "putting out fires" mode. That is, management will become proactive instead of reactive.

## BACKGROUND

Ostensibly there are several different approaches to organize a risk checklist into a logical, understandable, and useable format. One approach (Diekmann, 1988; C.I.I. Pub. 6-8 1989; Curran, 1989) proposes that risks should be organized in terms of the nature of the risk itself. Specifically, risks can be classified as either knowns, known-unknowns, or unknown-unknowns. A known risk is an item or condition that is understood, but cannot be measured with complete accuracy. Generally, such risks occur at a relatively high rate and contain a range of possible outcomes. Labor productivity is a good example of a known risk. Known-unknowns conditions or events that are foreseeable, but not normally expected. Normally, such events have



a relatively low frequency and result in severe consequences. Earthquakes, hurricanes, strikes and unusual difficulty with a contractor are examples of this type of risk. Unknown-unknowns are conditions or events that cannot be predicted. These items are generally catastrophic in nature and have a low probability of occurring. Examples of unknown-unknown include asbestos related hazards or AIDS before the were recognized. Once an unknown-unknown is identified, it becomes a known-unknown.

A second method for organizing a risk checklist is to classify the risks according to their nature and their primary sources (Wideman, 1992). Under this scenario, risks are placed into one of the following categories: external-unpredictable, external-predictable, internal non-technical, technical, and legal. Examples of external-unpredictable risks include natural hazards or regulatory changes. External-predictable risks involve inflation, currency changes, environmental impacts, and social impacts. Internal, non-technical risks are embodied by items such as schedule, cost, cash flow, and management. Technical risks evolve from changes in technology, from sheer size or complexity of the project, and from design or performance standards. Finally, legal risks arise from patent rights, force majeure, licensing, contractual problems, and insider and outsider lawsuits. This classification system provides the benefit of arranging the groups according to their relative controllability. For instance, natural hazards are considered external-unpredictable and have a low degree of controllability while contractual risks are ranked as legal risks with the highest controllability.

Yet another approach to classifying risks is based upon their effect on the project. Under this method, risks would be considered as either cost risks, schedule risks, or quality risks. Unfortunately, many risks fall into more than one category, and

accordingly, create the potential for double counting when mitigation procedures are being considered (Wideman, 1992).

## CONSTRUCTION AND FINANCIAL RISKS

In order to facilitate the next phase of the risk management process, i.e., risk measurement, the authors have divided risks into two broad categories: design and construction risks and financial risks. This is somewhat analogous to classifying risks broadly according to their source and is proper because the objective of this research is to analyze risks from the owner or the sponsor's point of view. So while major risk items deserve scrutiny, we are not interested in details that a contractor would want to be concerned with.

While financial risks appear to affect the project at the earlier stages (such as planning and feasibility phases when alternative methods of financing are evaluated), construction risks tend to accompany the project throughout its lifecycle and especially during the construction period. Also, financial risks tend to affect the project in a broad sense while construction and design risks are sometimes peculiar to a limited part of the project. For example, uncertainty in the tax revenue dedicated to the project can impact the whole project and even postpone it. But an unexpected condition at the site of a tunnel may impact the tunnel advance rate and impact those project components that are directly tied to the tunneling operation.



The effect of financial and construction risks are usually estimated independently using methods and models developed in two separate fields of engineering and finance. Despite this traditional approach, design, construction, and financial risks are complementary. For example, if a major impediment to the completion of a project surfaces during the construction phase, the contractor or owner may be forced to raise additional funds at a time when interest rates are unfavorably high. Alternately, it is possible that contingency financing is difficult or impossible to obtain in the short term, creating delays and engendering an increase in construction costs. An extensive example of the effect of the financial and the construction risks on project cost is developed in Chapter 5.

Subsequent to the establishment of the two major risk categories, a further breakdown is appropriate. This breakdown has been developed by considering various types of risks that can potentially affect the project chronologically from the feasibility study phase until completion of the construction. Subcategories

can be project size, contract clauses, factors such as geography and local economic conditions, site factors such as topography, site accessibility, etc. Perseverance will result in a checklist that will reflect all areas of risk for a particular project. Furthermore, it will provide a systematic and objective approach to the risk identification process of future projects, ensure that no major risk item is overlooked, and provide the basis for analyzing groups of projects as a portfolio.

## THE RISK CHECKLIST

The risk checklist presented in this report has been organized with the objective of developing an easy to understand and repeatable set of guidelines for fixed guideway transit systems from the owner's perspective. We have concluded that a checklist based upon the source of risk best achieves this goal because it is easy to understand and use. The following checklist (Table 2.1) is organized with a chronological format. That is, an item which would occur first in the normal lifecycle of a construction project is listed first in the checklist. Based upon the feedback that we have received from the industry, this is a very useful format. To elaborate somewhat, the checklist contains fifteen major risk categories, each of which is then divided into several sub-categories. Also note that the checklist developed can be used at various phases of the project lifecycle. For example, it can be used in the conceptual planning phase to establish broad risk factors affecting the project. Evaluation and re-evaluation of risk checklist can then be conducted at various stages of project lifecycle. It should be noted however, that the later one attempts to evaluate risks, the less flexible would be solutions to any potential problems.

Every item in the risk checklist can be earmarked as high, moderate, or low risk. For example, if an individual project involves major underground construction, then risks associated with some of the subcategories of "Site" will become very important and will deserve extra attention. The checklist can be examined for every project and filled in so as to reflect specific project characteristics. It provides a systematic and objective approach to risk identification process, ensures that no major risk item is overlooked, and provides a basis for risk measurement and mitigation. This checklist has been thoroughly reviewed by various experts from the government and industry. Most of their viewpoints have been incorporated into the checklist



TABLE 2.1 - An Outline for

THE RISK CHECKLIST
from the Owner's Point of View

This risk checklist is developed from the owner's point of view. Therefore it is possible that some important parameters that contribute to the project uncertainty, but were not owner's responsibility, have been left out. Also, not all the elements reported in this checklist have similar impact on the project cost and schedule. In fact, some items such as environmental regulations have a profound impact on the project cost, schedule, and construction while others may have only a marginal effect on cost and schedule. The checklist may be used as a reminder for the planners and all the items may not relate to a specific project.

I. Project Feasibility
   A. Technical feasibility
   B. Long-term viability
   C. Political circumstances

II. Funding
   A. Sources of funding
   B. Inflation and growth rates
   C. Accuracy of cost and contingency analysis
   D. Cash flow
   E. Exchange rates
   F. Appropriation

III. Planning
   A. Scope
   B. Complexity of the project
   C. Technical constraints
   D. Sole source material or service providers
   E. Constuctability
   F. Milestones (schedule)
   G. Tune to complete (schedule)
   H. Synchronization of work and payment schedules

IV. Engineering
   A. Design and performance standards
   B. Unreliable data
   C. Complexity
   D. Completeness of design
   E. Accountability for design
   F. System integration



Table 2.1 continued...

V. Type of Contract
   A. Lumpsum
   B. Unit price
   C. Cost plus

VI. Contracting Arrangement
   A. Turnkey
   B. Joint venture
   C. Single prime contractor
   D. Several prime contractors
   E. Innovative procurement methods

VII. Regional and Local Business Conditions

   A. Number of bidders
   B. Unemployment rate in construction trades

   C. Workload of regional contractors

VIII. Contractor Reliability
   A. Capability
   B. Capacity
   C. Credit worthiness
   D. Personnel experience

IX. Owner Involvement
   A. Management of project
   B. Supplying of material
   C. Testing and inspection
   D. Safety programs
   E. Communications and problem solving
   F. Partnering
   G. Start-up operations

X. Regulatory Conditions
   A. Licenses, permits, approvals
   B. Environmental regulations and requirements
   C. Patent infringement
   D. Taxes and duties
   E. DBE (Disadvantaged Business Enterprise) involvement

XI. Acts of God
   A. Storm
   B. Earthquake
   C. Flood
   D. Fire
   E. Impact of site location on any of the above

Table 2.1 Continued...

XII. Site
- A. Access
- B. Congestion
- C. Underground conditions
  - * Soil conditions (rock vs soil, etc.)
  - * Water
  - * Utilities (existing and new)
  - * Archeological finds
  - * Hazardous wastes
- D. Noise, fume, dust
- E. Abutting structures
- F. Security
- G. Disruption to public

XIII. Labor
- A. Productivity
- B. Strikes
- C. Minority representation
- D. Sabotage
- E. Availability
- F. Work ethics
- G. Wage scales
- H. Substance abuse
- I. Local rules
- J. Unions
- K. Material wastes
- L. Workman's compensation

XIV. Loss or Damages
- A. Owner's responsibility
- B. Contractor's responsibility
- C. Engineer's responsibility
- D. Vandalism, sabotages
- E. Accidents
- F. Third Party Claims

XV. Guarantees
- A. Schedule
- B. Performance
- C. Consequential losses
- D. Liquidated damages



Appendix B contains a commentary designed to clarify and highlight risk items enumerated in the checklist. As mentioned previously, dividing risk items according to financial, design, and construction risks, contributes to a better understanding of how

these uncertainties function and affect the project. It also distinguishes between the types of skills required to study and handle these risk items. It is only natural that many items in various categories of the checklist may relate to a combination of design, construction, and financial issues as these issues interact strongly. Table 2.2 divides the fifteen categories of the risk checklist into design, construction, and financial risks. For example, the site is considered a construction risk. This is due to the fact that difficulties originating at the site (i.e. excessive ground water, differing soil conditions, difficult access) predominantly affect construction.

Click HERE for graphic.



The degree to which each of the four principal parties (sponsor, owner, engineer, contractor) involved in a rail transit project is exposed to each type of risk is presented in Table 2.3. The main purpose in including this table was to emphasize the categories that are of higher importance to the sponsor and the owner.

Click HERE for graphic.



# CHAPTER 3 -- UNDERSTANDING FINANCIAL RISK FROM THE OWNER'S PERSPECTIVE

Financial risk is directly tied to the owner's (i.e., the Transportation Authority's) ability to design and execute an adequate financial plan. As project managers lose control over this process due to insufficient planning, unforeseen construction problems, or abrupt changes in financial markets, both the amount and cost of project financing are affected. This means that it is essential to examine financial risk from the owner's perspective.

It is important to remember that the owner's risk in a project is constantly reassessed by the various sponsors who have provided financing. This group includes not only the FTA and other public agencies, but private investors as well. Therefore, it is important that we also consider how these parties assess the risk of their investment in individual projects. Note that the owner must monitor and accept the risk associated with this particular

project while the outside sponsors (investors) may be more concerned with the risk that this project contributes to their total portfolio of investments. This "portfolio" perspective maintained by those who provide financing for a variety of projects means that their risk exposure from a single project is moderated (or in some cases, amplified) by the risks associated with other projects.

The owner's objective in the management of financial risk is to secure adequate financing at a reasonable cost. In this section, we begin with a discussion of the broadest sources of financial risk maintaining the perspective of the owner. These are sources of risk that all owners must bear and that they have little control over. Next, we review more specific sources of risk that will differ for different owners or for individual projects. Third, we consider operating risk factors. These factors are highly specific to an individual project. Finally, we return to a broader perspective to consider the project's financial risk in a portfolio context. The portfolio perspective is essential for parties at all levels of a large, scale construction project, owners, contractors, and investors.

While there are a number of critical decisions the owner will be involved in that will affect the financial risk of a particular project, it is the outside investor who must finance the lion's share of construction costs. The relevance of project risk to outside investors can not be overemphasized. It is their assessment of risk that will ultimately determine the cost of financing the project and it is this cost that the owner is obligated to pay.



## I. BROAD SOURCES OF FINANCIAL RISK FROM THE OWNER'S PERSPECTIVE

From the owner's perspective, risks associated with the construction of any large scale project can be assessed by considering the uncertainty in cash flows into and out of the project. Capital costs associated with fixed guideway transit system construction are sizable and they depend on a number of factors. Ultimately, these factors are evaluated by independent agencies (public and private) who will provide financing, for the project.

If a sufficient level of financing can be identified and secured prior to the construction phase, then financial risk is largely under control of the owner. This scenario assumes that the project proceeds through construction phases with no material surprises. However, it is the nature of such projects to produce surprises and in a minority of cases the owner has to obtain supplementary financing to cover these unexpected problems as they

arise. In addition, financing costs are uncertain. Even if outside parties have committed to provide initial or supplementary financing, the cost of those funds remains uncertain.

It is difficult to separate financial risk from construction risk since both are ways of describing variations in cash flows associated with the project. To describe financial risks, let's begin with the assumption that the owner, through careful assessment of the project, has determined the level of financing needed including, a reasonable amount for contingencies that may arise. Once this amount is determined, the owner is faced with the problem of obtaining the needed funds. The cost of obtaining this capital (i.e., the price of money) will be a function of several factors. These factors include expectations of inflation, real rates of return, and ultimately, the perceived creditworthiness of the owner who must repay the funds in the future.

## The Cost of Capital

The cost of capital is the interest rate the owner must promise to investors in order to raise enough funds to finance the project. For large scale construction projects, financial risk is uncertainty with respect to (1) the dollar amount of financial resources that the project is expected to consume and (2) the interest rate that the owner must pay to obtain those funds. The first element overlaps significantly with construction risk. The owner budgets a specific amount that includes an appropriate contingency sum. As the project progresses, the actual costs may be higher than expectations due to higher than expected contingencies. This will require the owner to locate supplemental financing for the overage. On the other hand, if contingencies are lower than expected, the owner has obtained financing. that is not needed. Interest expenses will be incurred on this surplus and the owner must seek short-term investments to produce income to offset this expense.

The second element of financial risk, deviation from the expected cost of capital, will vary over time as inflationary expectations, risk-free rates of interest, and the additional risk premium demanded by investors fluctuate. This cost of capital, denoted as i, can be modeled as follows:



$$i = R + IE + RP$$

where R is the risk-free rate of interest,
IE represents inflationary expectations,

RP represents the risk premium assigned to this particular project.

It is this third component that is of most interest to individual owners or transit agencies financing individual projects since this is what differentiates them from one another in the competition for investment funds. Each of these components will now be examined in detail.

## The Risk-Free Rate

The risk-free rate of interest refers to the component of the owner's cost of capital that represents the investor's desired growth in purchasing power. In other words, it is the interest rate that the investor needs in absence of inflation or risk of any kind. It is the minimum level of compensation any investor would need to make some riskless investment. One commonly cited proxy for this rate is the interest rate on Treasury Bills. Treasury Bills are short-term securities issued by the U.S. Treasury. They mature in one year or less with 90 days being the most common life span. Investors will also add a premium for inflationary expectations to the riskfree rate they are willing to accept. Therefore, these securities provide a widely used proxy for this component of the cost of capital. Consider the illustration on the next page (Figure 3.1) showing the yield on Treasury Bills and the inflation rate for the period from 1950 to 1993. As the following graph illustrates, investors have demanded a risk-free rate of return that exceeds the inflation rate by approximately 1.5% to 3% during this period.

## Inflationary Expectations

The rate of inflation is factored into all interest calculations since both borrowers and lenders know that the purchasing power of a dollar will change over time. There is some uncertainty associated with this inflation premium over time since the inflation rate changes. Examine Figure 3.2. The rate of inflation is measured by monitoring the change in price levels for inputs used by the construction industry. Note that the level has fluctuated significantly. Inflation was moderate throughout the 50s and through most of the 60s. However, it was extremely high in the early 70s and again in the early 80S. Thus far, the 90s have been characterized by very low inflation rates.



Click HERE for graphic.

Click HERE for graphic.



Clearly, investors are willing to provide capital for a project only if they believe that they will receive an adequate return. Therefore, the owner must include compensation for the expected level of inflation during the investment period. Since the level of inflation that will actually materialize during the project's construction and subsequent operation can not be known with certainty, the owner must also consider the risk of Unexpected inflation. As an example, suppose the owner must offer a 5% premium to meet investors' inflationary expectations (IE) and to secure financing over a ten year period. If actual inflation averages 3% during this period, then the owner has overcompensated investors. If actual inflation averages 7%, then the owner has obtained funds at a bargain rate.

While this source of financial risk may seem inevitable since all owners must provide compensation for it at the prevailing level, there are ways of sharing the risk with the investor. For example, consider the adjustable rate mortgage. In this arrangement, the home buyer (owner) is seeking funds but is willing to alter the interest payments to the bank (investor) to compensate for changes in inflation. Contrast this with a fixed rate mortgage. Now, if inflation is significantly higher than expected, the home buyer's fixed payments are worth less and the bank loses. However, if inflation is lower than expected, the home buyer's payments are worth more in real terms.

An example of the outcomes of alternative financing costs to the owner is provided in Table 3. 1. This illustrates the tradeoff between fixed and variable interest rate contracts under several inflation scenarios.

This means that the owner has a choice when financing: either negotiate fixed rate financing and place the risk of unexpected changes in the inflation rate with the investor, or negotiate a variable interest rate plan where the uncertainty of inflation rate changes is retained by the owner.

An example of a variable rate issue is the $90 million of bonds sold by the Massachusetts Bay Transportation Authority in 1984. These bonds carried an initial interest rate of 6.25%. After each 6 month period, the interest rate is readjusted to reflect rates on securities with similar maturity and risk. According, to the contract, the interest rate is capped at 12%.

The choice between fixed rate and variable rate financing is

not trivial. Investors will expect compensation for bearing inflation risk and therefore, the prevailing rate for fixed rate financing will typically be above that prevailing for variable rate financing. Variable rate bonds are most popular during periods of high expected inflation.

The Risk Premium

It is worth restating the simple equation that began this section with a minor modification:



$$i = (R + IE) + RP$$

This suggests that two of the three components of the cost of capital are largely determined by broad economic forces. While the owner must be aware of these forces and their influence on financing costs and risk, the owner has no material control over these factors. It is this third factor, the risk premium, that is somewhat under the control of the owner.

Click HERE for graphic.

The owner's cost of capital is largely a function of the investor's expectation of being compensated as promised. For a large transit project this will be a function of a variety of factors. One group of factors is related to the project's operating risk, or the variability of revenues and expenses during and beyond the construction phase. Other factors are more specific to the contract between the owner and those providing the financing.



## II. SOURCES OF FINANCIAL RISK THAT ARE SPECIFIC TO THE OWNER AND THE PROJECT

To obtain financing, the owner must be able to prove to public funding, agencies and private investors that there is significant expectation of future cash inflows from the project. There are four primary sources of revenue that the owner can use to meet interest and principal obligations. These are new tax revenues (sales or use taxes, or other special assessments), direct Federal grants from the FTA, guarantees of subsidies from the municipality, state, or a third party, and user fees (or farebox revenues) that begin to flow once the project is operational. We will discuss the first three of these sources and leave user fees for the subsequent

section regarding operating risk factors.

## The Breadth of the Revenue Stream

A primary determinant of the cost of financing, a large scale transit project is the sources of future cash flows that can be used to repay the financial obligation. Revenue bonds are sold to investors with the stipulation that repayment will be made from cash inflows generated directly from the project. There are a variety of examples of the types of projects financed with revenue bonds including turnpike construction (repaid with tolls), university facilities (repaid with tuition revenues), power plant construction (repaid by consumers of electricity), and public transit facilities (repaid with special taxes or fares).

Consider the inherent risk associated with such financing if the revenue stream does not materialize or is significantly below original expectations. A famous example of such a failure is illustrated by the default status of bonds issued in the 1970s by Washington Public Power Service. These bonds were sold to finance the construction of new, nuclear powered Generators needed to meet projected demand for electricity in the state of Washington in the coming, years. After these revenue bonds were sold, the project began to experience significant cost overruns. Moreover, the tide of public opinion began to move against the construction of nuclear power facilities. The combination of cost overruns and delays created by public opposition eventually caused the project to be abandoned. A similar fate awaited holders of Public Service of New Hampshire bonds issued at about the same time.

General Obligation bonds represent an alternative method of specifying the future cash flows that will be used to service project debt. Here, the municipality, state, or political region with the authority to levy taxes, agrees to accept the obligation to repay the debt. This means that if expected revenues do not materialize, the state (or other political entity) will make payments out of general tax revenues. From the investor's perspective, this is a more secure investment since repayment does not ultimately depend on project specific future cash flows. Hence, this explicit guarantee provided by the state will lower the risk premium associated with the bonds and result in a lower cost of capital. The vast majority of bonds associated with large scale transit projects fall into the General Obligation category.



## Specific Sources of Revenue Associated with Financing

Broad Based Taxes: A number of transit projects in recent years

have used a new sales or excise tax as a primary source of funds for construction and operation. For example, in 1992, the Orange County Local Transportation Authority raised $525 million for a variety of projects by initiating a 1/2% sales tax for a twenty year period. In a healthy economy, this represents a significant contribution to revenues. Yet, the expected revenue may not materialize if the level of economic activity falls below the original forecast. This means that the financial success of the project is closely tied to the vitality of the local economy. While the transit project may provide a stimulus for economic growth, the overall growth or contraction of the economy will depend on more fundamental economic factors such as the level of new investment and the unemployment rate. Macroeconomic factors such as these can not be managed by the owner and thus, they represent a source of risk that the owner and those who provide financing for the project must bear.

Even in a robust economy, these revenue sources may still be at risk. What the government grants in tax revenues, it can also take away. Consider the 1% sales tax recently approved to finance transit projects in metropolitan Houston. The transit authority can collect and employ these funds, but they have no authority to issue bonds for longer term project financing. This means that they may be obliged to "save up" tax revenues until they accumulate a sufficient amount to begin a capital project. However, there may be competition for these accumulated funds from other groups who see these funds as a source of financing, for alternative transit projects.

A second method of raising funds for construction and operation requires a special assessment of the municipalities served by the new project. These arrangements can be negotiated prior to the initiation of the project, minimizing the risk associated with these revenues. However, it is possible that problems will develop in the future if these districts do not see the expected benefits materializing. Local governments may attempt to withhold payment of this assessment in later years. Such issues of equity may also arise if the ability to pay the assessment differs significantly across communities receiving equal benefits from the project. Poorer communities may attempt to shift part of their assessment onto their wealthier neighbors. Again, many of these issues can be addressed in advance of the projects startup, but such problems may develop at some future point. The owner may find itself scrambling to find alternative sources of financing while the ultimate balance of assessments among communities served is determined through a lengthy legal or political process.

One additional method of financing, transit projects is through establishment of partnerships with private developers. Union Station in Washington, D.C. is an excellent example of such an arrangement. Not only is the station a high volume, multi-modal

transportation facility, it also houses a variety of shops and restaurants and is a legitimate tourist attraction. Private developers agreed to assist in the upgrade of the facility and to share operating costs with the public transit



authority partners. As in the initial discussion off sales tax financing, this arrangement will work well only if the shops and restaurants are successful. Otherwise, they will not generate revenues sufficient to cover their share of the station's operating costs. If the private partners default on the agreement to pay part of the operating costs, the transit owner will be obligated to cover them.

Federal Appropriations: The Federal government provides both Capital Expansion Funds and Operating Assistance Funds as outright grants through the FTA. Once a project has been approved for funding, it will receive these sources of financing. However, a different type of risk must be considered here. Much of the FTA's grant money is derived from the federal tax on gasoline. Their share of these revenues is not specified until late September or early October of each year. In practice, this means that the transit agency can expect to receive all funding allocated to the project, but is unlikely to receive funding exactly when it is needed. This leaves the transit agency with a financing gap that must be filled using alternative temporary sources of funds. There are several sources of such funding, one of which is the sale of Tax or Grant Anticipatory Notes. These are short term IOUs issued by the owner that are collateralized by the past approval of federal funding. This provides the owner with the needed financing to manage the project properly. However, it also saddles the owner with an additional interest expense since the investors who purchase these securities expect some compensation for their loan of financial resources.

Municipal, State, and Third Party Guarantees: Recall the distinction between Revenue bonds and General Obligation bonds discussed previously. Most large transit authority financing, involves a guarantor. The Guarantor may be the government sponsoring the transit authority or it may be a private insurer. General Obligation issues carry an explicit guarantee that the state will provide funds to meet the project's financial obligations in full if necessary. However, since transit authorities are public agencies, even revenue bond agreements may infer a guarantee that the sponsoring government will make up any revenue shortfalls associated with the transit project during construction or once under operation. This inference of a more general obligation, or "implicit guarantee," has been upheld in very few cases.

Even when the sponsoring government has explicitly guaranteed to subsidize the project, there is still uncertainty regarding the timing and extent of the government's supplemental payments. While most investors would expect the government to make good on such promised payments, some governments are perceived as more creditworthy than others. So, investors require some compensation for this uncertainty. This is the role of the private insurer. An owner can secure the explicit guarantee of payment in full to bondholders from a private agency. If this is done, there is less inference of coverage. However, the extent of the coverage will be a function of its cost. The owner must assess the tradeoff between the cost of coverage and the interest cost reduction that the coverage will produce.



An aggregate measure of financial risk: Bond Ratings

All of the factors previously discussed require careful scrutiny and synthesis to quantify financial risk. Nearly every substantial sale of long term securities requires the owner to engage the services of a rating agency to certify the level of financial risk. Few large investors will consider providing funds for a project that has not been rated by a bond rating agency. Moody's and Standard and Poor's are the two largest bond rating agencies in the U.S. A rating agency will issue a rating to a bond issue after carefully considering the details of the project and the financial history of the owner. A high rating denotes a high level of creditworthiness and means that investors will require a lower risk premium from the owner. An owner with a low rating is obliged to provide higher risk compensation to investors. One alternative is to find a larger investor who is willing to finance the entire project without obtaining a rating. However, such financing sources may be difficult to locate and will require some assessment of creditworthiness anyway.

The owner has significant incentive to manage the financial risk of the project as it will influence the bond rating, hence the cost of capital. The difference in interest expense between two adjacent bond ratings can easily be 0.5%. While this may not appear to be large, for a $100 million bond issue, it represents a recurring, annual difference of $500,000 for the life of the bonds issued. The owner also has the option of insuring the issue. This assures the bondholders of payment and provides the bond issuing agency with a lower interest expense since the bonds will carry the higher rating of the insurance company. As an example, Los Angeles County Transportation Commission issued two series of bonds in 1991. One series carried the bond rating of Los Angeles county,

"A". The other bonds were insured by AMBAC Indemnity Corporation and were given the superior rating of "Aaa". This translated into an approximately 0.3% interest rate differential between the issues that raised a combined total of $281.5 million.

Table 3.2 - A Sample of Recent Interest Rates for Municipal Bonds with Different Ratings: August to October 1993

| Twenty-Year Bonds | August | September | October | 12 mo. High |
|---|---|---|---|---|
| Aaa | 5.37% | 5.25% | 5.14% | 6.10% |
| Aa | 5.50 | 5.39 | 5.25 | 6.23 |
| A | 5.62 | 5.52 | 5.41 | 6.37 |
| Baa | 5.84 | 5.76 | 5.63 | 6.51 |
| Ten-Year Bonds | | | | |
| Aaa | 4.73 | 4.62 | 4.49 | 5.24 |
| Aa | 4.80 | 4.72 | 4.60 | 5.36 |

Source: Moody's Bond Record, October 1993.



In addition to factors that are specific to the project or the issuer, the size of the risk premium investors demand fluctuates with general economic conditions. During periods of growth, the differences between risk premia for projects (or owners) with differing levels of risk, grow smaller. Overall concern with partial, or complete default is minimal during such periods. Therefore, financing of risky projects is relatively cheap. However, during recessionary periods, the opposite is true. Investors are more wary of high risk projects and will finance them only at significantly higher rates compared to other projects. While the owner may have a sense of urgency to initiate and complete a risky project during an economic downturn, financing will be more costly. This source of financial risk can be managed with patience.

## Other Sources of Project Specific Financial Risk

1. Size of contract: Generally, financing, of smaller amounts (under $50 million) is more costly due to the fixed costs of finding buyers for what may be seen as a specialized issue. Also, as the aggregate value of total issue becomes smaller, so does the number of potential traders in the secondary market. In other words, as investors desire to resell the bonds they purchased in the original financing, they will find fewer buyers unless they are willing to sell at a heavily discounted price. The investor who purchases securities from a small issue must bear liquidity risk and will expect a higher interest rate as compensation.

2. Need for Working Capital: Since a large project requires significant funds for day-to-day operations, the cost of these funds also represents a source of financial risk. Short-term interest rates are more volatile than longer term rates. Yet, on average, they are lower. This produces a risk management decision for the owner. Do you finance most, or all of your working capital using short term sources? If so, then you expect to have a lower cost of capital, but there is also the risk that this cost will fluctuate adversely. Or do you finance most, or all of your working, capital with long term sources? Here, your cost of capital is certain, but will probably be higher than prevailing rates for short term sources.

3. Bankruptcy of Contractor: In all ma or construction projects, the contractor is required to secure a performance bond from a surety company. This reduces the loss associated with non-performance by the contractor. However, if the contractor is unable to complete the project because of an inability to contain costs on this project (or possibly on some other projects), the owner will experience a fluctuation in the cash flows dedicated to the project. These sources of financial risk may include changing the payment pattern to maintain solvency of the contractor, delays in obtaining payment from the surety, the amount of rework needed, or the cost of abandoning the project.

Although, the surety industry serves this purpose well, the financial health of the contractor is clearly an issue for the project owner. While much of this concern is addressed in the



prequalification process, it is worthwhile to briefly consider the primary determinants of the financial condition of the contractor. These can be assessed through thorough scrutiny of 0 financial statements and also by developing a variety of test statistics based on these figures. One well-known statistic, the Z-score, will be reviewed.

The central financial question the owner wants to answer with respect to the contractor is: Does the contractor have the financial capacity to complete the project in a timely manner and within other contractual standards? One common method of assessing the likelihood of contractor's financial viability is through financial statement analysis. This analysis examines the contractor's current and past financial statements to detect trends in various strengths and weaknesses. These trends may also be considered in conjunction with the trends exhibited by industry peers.

Financial ratios are the most common method of analyzing financial statements. These ratios show the relationship between various items in financial statements and are attempts to measure some dimension of financial strength, e.g., liquidity. They are simple mathematical calculations and have little meaning by themselves. Only by comparing ratios and determining the underlying causes of differences among them does ratio analysis become meaningful.

Ratios can be grouped into several categories including Liquidity, Profitability, Operating Efficiency, and Leverage. For example, the current ratio is a common measure of liquidity or the ability of a firm to meet its short term obligations. It is a simple ratio of current assets to current liabilities. A low or declining current ratio may be indicative of a firm with especially effective cash management or one that is having, increasing difficulty paying its bills. Profitability measures are the proverbial "bottom line". These measures examine profits (operating profits, after-tax profits, etc.) as a percentage of sales or assets. A number of financial ratios are used to measure the operating efficiency of a firm relative to some standard. These ratios provide a rough indication of the degree of idle investments in various assets and liabilities. They also measure the firm's effectiveness at generating revenues from various classes of assets.

The last group of ratios, Leverage ratios, examine the debt position of the firm. In addition to the need to generate sufficient financing to cover fixed operating costs, debt carries a fixed financial obligation. Therefore, high debt usage also indicates a high level of interest expense that remains high regardless of any increase or decrease in revenues generated. This means that firms with high levels of debt are riskier than similar firms with more moderate levels of debt. The effects of debt financing are often described in terms of creating financial leverage. This means that use of debt magnifies the gains or losses that the firm will experience.

Financial statement analysis, including ratio analysis, is further discussed in Chapter 4. For a more detailed examination of financial statement analysis, see Keown, et. al (1993).

There have been a variety of attempts to forecast financial failure, or bankruptcy, of firms by using financial ratios. One of the most widely cited is model developed by Altman (1968,



1983). This model generates an index, or Z-score, which has been shown to be a reasonable indicator of the likelihood of bankruptcy

of an individual firm during the upcoming 12 months. A current version of the Z-score model uses the following 7 ratios:

- Retained Earnings/Total Assets (measures profitability)
- Standard Deviation of Operating Income/Total Assets (stability of earnings)
- Earnings before Interest and Taxes/Total Assets (measures profitability)
- Earnings before Interest and Taxes/Interest Expense (measures leverage)
- Current Assets/Current Liabilities (measures liquidity)
- Market Value of Common Stock/Book Value of Equity (measures leverage)
- Total Assets

The Z-score model was developed by examining financial statements of a sample of firms one year prior to bankruptcy and financial statements for a sample of firms that survived. The statistical technique used here is called discriminant analysis. It is a form of regression analysis that distinguishes the best statistical relationship between the variables listed above and the Z-score. The weaker a finn's collective measures of financial health, the lower the resulting Z-score. Once this model was estimated using samples of bankrupt and surviving firms, its validity was verified using new samples of observations. The model has been shown to be 95% accurate at forecasting bankruptcy one year in advance and 72% accurate two years in advance.

Two problems with the general model outlined above are (i) the lack of stability in ratios for individual firms over time and (ii) the variation in ratios that results from different industry norms. These problems can be addressed if the ratios are expressed in "industry relative" form. This means that the ratios described above are restated, dividing each firm-specific ratio value by the average for its industry. This technique allows the owner to assess the financial health of an individual contractor relative to other contractors instead of a broader sample of firms from many different industries. Platt and Platt (1990) show that this refinement provides superior prediction of bankruptcy.

In summary, the owner has a significant interest in developing an independent evaluation of major contractors for a project. While this financial analysis is undertaken by the surety firm, the owner still bears some risk in the event of contractor default. The level of risk can be assessed through several modes of financial statement analysis and should be performed by the owner during the process of evaluating contractor bids.

4. Role of International Financing: Large scale capital projects require large scale financing. When arranging financing, the key

issue for the owner or sponsor of a transit project is the cost of this financing that is represented by the interest rate that investors require. Why limit this search for financing to domestic sources when there is a significant possibility that foreign investors would accept the same level of project risk in return for a lower rate of interest?

Capital markets are truly global. The investment banking industry has evolved to assist in



the financing of large projects. Investment bankers are adept at identifying potential sources of funds throughout the world. Foreign investors may be willing to finance a public transit project in the United States to diversify their holding and reduce their portfolio's overall risk. They may also want to buy bonds that make interest payments in dollars and use these funds to meet a dollar denominated liability. This reduces the need to make costly currency exchanges and also reduces the investor's exposure to risk from fluctuation in exchange rate.

Today, it is not uncommon for a large portion of capital needed for a major construction project to come from foreign investors. If financing is obtained through the sale of bonds or notes to foreign investors and these investors are expecting repayment in their home currencies, then the owner has an additional potential for cash flow swings: exchange rate fluctuations. For example, if Japanese investors purchase securities that are denominated in yen, then the owner must make interest and principal payments in yen according to a fixed schedule. As the dollar grows stronger against the yen, the owner can purchase the needed yen with fewer dollars and reduce financing costs. However, if the dollar weakens against the yen, the same amount of yen will cost more in dollar terms and financing, costs will increase. In fact, the dollar has weakened against the Yen and against other important currencies, such as the Deutchmark, in recent years as Figure 3.3 illustrates.

Click HERE for graphic.

Two other elements are important to keep in mind. First, the owner will not borrow funds abroad unless they are expected to be less costly than those that could be borrowed in the U.S. Second, there are well established methods involving forward and future contracts for foreign currencies that can be used to hedge this exchange rate risk, but these techniques are costly.

A simple example can illustrate exchange rate risk and hedging. Suppose a transit agency raises short-term funds by selling notes worth 110 million Yen. These notes mature in 6 months and carry a 3% interest rate. If the current exchange rate is 110 Yen per $ 1, then the sale will



raise $1 million. Now consider the three scenarios illustrated in Table 3.3.

Table 3.3 - Illustration of the Effects of Exchange Rate Risk on Borrowing Costs

| | Strong Dollar | Stable Dollar | Weak Dollar |
|---|---|---|---|
| Amount borrowed | $1 million | $1 million | $1 million |
| New exchange rate | 120 Yen/$1 | 110 Yen/$1 | 100 Yen/$1 |
| Yen to repay | 113.3 million | 113.3 million | 113.3 million |
| Dollar cost | $0.94 million | $1.03 million | $1.13 million |
| Interest expense | -6.0% | 3.0% | 13.0% |

Clearly, the fluctuation in exchange rates causes the interest expense to vary considerably. One simple method for stabilizing, or hedging, this risk is to enter into a forward contract by agreeing to take delivery of 113.3 million Yen in six months. This allows the transit agency to lock in an exchange rate for the future transaction. If the forward rate is 109.5 Yen per $1, then regardless of fluctuation in the exchange rate, the agency can purchase the 113.3 million Yen needed to satisfy the loan for $1.035 million. This effectively locks in an interest expense of 3.5% for the funds. While there are fees associated with these hedging transactions, there is also a reduction in exchange rate risk.

## III. OPERATING RISK FACTORS

Very few transit projects actually generate operating revenues in excess of operating costs. Therefore, operating cash flows are at best, a secondary consideration in determining the financial risk of a project. However, since the need for operating subsidies varies from year to year and since operating and financing costs are covered from a set of overlapping sources of funds, it is worthwhile to consider sources of operating risk. In this section, we first discuss the primary sources of operating revenue and then examine the impact of different types of operating costs on

operating risk.

Since the project that the owner is constructing is expected to have a long life, the revenue stream that the project will produce after it begins operation is a secondary source of funds for repayment. There are two primary sources of operating revenue that the owner can use to meet operating expenses and possibly contribute to interest and principal obligations. These are user fees (or farebox revenues) and operating subsidies (from the FTA, municipality, or state). In addition, the examples of broad based taxes described above may be designed to contribute to operating expenses after the original construction costs of the project have been repaid.



Sources of Operating Revenues

Farebox revenues: Any public transportation project must provide some forecast of ridership and farebox revenues in order to determine its feasibility. Such forecasts are essential to determine the likely levels of such revenues and the variability of these cash flows under various conditions. Forecasts of ridership and revenues will also depend upon fare structures that subsidize certain groups (e.g., senior citizens, students, non-peak time riders). This will make the task of forecasting farebox revenues more difficult. Refer to Pickrell (1990) for a more detailed discussion of the determinants of ridership and forecasting errors. But a more relevant source of operating risk related to the subsidization of riders is the political dimension. Governments within the region served by the project may force the owner to alter the subsidy mix at some future point. This means that the owner's ability to control this source of operating risk is imperfect at best.

It is also essential to put farebox revenues in perspective. They provide less than half of the revenues needed to cover operating expenses. For example, Table 3.4 provides the farebox revenues as a proportion of operating expenditures for a sample of transit systems that have recently issued new bonds:

| OWNER | Farebox Revenues as a % of Operating Expenditures |
|---|---|
| Metro. Atlanta Rapid Transit System | 37.2% |
| L.A. County Transportation Comm. | 39.0% |

| | |
|---|---|
| Regional Transportation Dist.(Denver | 15.0% |
| Greater Cleveland Reg. Transit Auth. | 24.1% |
| Orange County Local Trans. Authority | 26.9% |

Source: Moody's Municipal Credit Report, 1992

Furthermore, farebox revenues are initiated only after construction is completed. This means that other sources of revenue must be secured to meet financial obligations to investors.



Federal, State, and Municipal Subsidies:

A final source of operating revenues for the owner is direct operating subsidies from the FTA or the state, county, or municipality where it operates. For example, the Commonwealth of Massachusetts provided 62.2% of the total expenses incurred by the MBTA during 1991. Virtually all of this subsidy was used to cover operating expenses. The MBTA also received Operating Assistance Funds from the FTA during this time. The revenue stream from a specific source (farebox or sales tax revenues) may fluctuate in the future, but the government can levy taxes to assure continued operation of the transit system. It is important to emphasize the role that the governmment's willingness to subsidize operations plays in the determination of current and future costs of financing construction. If the subsidy is seen to be certain, investors will also see a high likelihood of repayment of capital costs and will accept a lower risk premium. This results in more moderate capital costs for the owner.

The Nature of Operating Risk: Operating Leverage

Operating, expenses can be categorized as variable or fixed. For example, some expenses, such as fuel, vary directly with the level of operations. As activity rises or falls, fuel costs do the same. Contrast this relationship with the expenses generated by the establishment of a new structure to house the administrative activities needed by the project. The maintenance and operation of this facility will not rise and fall with ridership. Once established, such a facility represents a fixed operating cost to the project. The level and proportion of fixed and variable expenses have an important relationship to operating risk. This relationship is referred to as operating leverage and will be discussed in the subsequent section.

The previous section detailed a variety of financing alternatives and the sources of risk associated with each. The

owner's risk exposure is also a function of the cost structure associated with the project. If we again consider the operating expenses of the project during construction and operation as fixed or variable, we can illustrate the influence of different levels of fixed cost. Variable cost items typically include such items as wages of non-administrative labor, supplies, and utility expenses. Variable cost items vary directly with the output of the project which may be measured in passenger miles. Fixed cost items are those expenses that are incurred in their entirety regardless of the planned or actual level of output. These would include salaries of administrators, office space, and construction costs.

The numerical example in Table 3.5 further illustrates the influence of cost structure on operating cash flows and risk. Consider two transit agencies, A and B. A generates revenues of $0.40 per passenger mile and incurs variable costs of $0.15 per passenger mile. A also has fixed operating costs of $6,000,000 per year. B also generates revenues of $0.40 per passenger mile. But B has variable operating costs of $0.30 per passenger mile and fixed operating, costs of $3,000,000 per year. Both A and B forecast ridership for the upcoming year at 20,000,000 passenger miles.



Table 3.5 - Illustration of the Effects of Operating, Leverage

| | Transit System A | Transit System B |
|---|---|---|
| Revenue per PM: | $0.40 | $0.40 |
| Var. Cost per PM: | 0.15 | 0.30 |
| Contribution to Fixed Costs per PM: | $0.25 | $0.10 |
| Forecast of PM for year: | 20,000,000 | 20,000,000 |
| Operating funds to apply to Fixed Costs: | $5,000,000 | $2,000,000 |
| Fixed Operating, Costs: | $6,000,000 | $3,000,000 |
| Forecast of Surplus or Subsidy needed | ($1,000,000) | ($1,000,000) |

In this example, both transit systems will require an additional $1,000,000 subsidy if the forecast of ridership is accurate. However, if actual ridership is 10% below the forecast, the situation will differ. Following the approach used in the above example, A will now need a subsidy of $1,500,000 and B will

need a subsidy of $1,200,000.

Why is the subsidy needed now greater for A? It is the relative prominence of fixed operating costs. This is the effect of operating leverage. When actual demand is below expected demand, the need for operating subsidies expands (or the operating surplus contracts) more rapidly for the organization with greater fixed operating costs. Conversely, the operating surplus expands (or the operating deficit is reduced) more quickly if actual demand is above expected demand.

This difference in cost structures can be illustrated across a broader range of ridership in the graph shown in Figure 3.4.

The graph illustrates the higher operating risk associated with B's operating cost structure. There is one additional method of measuring and interpreting this source of risk. It is called the Degree of Operating leverage, or DOL. DOL must be calculated with reference to some specific level of demand (or ridership). It is common to use to the estimate of expected demand to derive the measure. The simple formula for DOL is:

$$\text{DOL} = \frac{\text{(Total Revenues - Total Variable Costs)}}{\text{(Total Revenues - Total Variable Costs - Fixed Operating Costs)}}$$



Click HERE for graphic.

So, in this example, total revenues result from an expected ridership of 20,000,000 passenger miles times $0.40 per mile. This results in revenues of $8,000,000 for both A and B. The calculations are as follows:

$$\text{DOL for A} = \frac{[\$8{,}000{,}000 - (\$0.15)(20{,}000{,}000)]}{[\$8{,}000{,}000 - (\$0.15)(20{,}000{,}000) - \$6{,}000{,}000]}$$

$$= 5.0$$

$$\text{DOL for B} = \frac{[\$8{,}000{,}000 - (\$0.30)(20{,}000{,}000)]}{[\$8{,}000{,}000 - (\$0.30)(20{,}000{,}000) - \$3{,}000{,}000]}$$

$$= 2.0$$

These statistics can be interpreted as follows. Every 1%

decrease in ridership on system A will reduce the surplus or, in this case, increase the need for subsidization by 5%. However, system B's finances will be less severely affected by deviations from the expected level of ridership. It will experience a 2% increase in the need, for subsidization for every 1% reduction in passenger miles. In this example, both A and B are similarly affected by changes in demand,



but A has the greater risk of large operating losses due to unfavorable chances in ridership.

In summary, the more prominent the role played by fixed operating costs, the greater the degree of operating leverage, or operating risk. This is relevant to the planning process in the construction of large scale transit projects for two reasons. First, all large scale projects pass a significant fixed cost component on to the subsequent operation of the new or expanded system. Unless the new operating revenues can cover new, variable operating expenses and also make a significant contribution to covering new fixed costs, operating leverage and project risk will increase. Second, project managers may have several alternative construction and operating designs with different levels of fixed operating costs. The ability to select designs that result in lower fixed operating costs will reduce the leverage and risk associated with the project.

## IV. FINANCIAL RISK FROM THE PERSPECTIVE OF THE CONTRACTOR: THE PORTFOLIO PERSPECTIVE

Obviously, the owner and funding agencies will not grant funds to projects it does not expect to be completed. Yet, with every project there is some probability that events, unforeseen at the time of the award, will force both the local transit authority and other funding agencies to reevaluate the project's viability. This reassessment may lead to the need for a significant increase in the agency or owner's financial commitment, a scaling back of the project's scope, a postponement of the construction schedule, or outright abandonment of the project.

Again, in its assessment process, the owner considers the viability of projects prior to issuing grants to assist with construction. This assessment should entail significant examination of financial and construction risks and should account for many of the financial risk elements discussed in the previous section.

Yet, the contractor has one significant risk management tool that is not typically available to local transit authorities:

Diversification. This term refers to the contractor's ability to make investments in a variety of projects each of which generates a cash flow that is in some way different from cash flows generated by other active projects.

Consider the following simple example. Suppose Contractor X has been approved to participate in two projects, A and B. Further, suppose A and B represent two ma or rail projects in New England. Since both projects are in the same region, involve similar raw materials and production technologies, profitability of both projects will react similarly to changes in the cost of a key input or new local legislation. From a financial perspective, both projects will be helped or hurt by a change in a common factor.

Now suppose that A is a rail project in New England project and B is a rail project in the Southwestern U.S. While there are still many common factors regarding, inputs and technologies, there are also likely to be distinctions between wage rates, costs of other basic



inputs, and other aspects of the projects. It is these differences that provide Contractor X with the opportunity to diversify risk. It is possible that an interruption in the delivery of steel may slow progress on the project in Boston while the Santa Fe project continues unimpeded. The reverse situation could be true as well. In other words, by diversifying funds across regions of the U.S., a problem that is concentrated in any one region will have less of an impact on Contractor X's portfolio of projects.

Diversification can be achieved using other scales as well as location. For example, certain categories of projects may have similar construction inputs. The contractor could modify its exposure to this source of risk by developing a portfolio of projects with dissimilar construction inputs or technologies. This may mean that the contractor will bid for a project which appears very risky when compared to other alternatives because the costs associated with the risky project are not highly correlated with other ongoing projects. This means that it is not the "raw" risk of a project that matters to the contractor. It is the risk that the new project brings to the existing portfolio of projects.

It is apparent that large construction firms have greater opportunity to exploit diversification benefits than smaller firms. Smaller firms may be forced to specialize in a particular niche until they accumulate the flexibility to manage several large projects in different geographic regions or using different construction technologies or inputs. For example, Perini is a very

large firm that builds embassies for the U.S. government in foreign countries. But this firm also encases in the construction of tunnels and highways in the U.S. and elsewhere. This provides Perini with significant advantages that would be difficult to exploit for a smaller construction firm. The smaller firm must balance the risks associated with inexperience in a new line of construction with the potential benefits of diversification.

The concept of diversification is simple and powerful. By investing in projects that are viable when considered in isolation but also bearing distinct features not found in other projects, the contractor can reduce its exposure to financial risk and simultaneously improve its performance as measured by the budgetary success of projects funded.

## V. SUMMARY

Financial risk results from uncertainty regarding capital costs. This uncertainty results from changes in the rate of inflation and the risk-free rate of return. In addition, and unique to the project, a risk premium must be added to these other costs to compensate the investor for the possibility of default or delay in receiving interest and principal payments. Ibis premium is largely determined by risk associated with specific sources of revenues to be used to repay the funds borrowed. Investors will also require a higher risk premium during recessionary periods and a lower one during periods of growth since the economy wide rate of default changes during such periods.



Beyond the broad economic factors that influence capital costs, there are a variety of financial risk factors that are specific to,the owner and the project. One such factor is the breadth of potential sources of cash flow that can be applied to servicing the debt. General Obligation bonds provide an explicit promise by the state or municipality to use general tax revenues to cover interest and principal expenses if revenues generated from sources specific to the project are insufficient. Revenue bonds do not carry such an explicit promise and rely solely on project specific revenues for repayment. They are therefore more risky from the investor's perspective and more expensive from the owner's perspective. Further analysis of project specific revenues and other guarantees are needed to assess the level of financial risk.

Bond ratings represent a useful proxy for financial risk factors. These ratings reflect the creditworthiness of an owner as assessed by an independent rating agency. Since most of the bonds sold to finance large scale transit projects are sold to large

institutional investors, obtaining a bond rating is a necessity. Furthermore, the rating itself will have a significant influence on capital costs.

Other project specific sources of financial risk include the fluctuating need for working capital and the potential for delays due to a number of construction risk factors (i.e., chanced conditions, work stoppages, political concerns, and possibly the bankruptcy of the contractor). If the owner has financed using funds from a foreign country and is required to repay these funds with foreign currency, then there is also exposure to exchange rate risk. While there are several methods the owner can employ to minimize this exposure, each carries a cost.

Finally, from the perspective of the contractor, there may be significant opportunities to diversify risk associated with any individual project by investing in a varied portfolio of projects. If the sources of financial (and construction) risk vary by project type, geographic region, or some other distinguishing attribute, then there is opportunity for the contractor to reduce its overall exposure to risk. The ability to exploit these sources of risk reduction are largely a matter of size and experience of the contractor. Effective risk management by the contractor is relevant to the owner because diversified risk does not require compensation. Therefore, the well diversified contractor can afford to submit a lower bid for a project than a contractor who has not diversified effectively even if both perceive the project's "own" risk to be the same.



# CHAPTER 4 - SURETY'S RISK ASSESSMENT

One of the most important questions that an owner will ask.during the contractor selection process is: "Does this construction company have the financial strength, managerial talent, and technical expertise to complete the project successfully?" Essentially, this question focuses on die risk exposure to the owner in the event of default of the contractor. Since many of the projects financed by government agencies entail large sums of money and long durations, a contractor failure would inevitably result in schedule delays and cost overruns. Accordingly, an in-depth evaluation of the selected contractor is a necessary step in risk assessment. Surety, the provider of payment and performance bonds to the contractor has to answer the same question before bonding a contractor. So studying the methods that surety industry use in evaluating a contractor's riskiness can provide insight into project's risk assessment.

## BACKGROUND

Beginning with the passage of the Miller Act in 1935, the surety industry became a distinct, yet integral part of the construction business. The Miller Act requires that every contractor bidding on work for the Federal Government in excess of $25,000 be able to provide a bid bond, a payment bond, and a performance bond (Halpin and Woodhead, 1980). In the past few years there have been several suggestions that the $25,000 minimum should be increased to a higher level The Office of Federal Procurement Policy is studying the possibility of increasing the threshold for surety bonds and permitting the use of Letters of Credit in place of bonds (Hancher, et al (1991). These bonds are obtained from the contractor's Surety Agent. It is the function of the surety industry to first analyze each contractor applying for bonding and then to issue the appropriate bonds if it determines that the risk of failure on the part of the contractor is minimal. In essence, the surety prequalifies the contractor for each particular project. Accordingly, an owner should view the surety industry as a risk evaluation and transfer mechanism.

Suretyship is defined as the obligation to pay the debt of, or answer for, the default of another. It is therefore, a tripartite relationship. The surety contract binds the surety to guarantee the obligee (project owner) that the obligor (contractor) will complete the work as agreed in the construction contract. In the event of default, the owner has the right to request that the surety complete the work, or have it completed by another party. The surety is liable up to the face value of the performance bond (Halpin and Woodhead, 1980).



### Surety vs Insurance

Surety professionals are emphatic about the fact that their industry should not be confused with the insurance industry. There are many differences between the two groups. For example, the insurance industry is based upon the assumption that losses will occur. The probability of events such as hurricanes, fires, accidents, etc. are determined by actuaries from large populations. Premiums are based upon the likelihood of the disaster and their magnitude, and benefits are paid when a loss is sustained by the insured. On the other hand, the surety industry carries the assumption of no losses. According to surety professionals interviewed for this research, the premium that is charged is simply perceived as a fee for the extension of credit and for the prequalification services performed. Suretyship is a loss-avoidance mechanism designed to prequalify firms based on their credit strength. It should be noted that construction company

principals retain the economic risk of contract default by signing an indemnity agreement, which, in essence, holds the surety harmless for losses incurred (Bickelhaupt, 1983). Accordingly, construction bonds are risk-transfer mechanisms that shift the potential for loss from the owner to the surety. In the event of an actual loss, the surety can and will try to get its losses from defaulted contractors. This is perhaps the most profound difference between insurance and surety as far as the contractor is concerned.

## Regulations

All surety companies desiring to provide bonding to federally funded construction projects must attain certificates of authority from the Department of the Treasury. On July I of every year, the Department publishes a listing of acceptable sureties in the Federal Register, Circular No. 570 (1992). This pamphlet lists the names, addresses, underwriting limitation per bond and locations (States) in which each surety is licensed. As of July 1, 1992, 279 sureties were approved by the Department of the Treasury. Although limitations have been established on a per bond basis, the Department of the Treasury does not set limits on the total face value (penal sum) that a surety may have outstanding. The bonding ceilings set forth are not legal maximums, but rather boundaries below which a surety need not acquire external protection for itself. That is, ff a surety desires to provide a bond in excess of its underwriting limitation, it must protect the amount above the demarcation line with either reinsurance, coinsurance, or other methods of risk sharing in compliance with Treasury Circular 297 (1978). The Treasury considers these amounts to be an excess risk (Circ. 570, 1992). According to the responses obtained from our interviews, surety companies rarely reach their bonding limitation. This is due to the fact that being in the risk analysis business, they recognize that it is preferable to coinsure rather than put all of their eggs in one basket. On large-scale construction projects, there is typically more than one bonding company. In such instances the sureties will form an underwriting group, known in the trade as cosurety situation. The assemblage will have a lead surety and prorate the liability in accordance with each company's participation in the project. The mechanism for risk sharing between bonding companies is through a written agreement called a Side Agreement (Bickelhaupt, 1983). Thus, the sureties spread the risk over large populations and remain within their own self



imposed bonding limits. These firms generally have internal

bonding ceilings below those published in the Federal Register1.

An alternative to coinsurance is reinsurance. Reinsurance occurs when the risk (penal sum) is greater than the level that the surety may legally assume on one project, or is larger than it is willing to accept. Essentially, the company will "write the bond and reinsure the excess liability with other surety companies" (Bickelhaupt, 1983). As of July 1, 1992 there were eight companies listed by the Department of the Treasury as holding certificates of authority as acceptable reinsuring companies for Federal construction projects. Most of these firms are U.S. branches of foreign insurance companies. These eight firms are only authorized for reinsuring, whereas, the 279 other sureties are authorized for both bonding and reinsuring.

Seeing that the surety company is essentially extending unsecured credit to the contractor, it will perform a very careful analysis prior to making its decision to bond, or not to bond. It has been found that this yes/no decision is primarily based upon the credit worthiness and general character of the applicant. Inherent risks of the construction project itself are not fundamental factors in the surety's decision-making process. This bonding endorsement may be taken on its own merit, or may be used as a supplement to the owners own contractor qualification procedures.

## SURETY'S PERFORMANCE

During the mid to late 1980's, the surety industry as a whole, suffered significant losses from bonding operations (Table 4.1). Relative to the premiums collected, the combined loss and expense ratio in 1987 for bonding companies was 127%. In fact, losses have been so overwhelming that sureties had to hire claims handling consultants just to keep up with the demand Hancher, et al, 1991). Inasmuch as a prime tenet of this business is an assumption of no losses, it would seem obvious that the assessment techniques employed are not foolproof. While there may be many reasons why these net operating losses occurred, it seems plausible that macroeconomic factors such as the general downturn in the economy, the new tax laws of 1986, general industrial deregulation during 1980-1987, and the severe budget deficit were the primary factors.

In addition to macroeconomic and tax factors, the industry suffered losses in the 80's because there was an emphasis on "cash flow" underwriting. During this period, sureties were selling as many bonds as possible with the expectation that the income derived from investing the premiums at high rates of return would more than offset underwriting losses. To achieve this goal, the contractor prequalification guidelines were softened somewhat. As a consequence, more marginal construction companies acquired bonding, defaulted, and the bonding companies were

---

1Interview with D. McCarter, ITT Hartford, November, 1992.



called upon to meet their obligations. The "cash flow" theory did not work and therefore, the reimplementation of sound underwriting ideology has led to better profitability (Russell, 1992).

TABLE 4.1 - Surety Failure Data (Hinze, 1992)

| Year | No. Contractors Failed | Liability, $millions |
|---|---|---|
| 1945 | 92 | 3.6 |
| 1950 | 912 | 25.6 |
| 1960 | 2,600 | 201 |
| 1968 | 2,200 | 323 |
| 1987 | 6,735 | 2,387 |

During the latter part of the 1980's, the United States witnessed the disruption of the Savings and Loan Industry, a long-term recession, and an overall weakening of the insurance industry. Accordingly, owners would be wise to evaluate the surety company providing bonding to every project. This may be accomplished by inspecting "Best Insurance Report, Property-Casualty." Virtually, all bonding companies are evaluated and rated annually by A.M. Best Company. This organization publishes a corporate profile and financial data for each surety company. The surety is analyzed qualitatively and quantitatively, and then assigned a rating from A++ (superior) to F (in liquidation). Moreover, it has a Watch List for those firms which have suffered a decline in their profitability and/or liquidity parameters since year-end, but not to the extent that an actual reduction in rating is warranted (Best, 1992).

It may be interesting to note that the process of bonding the contractor as prevalent in the United States is not common in most other areas of the world. In Europe and many Asian countries, the owner (in many cases the government) requires a letter of credit (for example for 10% of the project bid) from the contractor.

## THE BONDING PROCESS

In this section, the surety's methods for bonding decision are elaborated. Risk items in a construction project can be divided into two broad categories: contractor related and project related.

Based on our research, we have found that sureties basically evaluate contractors. Projectrelated risks are then evaluated with much less detail. If they feel the contractor is competent, most of the time they will provide bonds assuming that the contractor has considered projectrelated and technical risks. In almost all cases, the surety only considers project characteristics cursorily. In other words, they are bonding the contractor and not the project. Although there is some justification in this approach, one can expect that in many occasions, the contractor defaults



because of difficulties experienced on the project due to the nature of the project and the contract It would be interesting to investigate the reasons for the increasing levels of surety failure data (Table 4. 1) and to see what portion of these failures are attributable to project difficulties. We have conducted a survey to inquire about the surety's current approach. Based on the responses received, one can say that the surety industry is looking more closely at the project characteristics and the contract specifications. The potential losses arising from hazardous wastes, differing site conditions, stringent liquidated damages clauses are all cause for concern for the surety. It is interesting to note that the sureties generally do not employ technical staff in the field of engineering. Time may come that they may utilize engineers or at least part-time consultants for evaluation of complex projects more regularly.

In a recent NCHRP study (Hancher, et al, 1991) key factors considered by the surety when evaluating contractors were compiled by conducting an extensive survey. Although most of these factors were of a financial nature (such as contractor's working capital, net worth, and profit history) a major concern was hazardous wastes. This is clearly a project-specific issue and analyzing cases of this nature require that the surety utilize knowledgeable technical personnel. It is common for the surety to hire a technical consultant to perform pre-default and post-default investigation of the contractor (Schwartzkopf, et al, 1990). It may be reasonable to use engineering expertise to evaluate the technical difficulties of the project in more depth when deciding to bond a contractor.

## Contractor Related Risks

In order for a contractor to be approved for bonding, a surety will evaluate what is known as the three C's: Character, Capacity, and Capital. Character relates to the assessment of a contractor's track record, including its reputation. Capacity answers the question of how much work can a company produce, given its current

resources. Capital is an analysis of a contractor's financial condition. Each of these categories will now be examined in greater detail.

Character: Character can be described as the corporate personality. Specifically, the surety will look at such items as whether the contractor has ever been involved in fraudulent activities, been engaged in price fixing with other bidders, been debarred from bidding on any government contracts, declared bankruptcy, is prone to excessive litigation, has not lived up to quality or schedule agreements, or has ever failed to finish a project. The surety will investigate the contractor's integrity by asking for references from suppliers, subcontractors, clients, and professional contacts. It will inquire about the contractor's ability to live up to its word, how it conducts normal business activities, and whether it performs administrative duties in a timely manner.

During the past decade sureties have been carefully scrutinizing the amount of work that is classified as underbilled. It was determined that large unrecognized losses were being placed into the wrong account and thereby avoiding the scrutiny of the surety examiner. Sureties currently



perform even closer inspection of corporate accounting practices. In fact, they will go so far as to evaluate the qualifications of the C.P.A. preparing the contractor's' financial statement (Russell, 1992). Other issues that the surety is likely to be interested in are potential and pending law suits and any tax liens on the contractor's property[goto pg. 42].

Bonding companies are also interested in the ability of a contractor to remain in business in the event of the death or disability of a principal during the projected duration of the project. In addition, if a construction company suffers from the loss of a key individual, the surety will want assurances that the business will have a stable (or at least well planned) transition. The surety will review the company's organizational chart to determine whether the individual who is next-in-line is capable of fulfilling the leadership position.

Capacity: Capacity is related to the amount and nature of resources needed to efficiently complete current work in progress plus work starting in the near future. Resources include company management, project management, labor, material, equipment, and

financial reserves. With respect to company management, a surety will first analyze how well previous projects have been administered. Specifically, they will evaluate the experience and education of the personnel involved with estimating, their track record with this company, the spreads on project bids, who determines the amount of profit to be added to project costs, and what controls are in place for the estimating system. The surety will consider contractor's job-cost monitoring system, as well as the ability to process paperwork such as change orders and pay requisitions (Russell, 1992).

Corporate practice on the dealings with subcontractors is an important concern of sureties. This concern is focused on the amount of work that the contractor "subs-out," whether these subcontractors are required to be bonded, and how well the subcontractor is monitored and controlled. Sureties that are to bond the general or prime contractor perceive far less exposure to themselves when the subcontractors are bonded. For example, if the total project cost is $100 million, and the prime contractor will perform $20 million worth of work, and bonded subcontractors will execute the remaining $80 million, then the bonding company for the prime contractor will only be exposed to $20 million in damages. Accordingly, it will be more likely to approve the bonding request than if no subcontractors were bonded. It should be noted that in the above example, the prime surety will still issue a bond for $100 million and charge the appropriate premium to its client. Since sureties are legally permitted to bond both the prime and subcontractors for a particular project, the potential exposure to the surety will vary with each individual situation. When a surety decides to bond both the prime and a subcontractor, the process is known as double-dipping3.

---

2Interview with Joseph Philips, Safeco, December, 1992.

3Interview with D. Hixon, Reliance Insurance Co., Nov., 1992.



An aspect of corporate management that demonstrates the ability to identify and correct weaknesses, and to improve strengths, is business planning. A surety will determine whether a contractor has attempted to improve current shortcomings, whether he has assessed the market and his competitors for future opportunities, and if he has generated pro forma financial statements. Moreover, the bonding agent will study the planning that has been put into future operations. What type, amount, and risk factors are involved with the companies' desired work? Does the company have plans to open regional offices in new locations?

To what extent has the connector established or increased bank lines of credit to achieve these goals (Russell, 1992).

One of the major techniques for measuring the ability of financial managers is to study cash flows. With a depressed economy, sureties are taking a closer look at the aging of accounts receivable. If a high percentage of accounts are in the over 90 day or over 120 day category, then the probability for bad accounts will be greater. Furthermore, the bonding agent will review whether the contractor has the ability to regulate his overhead expenses in conjunction with the vacillations in the economy4.

In a broad sense, the managerial capacity of a construction company is determined by its track record over the last three to five years. Normal items to evaluate are the number of completed jobs, the project locations, the project types, duration of each undertaking, contract amount (both bid and final), and gross profit (both bid and final). With the data for company and project management in hand, the surety is able to identify the corporation's managerial capacity. This information is then combined with work in progress to determine whether additional jobs can be managed properly.

Labor resources are carefully analyzed because of the labor intensive nature of the business. An investigation into the availability and character (union vs open shop) of workers is critical. If the project is to transpire in a unionized area, then the aggregate of laborers being employed at other projects will impact the availability of workers for the proposed undertaking. It is recommended that the current union contract be reviewed for items which may adversely effect future endeavors.

As a matter of standard procedure, sureties will study the type, quantity, and availability of construction equipment in the contractors possession. The agent will inquire about maintenance schedules and repair facilities. In addition, the method for determining depreciation and equipment rates will be requested. Finally, the bonding company will want to learn of any proposed equipment purchases or leases so as to determine the impact on the bottom line.

Sureties are interested in what materials will be used on a particular project to the extent of the potential impact on profitability. This concern is bilateral. First, any materials which are on the critical path and subject to potential delays in delivery may subject the contractor to

---

4Interview with D. Hixon, Reliance Insurance Co., Nov., 1992.

liquidated damages. Second, any material prices linked to some index (such as asphalt being tied to crude oil) will create an extra risk in terms of cost instability (Russell, 1992).

Capital: Capital, the third C, entails a thorough analysis of the contractors financial condition. In order to perform a proper evaluation, the surety will generally request three years of financial statements. This information is studied for the quality of the data contained and then is analyzed for a comparison to industry standards. Of the four gills of certified public accountant's opinions that could be attached to the statement, a surety will prefer to see an unqualified opinion. An unqualified opinion will declare that the auditor's examination as well as the statements themselves, were properly prepared and presented. With reference to the accuracy of the data itself, the bonding company is most comfortable with an audited statement An audited statement is generated when the contractor's C.P.A. applies extensive procedures to verify that the underlying data is in fact correct, and that it has been presented in accordance with generally accepted accounting principles. Sureties prefer income to be recognized by a technique known as the percentage of completion method. This procedure requires the contractor's CPA. to make an estimate of what percent complete each project is on a certain date. This percentage is then multiplied by the anticipated total project estimate to calculate the value of completed jobs. Thus, income is recognized as work progresses. The advantage of this tactic is that it provides the best correlation between income to expense (Russell, 1992).

Finally, sureties will make an evaluation of the accounting firm that prepared the financial statements for the contractor. If the organization is perceived by its peers as being highly professional and objective, then the surety will take the statements at face value. However, ff the accounting company has some flaws in its reputation, then the bonding analyst will inspect the report with a bit of concern5. Subsequent to the financial statements being evaluated for quality, the surety will proceed to perform a financial analysis on the data itself. A summary of ratios typically employed by bonding companies is presented below.

Financial Ratio Analysis: One of the most common techniques employed by the surety industry to identify sources of potential risk is the analysis of the contractor's finances. The primary objective of this analysis is to identify irregularities in a financial statement that need further study to fully understand a company's current and future standing. Important insights into a

firm's performance can be secured using financial ratios. Analysts typically evaluate a firm's ratios by two methods: first, they will compare a specific company's standing to industry norms, and second, they perform a trend analysis.

Financial rating agencies such as Robert Morris Associates and Dun and Bradstreet annually publish information regarding the range of various ratios for different industries. The financial rating community has segmented all businesses into hundreds of specific industry groups. For

---

5Interview with D. Hixon, Reliance Insurance Co., November, 1992.



purposes of this report, we have chosen Group No. 1622 of the S.I.C.(Securities Industry Classification) groups tided "Bridge, Tunnel, and Elevated Highway Contractors." Table 4.2 contains median and average values of different financial ratios discussed in this research. A surety underwriter may compare ratios generated for a contractor to the norms reported for this group in order to determine the contractor's relative position. If several ratios for the contractor fall below his peer group, then the underwriter will perceive high risk and possibly deny bonding.

Trend analysis is another method for evaluating the contractor. The underwriter will evaluate the trend of a firm's ratios for the past few years relative to the industry. If the contractor's trend is upward (or at least better than the industry trend), then an indication of sound management is evident. Accordingly, it may be a less risky situation for the surety.

For purposes of ratio analysis, a surety may look at four groups of financial ratios, namely, Liquidity Ratios, Operations Ratios, Leverage Ratios, and Profitability Ratios. These ratios are briefly discussed below.

Liquidity Ratios: The goal of liquidity is for an organization to have sufficient funds on hand to meet short-term (within one year) obligations when they become due and to have sufficient cash for emergencies. The most common ratios used for evaluating liquidity are the Current Ratio and the Quick Ratio. The Current Ratio is determined by dividing current assets by current liabilities. Current assets are defined as cash, short-term investments, notes receivable, accounts receivable, merchandise inventories, and prepaid expenses. Current liabilities are all liabilities that are

due within one year.

$$\text{CURRENT RATIO} = \frac{\text{Current Assets}}{\text{Current Liabilities}}$$

The Current Ratio is commonly used as an indicator of a firm's liquidity and ability to settle short-term debts. A careful analysis must be made as to the quality and constituents of each contractor's current assets and current liabilities. Oftentimes a surety will ignore the total current asset category given in a financial statement, and create its own new current asset total after a thorough examination of the underlying data (Needles, 1989). The higher the ratio, the more assurance exists that the retirement of current liabilities can be made (Duns, 1991). A Current Ratio of 1.5 or greater is considered favorable in the construction industry (Clough, 1986).

One of the shortcomings of the Current Ratio is that it does not consider the composition of current assets. Since these items may be received or converted into cash within one year, some cannot be readily used to pay bills. For example, a dollar in cash is much more liquid than a dollar of inventory. Therefore, the Quick Ratio adjusts for this fault by measuring short-term liquidity. The Quick (or Acid Test) Ratio is cash plus marketable securities plus cash equivalents, all divided by current liabilities.



Click HERE for graphic.



$$\text{QUICK RATIO} = \frac{\text{Cash + Cash Equivalents + Marketable Securities}}{\text{Current Liabilities}}$$

A Quick Ratio of less than 1.0 indicates that current liabilities may be becoming dependent upon inventory or other current assets for payment While a relatively high Quick Ratio is a sip of security for creditors, if excessive, it will signal a low return on current assets.

Operations Ratio: Operating abilities are evaluated by the ratios of Receivable Turnover, Average Days Sales Uncollected, Equity Turnover, and Working Capital Turnover. Receivable Turnover

measures the relative weight of a firm's Accounts Receivable and the contractors ability to collect credit sales in an efficient manner. It is a reflection of the companies credit and collection policies. It is indicative of how many times, on average, the Receivables were converted into cash during the year. This ratio is calculated by dividing net credit sales by average accounts receivable. An average of two consecutive periods will provide a better picture of Accounts Receivable than only one period. This will help to smooth out the variations that tend to occur within the year.

$$\text{RECEIVABLE TURNOVER} = \frac{\text{Net Credit Sales}}{\text{Average Accounts Receivable}}$$

A more understandable way of looking at this data is to calculate Average Day's Sales Uncollected. This ratio expresses the waiting period, in days, before an average payment is received. It is computed by dividing the number of days in a year by the Receivables Turnover.

$$\text{AVERAGE DAY'S SALES UNCOLLECTED} = \frac{365}{\text{Receivables Turnover}}$$

In construction, this period is usually the amount of time between the date the contractor bills the owner and the date that he receives payment.

Sureties measure how hard a firm's invested capital is working by calculating the Equity Turnover. This ratio is determined by dividing net sales by tangible net worth.

$$\text{EQUITY TURNOVER} = \frac{\text{Net Sales}}{\text{Tangible Net Worth}}$$

Working Capital Turnover is a measure of the degree of safety for current creditors. It is a gauge of the firms proficiency in financing current operations. Specifically, it reflects how efficiently working capital is used. This ratio is calculated as follows:



$$\text{WORKING CAPITAL TURNOVER} = \frac{\text{Net Sales}}{\text{Current Assets - Current Liabilities}}$$

Creditors compare this ratio with that of industry averages and

company historical data. An unusually low ratio may be indicative of poor use of working capital, while a high ratio will signal overtrading. This ratio must be viewed in conjunction with other ratios (Current Ratio, for example). Sluggish sales and an extremely thin Working Capital position will still provide a high Working Capital Turnover Ratio.

Leverage Ratios: Leverage ratios gauge the amount of debt pressure and the susceptibility of the company to downturns in the economy. Of highest importance is the Debt to Equity Ratio. This measures the proportion between capital lent by creditors and capital invested by owners. It is indicative of the degree of safety provided to the creditors by the owners. A company with a low ratio will have a far better chance for long-term survival than a company with a high ratio. The calculation is as follows:

$$\text{DEBT TO EQUITY RATIO} = \frac{\text{Total Liabilities}}{\text{Net Worth}}$$

A firm with a high Debt to Equity ratio is said to be highly leveraged and will generally find it difficult or costly to borrow additional funds. Values ranging from 1.0 to 2.0 are generally deemed acceptable to creditors (Clough, 1986).

To measure the proportion of the capital invested by the owners that has been reinvested in fixed assets(land, buildings, equipment), the ratio of Fixed Assets to Tangible Net Worth is computed. Essentially, this ratio expresses the degree of safety to creditors in the event of bankruptcy. A low ratio is preferred by creditors. The computation is as follows:

$$\frac{\text{Net Fixed Assets}}{\text{Tangible Net Worth}}$$

Potential creditors will generally check the amount of equipment that the firm has leased since such arrangements will lower the ratio. Since some leased equipment does not appear on the balance sheet an analyst must pay extra attention to these items.

Profitability Ratios: A contractor's long-term solvency is contingent upon its being capable of earning satisfactory income. An analysis of a contractor's prior profitability may help to predict the future profit margins. Creditors look at profitability because it also affects a firm's liquidity. The greater the profitability, the greater will be the firm's ability to settle short and long-term debts. The three primary ratios used to evaluate profitability are: Profit Margin, Return On Assets, and

Return On Equity.



Profit Margin is determined by dividing net income by net sales.

$$\text{PROFIT MARGIN} = \frac{\text{Net income (after taxes)}}{\text{Net Sales}} \times 100$$

it is a measurement of how much income is produced by each dollar of revenue. The greater the value of this ratio, the better. If the trend of this ratio is upward, then a surety will be more likely to approve a bonding request.

Return on Assets is the best gauge of the overall earning power of a company. It quantifies the amount of money earned on each dollar of assets employed. The return on assets is determined by dividing net income (after taxes) by average total assets.

$$\text{RETURN ON ASSETS} = \frac{\text{Net Income (after taxes)}}{\text{Average Total Assets}} \times 100$$

It is considered to be an outstanding measure of profitability because it blends the Profit Margin and Equity Turnover ratios (Needles, 1989).

If the contractor is organized in the form of a corporation, an important measure of profitability is Return on Equity. This ratio determines how much money was generated for each dollar that was invested by the owners. It is computed by dividing net income (after taxes) by net worth.

$$\text{RETURN ON EQUITY} = \frac{\text{Net Income (after taxes)}}{\text{Net Worth}}$$

Its distinguishing characteristic from Return on Assets is that it will vary in accordance with the amount of debt that the company has. If the money generated from borrowing earns more than it costs, then Return on Equity will increase at a greater rate than Return on Assets. A novice to financial analysis should use this ratio with caution. A high ratio would seem to indicate that management is effective, but it is possible that a high ratio reflects an overreliance on debt.

While there are many ratios available for analysis of financial statements, the foregoing are the most commonly used by surety professionals. Each ratio must be evaluated in light of

industry averages and the contractors historical values. Moreover, the data employed in the ratios is often re-classified by underwriters to fine tune their evaluation. For example, goodwill will be eliminated from the asset account because it cannot be used to satisfy debts. Certain inventory items will be eliminated if they cannot be sold within a reasonable amount of time. Slow Accounts Receivable and Notes Payable to officers or owners will be discounted for similar reasons. The surety companies that we interviewed did not take similar approaches to ratio analysis. While some worked with these ratios intensely, others emphasized their relationship



with and knowledge of the specific contractor requiring bonds. The quantity, type, and relative weight of the ratios employed varied from surety to surety.

The one thread that joins all bonding companies in contractor analysis is that they are interested in the contractors ability to satisfy losses quickly. If a contractor does not appear to have the capability to rapidly settle claims upon default, then the surety will most likely decline the bonding request. Also what surety perceives to be acceptable ratios would vary from contractor to contractor depending on their past performance and capabilities. For evaluating certain contractors some of these ratios are more critical. For example, ff the surety wants to bond a subcontractor, it will analyze receivables carefully as there would be some concern about how soon the subcontractor would be paid for the work performed. Debt to Equity Ratio seems to be very important to some sureties as it would indicate the contractor's financial stability and strength. Table 4.2 summarizes the trends of the above financial ratios for the group of constructors classified as Bridge, Tunnel, and Elevated Highway Contractors.

Contractor's Bonding Capacity: After a surety has evaluated the three C's of a construction company, it will proceed with a determination of the contractors bonding capacity. As a general rule-of-thumb, the bonding limit will be the contractor net worth times 10 to 20. Alternately, capacity may be determined by summing cash and accounts receivable and then multiplying the sum by 20. These multipliers will vary from surety to surety.

The surety will test to see whether the contractor has sufficient bonding capacity remaining to take on the work. Remaining bonding capacity is calculated as follows:

Remaining Bonding Capacity = Maximum Total Bonding Capacity -

(Total Jobs + Total Bids Pending - Work Completed to Date on Jobs)6

It should be noted that the contractor's backlog may not be all bonded (private projects for example). Despite this, all the contractor's projects will be included in the formula given above.

Project-Specific Risks

Prior to bidding on a job the contractor informs the surety agent about its decision to bid on a project. The surety will evaluate each proposed project individually. Among the project characteristics that will be examined will be the following:

- contract price
- contract type
- nature of the project

---

6Interview with D. McCarter, ITT Hartford, November 1992.



- contract duration
- liquidated damages clauses
- retainage provisions
- insurance coverage
- potential for exposure to hazardous wastes
- the amount of soil and underground related activities, such as tunneling, pile driving, and steel sheeting

As can be seen items enumerated above are mainly project-related issues. The surety should be comfortable with the contractor's three C's to provide the bid bond. The surety will also check the contractor's remaining bonding capacity by considering the contractor's backlog to ensure that by bonding the contractor for this project, the capacity limit will not exceed. This process was described earlier. The face value of the bid bond will vary between 5 to 20 percent of the amount of bid. The surety may provide the contractor with the bid bond. The owner's understanding would be that the surety will be providing the payment and performance bonds if the contractor turns out to be the low bidder (Halpin and Woodhead, 1980). Despite this expectation, the surety is not committed to providing performance and payment bonds. If the contractor is awarded the project, then the surety may issue the remaining bonds prior to the start of construction. When the award is made, the governmental agency securing the work will announce the bid values of all competitors. The surety that

provided the bid bond to the winner will have an interest in these figures. In the event that the lowest bid is below the second lowest bid by a large margin (for example by more than 10% according to Russell (1990), but this figure will vary from surety to surety) the bonding company will inquire why their client's bid was abnormally low. The surety is concerned that the contractor may have erred in his estimate and that he may be subjecting himself to financial losses if he takes on the work. If no reasonable explanation is given by the contractor, then the surety may decline to provide the performance and materials bonds7.

Surety companies are interested in the type of contract that will be formed between the contractor and the owner. They are most comfortable with conventional fixed price competitive and negotiated cost plus contracts because these formats have been thoroughly tested by the courts7. In recent years, design-build and turnkey contracts have gained some acceptance by government agencies. Section 3019 of the Federal Transit Act Amendments of 1991, incorporated into the Intermodal Surface Transportation Efficiency Act (ISTEA) defines Turnkey as "A project under which recipient contracts with a consortium of firms, individual firms, or a vendor to build a transit system that meets specific performance criteria and which is operated by the vendor for a period of time" (Luglio, 1992). Turnkey contracts are riskier than the conventional contracts because in turnkey the contractor will be responsible for both design and construction. in fact the contractor has to commit itself to a fixed price at a stage when the design is incomplete and the scope is not perfectly clear. While this contracting strategy may prove to be an effective mode for risk sharing between contractors and owners, it is viewed with a bit of skepticism by the

---

7Interview with D. McCarter, ITT Hartford, November, 1992.



surety industry. This is due to the fact that it is a novel approach with many unknown outcomes that could seriously harm the surety.

## SUMMARY

In this chapter we reviewed the surety industry as it relates to public works construction contractors. First, we provided information about the surety industry and how it differs from the

insurance industry. We then provided some background on surety's performance in the past decade. Surety's main concern is an accurate assessment of the probability of the contractor's failure and its main objective is to either accept or to decline to provide bonds to the contractor. In this chapter we have elaborated on the methodologies and procedures used by the surety in order to arrive at the decision of whether to bond or not to bond a contractor. Contractor's financial health, character, capacity, the volume of backlog, the type of work performed in the past and its future plans all play a role in surety's decision. Typical financial ratios analyzed by the surety are also covered. Although the surety does not formally evaluate the project risks and complexity, its approach in evaluating the contractor is valuable. As can be observed from the checklist provided in this report, many of the risk items contributing to the project uncertainty are related to the contractor. Surety's approach can be useful in developing or improving procedures for contractor prequalification. Because of decades of the surety's experience in this process, we think that familiarity with their approach will be beneficial to the sponsor or the owner of capital intensive transit projects.



# CHAPTER 5 - RISK MODELING AND ASSESSMENT

This chapter deals with the issue of risk modeling and measurement. In order to quantify the impact of risk one needs to develop a logical model for risk measurement. This model should be used in conjunction with the identified risk items described previously in this report. Two major approaches to risk measurement are covered: deterministic approach and probabilistic approach. Most of the concepts presented are described using case studies and examples.

Keeping projects on time and within budget are two of the most important functions of project management Estimates of project cost and duration are based on the knowledge of the estimators and schedulers, experience and data from similar projects completed previously, and a large number of assumptions made regarding productivity rates and material prices.

Almost every project component that consumes time and/or money is prone to some chance variations. Some items such as material prices, when a vendor has guaranteed his prices, have a lower chance of variability. Other items such as various labor productivity rates that can be sensitive to many factors such as weather, temperature, state of economy, unions involved, and

location, have a much higher chance of variation and can impact the project duration and cost. Risk measurement and analysis, at least in the context of this report, is the process of developing a logical vehicle for predicting the extent of these variations and possibly forecasting the worst case and the best case scenario for the project budget and schedule.

## OWNER'S RISK

Almost every party involved in the project needs to perform its own kind of risk analysis. While the owner has to look at risk issues at a more macro or aggregate level, the contractor would be wise to consider chance variations at a more detailed level. The owner, public or private, needs to assess the amount of uncertainty in the project cost and schedule in order to make plans for seeking project funding. Multi-year megaprojects are particularly sensitive to variations in project duration. The cost of money needed to finance these projects become prohibitively high as the project duration increases. Because of these issues, financial risks become of paramount importance to the owner. If the sponsor is the Federal government, legislative issues such as funding authorization and appropriation have to be considered also. Sources of funding and its composition, the commitment and reliability of local sources, the accuracy of estimating funding levels over project life, and the probability of project failure due to optimistic assumptions all add to the project's financial risks. The owner should also concern



itself with the contractor selection process, the stability and strength of the contractor in executing a large transit project, and expected loss levels in case the contractor fails to complete the project. Even if the contractor does not default, the owner or the sponsor (for example, FTA funding of a transit project) has to evaluate the probability and the potential loss in the case of project delay and cost overrun.

## CONTRACTOR'S RISK

The traditional contractor on the other hand, looks at a project's risks from a different angle. Although financial risks are very important and the contractor would want to be sure that the owner has sufficient funding to finance the project, he will be concerned with the amount of funding that would be needed for interim financing. Interim financing fills the gap between the contractor's spending and income in a project. The smaller this

gap, the less expensive it would be to finance the difference between the contractor's expenditures and progress payments. The cost of interim financing cuts through the contractor's profit margin and because of this the contractor should carefully study the expected levels of needed financing. Also, with the emergence of innovative contracting arrangements, contractors have been asked to provide financing for some public projects. For example, on several new correctional facilities, the contractor has been asked to finance, design, and build the facility. In some recent transit projects, the contractors were required to come up with financing schemes. If this trend continues, many of the major construction companies have to start looking at project's financial risks in much the same way as a private owner. Also the contractor needs to pinpoint areas of risk and uncertainty in the project and assess the impact of those areas on the project cost and duration in order to include a reasonable contingency in the bid, especially in competitive lumpsum contracts. Careful evaluation of this contingency is important. A low estimate of the required contingency may get the contractor the job but may cost him dearly after the project starts as the time and cost variations may develop an unfavorable impact on the project. A high or conservative estimate of contingency on the other hand, will put the contractor at a disadvantage because his bid may not be competitive enough to get him the job.

## TURNKEY

Recently, there has been a renewed interest in turnkey projects at the Federal level. Department of Transportation has started implementing pilot projects using a fixed-price turnkey approach. Turnkey has several benefits from the owner's point of view. Because the con gets involved in the design phase, he can bring the construction expertise to the design team. This will hopefully make the project more constructable. The concept of constructability has been the focus of considerable research in private industrial construction (Constructability, 1986). Constructable projects are easier and more economical to build. More recently, attention is also being paid to building the projects in a way that they would be easier to maintain. Again, having the constructor's feedback during the design phase helps in project's long-term maintainability. Another important advantage of turnkey project is that it reduces the possibility for the



contractor's claims for the changed conditions because the contractor was responsible for design. This will help to keep the project's estimated budget on target. Moreover, the owner will be able to establish a firm estimate of the required budget much

sooner as the con r will have to commit itself to a fixed-price before the final design is complete. For example, on the Honolulu Transit Program, the contractor submitted a hard-dollar estimate at the end of the Conceptual Design phase (FEIS, Honolulu, 1992). So the sponsor and the local agency had a cost estimate several months sooner compared to the case where the project has to go to bidding with a complete design. For various phases of a capital transit project development and their typical duration refer to Project Development Process, FTA (undated) (Figure 5. 1).

Click HERE for graphic.

Turnkey advantages come at a price. The contractor that has to bid on a project after the Preliminary Engineering or even at the end of Alternatives Analysis phase will increase the contingency accordingly to protect itself in case the project design and construction do not proceed as expected. As Figure 5.1 shows, in earlier phases of the project life cycle, uncertainties regarding project cost and duration are larger. The owner pays for these contingency sums whether they are actually being used or not. Based on the foregoing discussion, it is clear that



depending on who is interested in risk analysis, the objective may be different but the general approach is the same; i.e., identify areas that are prone to uncertainty and develop a model that can predict the combined effect of these areas on the project's budget and schedule.

## APPROACH

There are two general approaches to evaluation of variations of project components. Some approaches are based on some deterministic safety margin for critical items based on expertise of the seasoned personnel or historical data compiled from similar projects. In some cases these deterministic methods tend to work well because of the nature of the available data and the experience of the analysts. For example, in many cases a well-designed sensitivity analysis is all that is needed for assessing the risk impact on a project. Other approaches are based on some probabilistic model where the variability of important parameters are formally introduced into the predictive models. With the recent developments in risk analysis software and the increasing familiarity of engineers and analysts with probabilistic approach, we feel that it is time to use these methods much more extensively.

The probabilistic method provide the user with much more information compared to deterministic method and helps the user make informed decisions as will be described in this chapter.

## 1. DETERMINISTIC APPROACH

In the deterministic approach, the potential cost overrun for the project is estimated based on the experience of the personnel and all the information that can be obtained from similar projects and the project under study. It is common to see a contingency rate of around 10% added to the total project cost in order to cope with project uncertainties. This approach, especially if taken by the owner can lead to problematic results. Pickrell (1990) suggests that the contingency funds used for Federally funded transit projects seem to be insufficient The contingency for projects studied by Pickrell ranged from 5% to 15%.

### An Overall Contingency Rate

The contractor bidding on traditional contracts based on final design, is anxious to become the lowest bidder. He may anticipate that his contingency may not be sufficient but he knows that he may count on changes, considered to be inevitable in the traditional lumpsum contracts. No matter how much time is spent on design and scope definition, there is always the possibility that the contractor may be able to claim some changes and to receive additional reimbursements. The price of changes are arrived at on a non-competitive basis and can be higher than what the owner expects. In the interviews conducted with contractors for this research, it became evident that many contractors bid on several projects anticipating that they may lose money on some contracts. Their main objective is to be able to earn an acceptable rate of return on the portfolio of the projects that they are executing. If based on years of experience, they feel that a 10 or



15% contingency is appropriate for maintaining their profitability and their success in obtaining the jobs, then they see no reason for changing that. Also, most of the estimators consider many of the risk elements (listed in the risk checklist in this report) while preparing the detailed estimate for the job. So by the time the estimate is complete, it y includes certain allowances for contingency. The contractor will be well-advised not to take this approach especially on turnkey projects where his chances of obtaining change orders are small. It is also clear that this approach cannot be utilized by the owner or the sponsor of a public project.

There are several reasons for the owner to calculate contingency using a systematic approach to risk identification and assessment. Many times the contingency rate is added arbitrarily and not without elaborate analysis. Also, some risk elements are counted twice as they have been considered in the estimating phase. Adding an overall contingency rate only considers the potential for loss as it increases the project costs. It many cases though, the probability of underrunning certain cost elements is reasonably large and has to be incorporated into the model (Hayes, et al, 1987). Furthermore, often it is not clear that the contingency gives the expected value of cost overrun, the most likely value of the cost overrun, or the worst case scenario for the project cost. The likelihood of arriving at a certain project budget cannot be assessed with this method. Even if its definition is clearly given, still the owner may not be able to decide on the actual level of reserve funds. For example, is it reasonable to provide for the worst possible scenario and hence possibly jeopardize project's viability when the probability of realizing such a cost is extremely low?

## Assigning Various Contingency Rates to Different Project Components

A more reasonable approach is to identify major risk elements in the project and assign reasonable contingency rates to these various items. These contingency rates may not be the same from area to area. For example, in a transit project, the planner may assign a 15% contingency rate to the cost items that relate to underground construction and a 10% contingency rate to the budget for train purchase. The total contingency budget will be the sum of the products of the individual contingency rates and respective component estimates. This approach has the added benefit of earmarking contingency budget for various project components. This will allow for a more efficient contingency drawdown policy and can alert the management if a certain component is using too much of the reserve funds. In these approaches it is important that costs be estimated as realistically as possible. In other words, based on the information at the time of preparing the estimate a fair cost of the component should be calculated without trying to safeguard against risk elements. The impact of uncertainty shall then be considered when arriving at the contingency rates by carefully evaluating the risk checklist and drawing upon the experience of the people involved in the project and historical data from similar jobs.

Case: One example of using weighted averages in calculating contingency rate is the ongoing Central Artery/Third Harbor Tunnel Project in Boston. In this multi-billion dollar project, the owner has assumed responsibility for a number of risky components of the project. This will discourage bidders from inflating their bids with large contingencies. The owner will pay for

project risks only if they actually happen. The total project has been broken down to several construction packages or subprojects and are bid separately. seven areas of risk have been identified for each subproject. These areas include 1) design difficulty, 2) geological conditions, 3) joint occupancy of site, 4) schedule constraints, 5) project duration, 6) economic stability and escalation factors, and 7) urban environment. Contribution of each of these seven areas to the total project cost risk have been assessed and range from 5% to 30% (Table 5.1). The project has a 12% contingency budget not including cases where the owner expects several change orders will be issued due to the nature of the work. For each subproject, a group of the owner's experts evaluate the severity of each of these seven areas and assign a weight to each area ranging from 0 to 0.12. For example, if the contractor on a specific subproject is faced with several milestone dates on the critical path in a relatively short duration project where the staging and sequencing of the operations are assessed to be very critical, then a value close to 0.12 is assigned to the area schedule constraints. On the other hand if the same subproject has a duration of less than one year then the escalation factor is assumed to be ). The product of these assigned values and their respective area weights are summed up to give the total contingency for the subproject (Instructions, Construction Contract Risk Analysis, 1992).

Table 5.1 shows a contingency analysis for a hypothetical construction contract. Column (2) gives the percent contribution of each risk area to the contract contingency. The range of values in the "weight" column is 0 to 0.12. The owner's experts have established a contingency budget of 8.35% of the total bid price for this contract. As can be seen, geological conditions and schedule constraints (probably several milestones in a tight schedule) are high risk areas while other areas seem to be of average difficulty. The owner will only expense this fund if necessary. The contractor on the other hand, is protected against these seven risk areas and he will not add these in his bid, resulting in a lower bid.

TABLE 5.1 - Construction Contingency Assessment

| (1) Area | (2) Percent Contribution | (3) Weight | (4) Value (2)x(3) |
|---|---|---|---|
| 1. Design difficulty | 25% | 0.05 | 1.25% |
| 2. Geological conditions | 30% | 0.12 | 3.6% |

| | | | |
|---|---|---|---|
| 3. Joint occupancy of site | 15% | 0.06 | 0.9% |
| 4. Schedule constraints | 15% | 0.12 | 1.8% |
| 5. Project duration | 5% | 0.04 | 0.2% |
| 6. Escalation | 5% | 0.06 | 0.3% |
| 7. Urban environment | 5% | 0.06 | 0.3% |
| TOTAL | 100% | | 8.35% |



Schedule Contingency

Project cost and schedule are interrelated. Pickrell (1990) shows that on several transit projects investigated, major portions of cost overruns were attributable to project delays. Given the shear size of transit projects and large amounts of financing required, project delays drive up the cost of money drastically. Setting realistic objectives for project milestones and the completion date is one of the first steps in calculating the project financial needs. The project financial needs in turn impact the budget and the cost contingency. A logical approach in schedule risk analysis is to refer to a carefully developed CPM schedule. Through the CPM one will be able to see the interrelationships between various elements of the project and to evaluate the impact of an activity delay on various milestones and the completion date.

The schedule for the owner/sponsor will be different from the contractor's schedule in that it will encompass planning and design phases in addition to the construction phase. Reasonable contingencies can be built into project schedule in terms of floats for various milestones. The larger the amount of these floats and the smaller the number of milestones that carry liquidated damages clauses, the less risky the project from the constructor point of view. Including stiff liquidated damages in a tight schedule with several milestones will result in bids with high contingencies. An important benefit of using. CPM schedule is that it ranks activities (or the project components) according to their impact on project milestones and the final completion time. The activities that have higher floats are less likely to create schedule delays.

## 2. SENSITIVITY ANALYSIS

Sensitivity analysis can and should be applied to both deterministic and probabilistic approaches in risk measurement. The basic principle is to vary a certain cost or schedule parameter while keeping other parameters fixed and to study the impact of this change on total project cost or schedule. In other words, sensitivity analysis lets the analyst perform "what if' scenarios.

For example, in a financial risk analysis, one may not be sure about the interest rate promised on revenue bonds that are going to be issued for a transit project. Let us assume that the interest rate may be anywhere from 5 to 7 percent. The financial spreadsheet can be analyzed several times, every time changing the interest rate by 0.25%. The analysis has to be performed 9 times and every time the impact on the total project cost can be evaluated. In every scenario it is assumed that the parameter takes the value assumed in that specific case. So although the effect of the parameter on the project can be evaluated, there is no information regarding the likelihood that the parameter takes such a value. For example, there is no indication that with what probability the interest rate will be 5%.

Sometimes it is convenient to use a spider diagram (Hayes, et al. 1987; Toumn and Ladick, 1989) to show the impact of variations of several parameters on total project cost (or viability). Figure 5.2 shows a simple spider diagram prepared for a hypothetical tunneling project. It shows the effect of varying labor rates, TBM down-time and groundwater inflow on the total cost of



the project. The slope of the lines representing each parameter indicates the model's sensitivity regarding that parameter.

Click HERE for graphic.

The milder the slope, the higher is the effect of variations of the parameter value on total project cost. Note that the sensitivity analysis depicted in Figure 5.2 does not consider the effect of combined parameter changes on project costs. For every scenario, only one parameter is changed and the result calculated. Sensitivity analysis can also be performed on project schedule. CPM also allows convenient sensitivity analysis. By changing the duration of an individual activity (or a group of activities) while keeping other activity durations constant, one can easily compute the impact of these changes on project milestones and the completion time.

## 3. PROBABILISTIC APPROACH

A deterministic risk analysis can at best provide an upper limit and/or a most likely value (or in some cases an expected value) for the risk of performing a project. The user will not have information about the likelihood of needing a certain level of

contingency. The importance of relating various levels of exposure (or contingency) with probability of their realization cannot



be overemphasized. Without knowledge of this relationship, the effectiveness of decision making will become random. On the other hand, if uncertainty of various variables are formally introduced into the cost and schedule models, then one can arrive at a distribution for the outcome of the analysis. This distribution allows the analyst or the decision maker to make informed decisions regarding the project's management, budget and schedule. Indeed, many may suggest that there is no such thing as "deterministic risk analysis" because risk by definition is derived from uncertainty which in turn is a probabilistic concept.

Implementing a probabilistic approach in risk assessment is generally more complex than the traditional deterministic approaches and requires more input data. Conveying the results of a probabilistic approach to the top decision makers may be more difficult as well. Despite these issues, we feel that every effort should be made that a probabilistic analysis be conducted to assess the levels of risk in a project. Without a probabilistic approach a complete profile of project risks cannot be developed. In this section some of the more common probabilistic approaches in construction management are described.

In general, the probabilistic approach in assessing risk or measuring probability of cost or schedule overrun/underrun is to treat various components of the project, especially those components that are expected to vary greatly, as random variables. The underlying assumptions in both probabilistic scheduling and estimating arc so similar that we can discuss both subjects at the same time. In almost every case, a model is developed for predicting the project cost or schedule. As this model is a function of several random variables (those components of cost or schedule that have a fair chance of variation and are expected to contribute to the total project uncertainty), it is itself a random variable. If one can estimate the distribution of the random variable that is used to model total project cost or total project duration, then one can compute probabilities associated with various levels of confidence regarding meeting a specific deadline or a prescribed budget level. The problem is that in many cases it would be very difficult if at all possible, to analytically find the distribution of the random variable representing total project cost or schedule. That is why in many cases a simulation analysis is conducted to arrive at the Cumulative Distribution Function (CDF) of the total cost or schedule.

The following factors may affect the analysis outcome:

- The choice of statistical distributions and parameters used to model individual project components

- The choice of the mathematical model for the total project cost or schedule

- The choice of analytical technique used to solve the predictive model

In this report, these issues are described using a number of examples.



## Statistical Distributions

As mentioned earlier, the general approach in assessing uncertainty in construction projects is to treat project components with a high potential for variability as random variables. So an activity's duration traditionally estimated with a single number, or a unit cost item that the estimator usually estimates based on the information available deterministically, are modeled as random variables with specified means and variances. In most cases, specification of a distribution type is also needed in order to be able to conduct a probabilistic analysis. Almost always, a well-known theoretical statistical distribution is used to model the item's variability. This is due to the fact that these statistical distributions are well-known, usually fully documented, and therefore easier to work with and to evaluate. Given the variety of statistical distributions available, one is generally able to choose a reasonable distribution for modeling a certain parameter's variability.

In the past three decades research has been conducted on the nature of construction cost and duration distributions. Several features of cost and duration distributions have been identified. For example, it is understood that the distribution should preferably have confined limits, should only take positive values in the ranges of interest, should be unimodal, and may be skewed (unsymmetrical) (Spooner, 1974). For example, developers of PERT (Program Evaluation and Review Technique), a probabilistic network-based scheduling technique (PERT Cost Systems Design, 1962), have suggested using a beta distribution to model activity duration times. Beta is a unimodal distribution with confined lower and upper bounds (Fig.5.3) and can take several shapes depending on the distribution's shape factors. It provides a flexible means for modeling activity duration times. PERT has been in use since the

late fifties.

Teicholz (1964) found out that the cycle times of construction equipment (e.g. scrapers) follow a lognormal distribution. This was later supported by observations of O'Shea el al (1966) and Gaarslev (1969). Lognormal (Fig.5.4) is a unimodal distribution that can take only positive values, and is skewed to the right.

Click HERE for graphic.



Click HERE for graphic.

In a more recent study, it was found that the cost items (such as overhead, concrete, electrical mechanical, etc.) in low-rise office buildings (2-4 stories) are lognormally distributed (Touran and Wiser, 1992). Other researchers have considered uniform (Fig 5.5) and triangular (Fig.5.6) distributions for modeling cost or duration (Makar and Bryant, 1990).

Regarding financial risks, one of the most important items is the interest rate used in the analysis. Interest rate is a function of the inflation rate, economic growth, and loan duration. Both inflation and economic growth can be closely modeled by a normal distribution. The additional premium associated with loan duration may be modeled as a linear function of time. So the interest rate can also be modeled as a distribution. Figure 5.7 shows a histogram of inflation rates in the United States. As can be observed, a normal distribution can probably model the inflation and the interest rate reasonably accurately. For other economic indicators such as growth rate a large number of dam is available in various financial references (Bodie, et al, 1993).

Click HERE for graphic.



Click HERE for graphic.

Click HERE for graphic.

General Guidelines for the Selection of Distribution: The

following guidelines can be used for specifying distributions: if the amount of dam regarding a component is very limited, or if the component is expected to vary within a very narrow range, then a uniform distribution can be used since there is no preference regarding the most likely value of the distribution. An advantage of uniform distribution is its simplicity and its ease of visualization. If the range is appreciable and some dam is available regarding the most likely value of the distribution, then a triangular distribution may be advantageous. For example, if the estimator feels that the cost of ready-mix concrete is $65/cy but may vary between $60/cy and $72/cy, then a triangular distribution with a minimum value of 60, a maximum value of 72 and the most likely value of 65 may be a proper choice. If on the other hand, the estimator thinks that the same unit cost varies between $65 and $69, then one may consider using a uniform distribution with a minimum value of 65 and a maximum value of 69. This would mean that it is equally likely that the unit cost of ready-mix concrete takes any value between $65 and $69 per cubic yard.

Both beta and lognormal distributions resemble the triangular distribution in the sense that the data is grouped around a mode and the distribution is not necessarily symmetrical. In fact,



in PERT scheduling, the scheduler defines a beta distribution for each activity duration by specifying a lower bound, an upper bound, and a most likely value (Touran, 1992).

Another approach sometimes employed is to use an empirical distribution to model a random component In this case, a histogram of data collected previously on the component is used to model the component's variation. The use of empirical distributions generally requires a computer simulation for arriving at the function representing the total cost or schedule.

## PROBABILISTIC MODELING OF THE PROJECT SCHEDULE

### PERT Approach

The most common approach in probabilistic scheduling is PERT where every activity is modeled as a random variable distributed according to a beta distribution. The total project duration is computed along the network's critical path (the longest path) by adding the means of the activities on the critical path. According to Central Limit Theorem (CLT), the sum of several independent and identical random variables is a random variable with an approximately normal distribution. The mean of this normal random variable is the sum of the means of the individual random variables

and the variance of the total is the sum of the variances of the individual random variables. In this way, the total project duration is modeled as a normal distribution and its parameters can be conveniently estimated from the activity data. If activity durations are not independent then the use of Central Limit Theorem is not theoretically justified. For further explanation of PERT refer to Moder, et al (1983).

The CLT can be used if the number of activities contributing to the total project duration (i.e. activities on the critical path) is relatively "large". Although some statisticians have suggested that the number of random variables should be larger than 30 (e.g., Devore, 1991), experience shows that with numbers larger than 10 (Miller, 1963), reasonable approximations to normal distribution can be expected.

The other concern in applying CLT to PERT is that in some. cases, several paths in the project are almost as long as the critical path. In these cases it is possible that the shorter paths that happen to have larger variances than critical path will become critical. In such cases, the question is to what path the CLT should be applied and which path is actually going to be the longest? One suggested solution has been to use the Monte Carlo simulation in analyzing these cases. This issue has been discussed under merge event bias problem in various publications (Moder et al, 1983).

Monte Carlo Simulation Technique

In the Monte Carlo simulation approach, a random number is generated on a computer to generate a duration for each activity using its distribution. These numbers are used to schedule



the network and the total project duration is computed. In this process the activities on the critical path (the sequence of activities with the longest total duration) are identified. This process of generating random numbers according to various activity distributions is repeated many times (from several hundred times to several thousand times) and every time the critical activities are identified. Then a criticality index is computed for each activity that reflects the probability of the specified activity becoming critical. This criticality index is simply the ratio of the number of times an activity was on the critical path to the total number of simulation runs. In this way, the activities with a high probability of becoming critical are identified. This can help the management to allocate a proper level of attention to these components of the project.

## Software

The analyst has the option of using either a general purpose simulation language such as SLAM (Pritsker, 1986) or SIMAN (Pegden, et al, 1990) to develop a model of the project schedule, or use a specially designed software package that allows conducting Monte Carlo simulation on a scheduling network. The first approach is much more flexible but requires more time and the user has to have expertise in modeling probabilistic systems. In such an approach, risk measurement can be done either using traditional network-based schedules or utilizing any appropriate relationship that realistically defines a duration or productivity rate. Using a CPM schedule has the advantage that depicts activity precedence and can serve as a convenient environment for developing a schedule risk study.

The traditional network lacks the flexibility needed in modeling complex yet quite probable situations. One such flexibility is the possibility of probabilistic branching. As an example, consider a transit project where the source of local funding is uncertain. Maybe the local agency or the owner is not sure if the public is ready to foot the bill required for the local contribution. In developing a schedule for the project, it would be wise to consider two paths. Each path has a certain probability of realization. For example, the analyst may think that there is a 75% probability that the public will support a new tax to pay for the local share. There is a 25% probability however, that the proposed tax will not be accepted and this can direct the project schedule through a loop consisting of several activities (further negotiations, study, etc.) with a duration of several months. If the network can be modeled such that it allows probabilistic branching after every milestone, this uncertainty can be incorporated into the model and proper actions anticipated. Other potentially useful information would include but not be limited to activity criticality indices, the distribution of time between any two milestones in the network (Pzitsker, et al, 1989), and flexibility in modeling correlations between activities.

The second and easier option is to use a software package specifically designed to perform Monte Carlo simulation on a CPM network. Because of the increasing interest in probabilistic scheduling, software, companies have developed such computer programs. In one such example (Monte Carlo, 1992), the software allows the user to.either define an empirical distribution for an activity or choose from a number of distributions (triangular, negative exponential, empirical) for modeling activity duration times. The software allows the user to model activity correlations

by using the same percentile values when sampling from correlated distributions. This assumption reduces the system's flexibility somehow, but is an improvement over the assumption of independence that PERT uses. The software also permits probabilistic branching. It is expected that many more software developers will market software in this area in the near future.

Many factors affect the choice of methodology in network analysis. Two examples are presented in the following sections to illustrate some of these concerns.

## EXAMPLE I

In order to illustrate the application of probabilistic scheduling we have chosen a transit project currently underway. Old Colony Railroad Rehabilitation Project (Old Colony DEIS, 1990) involves the restoration of about 60 miles of railroad tracks, construction of 14 new stations and the construction of a 1,200 ft long bridge over the Neponset River in the south of Boston. The area served by the Old Colony Project has seen rapid growth in the past two decades and the existing highway and transit facilities do not meet existing and especially future needs for access to Boston. The main objectives of this project are to improve transportation services, provide cost-effective transit services, and provide a more equitable distribution of transportation benefits to the residents of the area covered by the project (D'Eramo and Martinez, 1991). The project is funded locally and by the Federal Transit Administration (FTA). The owner is Massachusetts Bay Transportation Authority (MBTA).

The module chosen for this study is "South Bay Undercrossing". This is a construction module with an estimated cost of $18 million involving building an underpass structure under the existing MBTA Red Line. The major problem is that the Red Line service should not be disrupted under any circumstances. This will require that the contractor work on the Red Line relocation activities only in the weekends in restricted hours. This requirement complicates accurate estimation of these activity durations and creates uncertainty regarding the schedule. A CPM network of the project consisting of 44 activities was developed by the Engineer. Table 5.2 shows activities affected by the Red Line relocation operation and their possible duration ranges.

Ranges provided in Table 5.2 were furnished by the experienced Engineer's personnel. Further, it was felt that although it was possible that an activity might take anywhere between the minimum and maximum durations given above, the duration distributions would have a modal point or a most likely value. Estimates of the most

likely durations are provided in Column (2) of Table 5.2. Because of this observation is was decided to model activity duration times according to a triangular distribution (Fig. 5-6). Other activities of this 44-activity network were modeled with deterministic durations because a large variance was not expected for their durations.

Monte CarloTM software package by Primavera, Inc. was used to conduct a risk analysis for this construction project. The objective was to assess the impact of activity duration uncertainty on total project duration. Figure 5.8 shows the CDF and the PDF of the total project duration.



The expected duration of the project is 588 days but the duration range is from 525 to 625 days. By looking at the PDF one can see that the most likely range for the duration is between 565 and 605 days. The probability of duration exceeding 617 days is extremely and can be reasonably disregarded

Click HERE for graphic.

This information can help in assessing the impact of this module on other construction packages in this transit project. Depending on the Master Schedule for the project, if the module studied here is on the critical path and can cause delay in the final project completion time, then it would be wise to study alternatives for schedule compression. Otherwise, a project duration of approximately 605 days (with a probability of exceeding being only 20%) seems to provide a reasonable margin of safety for the schedule.

This example illustrated the process of performing a schedule risk analysis. The process of systematically studying a schedule and identifying activities that may cause delays and modeling the potential delays using statistical distributions, one can assess the extent of the potential delay. The impact of this potential delay on the project budget and master schedule can then be investigated and mitigating measures can be adopted.



Click HERE for graphic.

Example II

This example is taken from Touran (1992). It illustrates the fact that risk assessment and analysis for project duration do not necessarily have to be tied to a scheduling network. Large portions of the schedule may not be of interest to top management or may not show a large potential for variability. In such cases it will be wise to focus on c areas where variations in duration can have a strong impact on the project. As an example, we will examine a risk model that was developed as part of the Concept Design Report for the MWRA Inter Island and Outfall tunnels (Tunnel Risk Assessment, 1989).

One objective of the study was to develop a CDF for the total duration of tunnel boring for Inter Island and Outfall tunnels. It was argued that within the Deer Island Treatment Plant and Facilities, the Outfall tunnel was on the critical path and moreover the activity with highest potential for variability was tunnel boring. So it was sensible to conduct a risk analysis on the tunnel boring operation. The tunnel duration consisted of several components all of which were computed according to the following procedure:

Time to tunnel in certain rock type, with a certain quality, with a certain water inflow is equal to the length of the tunnel segment divided by TBM achieved rate in the same type of rock with the same quality and water inflow (Eq.1). TBM achieved rate is defined as the product of TBM utilization rate (the time machine is boring as a proportion of the total working hours) and



the TBM penetration rate (instantaneous penetration rate) in the same type of rock with the same quality and water inflow. We have simplified the model so that it can be discussed here in a reasonable space and at the same time have preserved the essentials of the approach taken in the actual study.

The following criteria are considered:

$$T_{ijk} = \frac{L_{ijk}}{P_{ijk} \; U_{ijk}} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; (1)$$

In Eq.(I), Tijk is the time required to tunnel segment denoted by ijk, i is the rock type, j is rock quality (excellent, good, fair, poor, or altered based on Rock Quality Designation (RQD)), k is water inflow rate (high, medium, low based on permeability), Lijk is

the length of the tunnel in a certain rock, with a certain quality and water inflow rate, Pijk and Uijk are TBM penetration rate and utilization rate at the given conditions.

$$L_{ijk} = L\ W_{ijk}\ R_i\ Q_{ij} \quad \ldots\ldots\ldots (2)$$

In Eq.(2), L is the total tunnel length, Ri is the probability that rock type i is encountered, Qij is the probability that rock of quality j is encountered given rock type is i, and Wijk is the probability of having water inflow rate k, given rock type is i and rock quality is j.

From this it is clear that $\sum_k W_{ijk} = 1$ and also $\sum_{ijk} L_{ijk} = L$.

In Eq.(1), Pijk and Uijk are both random variables that provide ranges for the utilization and penetration rates under assumed i, j, and k conditions. Every random variable has to be identified with a distribution and the relevant parameters. In the actual study, two sets of computations have been carried out. In one, uniform distributions have been assumed for every random variable. In the second, triangular distributions have been assumed for every random variable. For the uniform distributions, ranges of distributions have been estimated based on the available information, experience and expert opinions. For the triangular distributions, the most likely value of every distribution was estimated in addition to the distribution range.

For example, TBM penetration rate in Argillite, in excellent rock conditions (RQD>96), was estimated to vary between 10.1 and 14.1 ft/hr. The most likely value for this rate was estimated as 12.1 ft/hr. Also, it was assumed that water inflow will only affect the utilization rate rather than the penetration rate. So the specified ranges for TBM penetration were assumed to be valid regardless of water inflow conditions. In this way a triangular distribution or a uniform distribution was completely specified for penetration rate in Argillite in excellent conditions. The same approach was used to estimate ranges of distributions to model penetration rates with other qualities of Argillite or with other types of rock expected to be encountered in the tunneling operation. It is clear that a large number of random variables had to be specified in order to estimate various Tijk's.



For computing the CDF of the total tunnel duration, a Monte Carlo simulation approach was utilized. A computer program was developed that sampled various statistical distributions specified by the modelers to pick up values used in Eq.(1). Every random

variate specified was sampled once. Values of Tijk's were computed depending on the i, j, and k that was sampled. The Ttot = 蹤ijk's were computed to provide total number of hours required for tunnel boring. This process of sampling the distributions was repeated 100,000 times and every time a Ttot was computed. These Ttot's were used to construct a CDF for the total tunnel duration. Using this CDF, various confidence levels could be computed for the completion of the tunneling operation. It is apparent that any existing correlations among model parameters in adjacent tunnel segments were neglected. Given the nature of the project, one would expect that it would be natural to expect correlation in tunneling conditions in the adjacent tunnel segments. The impact of disregarding these correlations, is that as most of the time these correlations are positive, the actual variance for project duration will be higher than the calculated variance from the model. This can give a false sense of security to the planner regarding the chances for schedule delay. Readers interested in further discussion of tunnel risk analysis are referred to Kim (1984). In this report we shall address the issue of correlation among random variables in the cost section where its impact is more obvious.

In order to illustrate the process of risk assessment, a much simplified scenario of the above problem is presented and a simulation approach is used to calculate the distribution of the project duration. Touran (1992) provides an alternative solution to this problem using a direct analytical approach in lieu of simulation.

Monte Carlo Simulation Approach: A Monte Carlo simulation study is conducted on a simplified version of Example 2 and computations are carried out with hypothetical data. It is assumed that one is interested in estimating the duration time required for tunneling a 1,000 ft segment in a certain rock under specific conditions. The duration time can be modeled as Eq.(3):

$$T = \frac{L}{P\,U} \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

In Eq.(3), L = 1,000 ft, and P and U are random variables that portray variations in the expected TBM penetration rate (P) and utilization rate (U). Further it is assumed that both P and U are independent and both follow a uniform distribution. The bounds of the distributions may be estimated by doing a literature search, examining historical data, or consulting experienced personnel. It is assumed that P may be any number between 8 ft/hr and 12 ft/hr and U may be between 40% and 60%.

A simple Monte Carlo simulation model was developed using SLAM-II software package. The simulation was run for 10,000 times. At every run T was computed. Table 5.3 shows the result of the simulation experiment.

TABLE 5.3 - Tunnel Duration (Example II)

| Duration (hours) (1) | Probability of finishing the project by the duration in Col.(1) (2) |
|---|---|
| 140 | 0 |
| 160 | 0.08 |
| 175 | 0.20 |
| 190 | 0.36 |
| 205 | 0.55 |
| 220 | 0.70 |
| 235 | 0.80 |
| 250 | 0.88 |
| 265 | 0.92 |
| 280 | 0.95 |

Using this Table various confidence levels can be investigated. According to analysis results, the average time to bore the tunnel was 205 hours with a standard deviation of 33.8 hours. From Table 5.3 it can be deduced that there is a 70% chance that the project can be completed within 220 hours. On the other hand, the probability of finishing the project in 175 hours is only 20%.

Examples discussed so far have illustrated typical applications of probabilistic analysis to duration estimation. All the examples cited above assume independence among variables. Analysis of correlated random variates is significantly more complicated than independent variates. General concerns in this regard are explained in the next section of this chapter when cost risk analysis is discussed.

## PROBABILISTIC MODELING OF THE PROJECT COST

A common application of risk analysis in construction is to compute the CDF of the total project cost. This in turn can help the owner specify margins of safety needed for the levels of funding required. The CDF developed by the contractor can help him arrive at a reasonable contingency sum and to allocate contingency to various project activities (Diekmann, et al, 1988; Hackney, 1985; Jackson, et al, 1985). Again Monte Carlo simulation technique is continuously used in cost risk assessment. At this point we will examine the typical cost functions that are used for risk modeling.

The total project cost is modeled as a random variable that is the sum of several cost items, themselves being random numbers. In Eq.(4), Ctot is the total project cost, and Ci's are various project cost components.



$$Ctot = \sum_{i=1}^{n} Ci \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Obviously, if one wants to consider cost variations in every small cost component that goes into a detailed estimate, the approach would be impractical. Because of this, the Ci's considered are major items that generally appear on the estimate summary sheets and ;he recap sheets. Also, it is understood that most of the total cost variation is due to the variability of a limited number of components (Management of risk, 1989; Curran, 1989). So only those items with high potential for variation are considered as random variables and the Test of the items am assumed to be fixed. Curran (1989) defines a critical variance for the bottom line. Any single component that has the potential of changing the project bottom line by more than this critical variance is considered a critical component and should be modeled as a random variable. Curran suggests the critical variance to be 0.5% of the project bottom line for conceptual estimates and 0.2% of the bottom line for detailed estimates. So, for example, in a $10,000,000 conceptual budget estimate, if any single component has the potential of changing the total cost by more than (0.5%)($10m) = $50,000, then this component is considered critical. Furthermore, Curran (1989) suggests that in over 90% of projects of all types, the number of critical items was fewer than 30. Other cost items in the project then, can be established as fixed values. Ctot in Eq.(4) is then composed of a fixed and a random component. As various Ci's can have various distributions, accurate computation of Ctot involves the computation of a number of convolution integrals and becomes very lengthy.

Monte Carlo simulation can simplify the process if a computer and the relevant software are available. It consists of generating random numbers according to q distributions, adding up these items, adding the fixed costs to these, and computing the total project cost. This procedure is repeated at least several hundred times, and every time a value for Ctot is computed. The number of iterations needed depends on the complexity of the model and how quickly the results of the analysis converge. It should be chosen sufficiently large so that the outcome of the analysis does not change by further increasing the number of iterations. A histogram, and later a Cumulative Distribution Function (CDF) can

be constructed with the values of Ctot. The CDF can then be used to estimate the probability of completing a project at or below a certain budget.

## Problems with Monte Carlo Approach

Although the Monte Carlo approach provides a straight forward means for probabilistic estimating, there are major limitations in its application. First, one needs to establish statistical distributions for various cost components. Second, if the random numbers are not independent, their correlations should be fully documented for the correct implementation of the Monte Carlo technique.



Underlying Statistical Distributions: One logical method for investigating the distribution type is to collect data from similar projects, assume a distribution, and perform a proper test of goodness of fit to evaluate the hypothesis. In the absence of historical data, the same general guidelines regarding the choice of distribution mentioned earlier in the report can be used.

Correlation between project cost components: One of the more common sources of error in Monte Carlo simulation is that it is assumed that cost components are independent and changes in one cost component do not affect any other cost component. This is clearly inaccurate in typical construction projects; however, it is assumed that if the correlation between variables is sufficiently small, the assumption of independence does not create large errors. Generally, disregarding the correlation between variables in a Monte Carlo simulation results in an underestimation of the total cost variance as the effect of covariances (that are mostly positive) in computing the variance is neglected. In a study, Toumn and Wiser (1992) analyzed the cost data for more than one thousand low-rise apartment buildings. It was found that by neglecting the effect of correlations among variables, the variance of the total cost was underestimated by 50%. This is clearly an error in the unsafe direction as larger variances mean higher probability of cost deviation.

Click HERE for graphic.

An Approximate Method for Incorporating Correlations: The accurate method of incorporating correlations is time-consuming and requires

a great deal of data that is not always available. In some cases, if the underlying distributions are not normal, it is not possible to make an accurate analysis. One suggested method (Curran, 1990) involves combining highly correlated cost items into a single cost item such that all the remaining cost items (some of which are a combination of several correlated cost items) can be considered independent. For example, assume that a project cost consists of ten cost items C1 to C10 (Touran and Wiser, 1992). So we have,



$$Ctot = \sum_{n=1}^{10} i \quad \ldots\ldots\ldots\ldots\ldots (7)$$

Further, assume that we have reason to believe that C4, C5, and C6 are highly correlated and that C9 is correlated with C10. Define C' and C" such that:

$$C' = C4+C5+C6 \quad \ldots\ldots\ldots\ldots\ldots (8)$$
$$C'' = C9+C10 \quad \ldots\ldots\ldots\ldots\ldots (9)$$

If the estimator can specify underlying distributions and parameters of C' and C", and if the rest of cost components can be assumed to be independent, then by rewriting Eq.(7) as Eq.(10). one can conduct a Monte Carlo simulation.

$$Ctot = C1+C2+C3+C'+C7+C8+C'' \quad \ldots\ldots (10)$$

In Eq.(10) all the items are assumed to be independent.

Curran (1990) presents a hypothetical example to show the application of the method described above. The problem is that in many cases it will be difficult and even unnatural to lump together various cost components and estimate their combined range, parameters, and distribution.

The Accurate Method for Incorporating Correlations: For conducting an accurate analysis of total cost variance, the joint density functions of the correlated cost components are needed. The PDF that the estimator or risk analyst specifies for a certain cost component is actually the marginal distribution of that cost component In general, if different cost components are not independent, knowing the marginals of these random variables is not sufficient to obtain their joint density functions. Without the joint density function, the correlated random numbers cannot be generated for Monte Carlo simulation. The case of multivariate normal distribution is an exception, however. If one has marginals of the multivariate normal distribution and the covariance matrix,

then one can generally find the joint density and conduct the analysis. This means that the cost components have to be normally distributed. Multivariate normal distribution can be transformed to multivariate lognormal (Johnson and Ramberg, 1978). Also, in special cases, one can use approximations to analyze the correlated random variates at the cost of reduced accuracy (Touran and Wiser, 1992; Touran, 1993). This level of detail in conducting risk analysis in construction however, is almost never attempted in practice and the assumption of independence or the simpler method described above is all that is actually used.

The Use of Rank-Order Correlations in Simulation: Although it is not generally possible to generate correlated random numbers according to non-normal marginal distributions, Iman and Conover (1982) have presented a method for generating variables with specified rank-ordered



correlation coefficients (Morgan and Henrion, 1990). Rank correlation coefficient between two random variables measures the correlation between the of the values of the two random variables. Many of the software packages developed for risk analysis (@RISKTM, for example) allow the user to specify correlation coefficients between several random variables and then generate correlated random numbers. It should be noted that these specified correlations are rank correlations rather than the more familiar Pearson correlation coefficients. Although several authors have claimed that rank correlations are indeed very good measures for describing the degree of association between variables, we believe that this assertion requires further study, especially in the domain of cost and schedule risk analysis.

Comprehensive Cost Functions

Eq.(4) is the simplest form of function that may be used for cost risk analysis. A more general model was suggested by Diekmann (1983) and is presented with slight modification in Eq.(11):

$$Ctot = \sum_{i}[ mi + wi\ li ] + \sum_{j} \ldots \quad (11)$$

where the total cost is composed of i categories of work and j indirect cost items. qi is the work quantity in category i, mi is the unit material cost of category i, li is the labor productivity rate (man-hours/q) for category i, wi is the wage rate related to labor li, and Cj is the indirect cost item j.

Again the Monte Carlo approach can be used to develop a CDF for Ctot. Any of the parameters described above may have variations that have to be considered in the analysis. An analytical solution may not be always convenient or even feasible depending on the shape of the cost function. Computations become cumbersome especially if reasonably complex and realistic distributions such as lognormal or beta are assumed for the parameters.

## Commercial Software

Most project cost functions can be modeled in a format similar to Eqs.(4) and (11). Several software packages are available that allow the user to conduct risk analysis on a personal computer (generally using a simulation approach). In using these packages, the user loses some flexibility in modeling but the process becomes convenient and fast. Understanding underlying assumptions used in the development of these packages are important if one wants to avoid errors in the interpretation of results. Many of these packages are designed as add-in modules to popular spreadsheet programs for personal computers (either IBM compatible or Macintosh) and are relatively inexpensive (e.g., @RiskTM(1991) or Crystal BallTM(1992)). So the user that is familiar with a computer spreadsheet will now have the capability of modeling any cell value in the spreadsheet as a random variable. There is a wealth of distributions to choose from and some



graphics capability is available. Furthermore, as noted above, these software systems allow the user to specify different values of correlation between various random variables.

## Example III

Assume a fixed guideway transit project's budget (or target estimate) was estimated at $1,205 million. Further, assume that the project's critical components have been identified, their distributions and parameters specified and a Monte Carlo simulation was conducted using the general format of Eq.(4). A histogram and a Cumulative Distribution Function (CDF) for the project has been developed as presented in Figs. 5.9 and 5.10.

Click HERE for graphic.

Click HERE for graphic.



Click HERE for graphic.

Table 5.4 gives statistics for the total costs. The computation of the CDF by Monte Carlo simulation technique is very similar to the method described in Example 11 and will not be repeated here. Table 5.4 shows that there is a 49.3% chance of having a cost overrun for the

TABLE 5.4 - Total Project Costs Statistics

| | |
|---|---|
| Simulation Iterations | 2,000 |
| Mean ($millions) | 1,202.47 |
| Maximum ($millions) | 1,497.80 |
| Minimum ($millions) | 800.85 |
| Total Cost (80% point on CDF of Fig.5.10)($m) | 1,291.60 |
| Probability of Cost exceeding Target ($1,205m) | 49.3% |

project with the estimated or desired budget. If the owner is not comfortable with this likelihood level and would prefer a confidence level of, say, 80%, then the budget required would be about $1,291.6 millions. In other words an $86.6 million contingency reserve is needed to assure with



a level of confidence of 80% (Table 5.4) that the project will not suffer cost overrun. Some practitioners prefer to arrange the CDF of Fig.5.10 in a slightly different way and develop a so called overrun profile for the project cost (Curran, 1989; CII Publ.6-8, 1989) (Fig. 5.11). In this figure, the values of the y-axis are simply the complements of the values of y-axis of Fig.5.10. The same conclusions can be drawn from Fig.5.11. There is a 49.3% chance of budget overrun if the target estimate is $1,205 million and there is a 20% (100% - 80%) chance of budget overrun if the target estimate is $1,291.6 million.

The same approach can be used by the contractor for arriving at a reasonable contingency sum for the project. The contractor can develop a CDF for project cost (excluding contingency or profit) and then choose a markup such that the probability of losing money on the project falls below a certain threshold

acceptable to him.

## INTEGRATION OF FINANCIAL AND CONSTRUCTION RISKS

So far we have discussed project construction cost and schedule risks, and financial risks separately. These risks all impact the project. A better picture of project's overall risks can be constructed if financial and construction risks arc incorporated in a single analysis. While separate analyses described earlier can pinpoint specific problem areas, this combined impact shows the overall project's chance of success. It is especially useful from the sponsor and the owner's point of view as it evaluates the adequacy of funding, the impact of the shortage of local funds or the increase of construction costs on the project's fate.

## EXAMPLE IV

In order to illustrate the implementation of both financial and construction risks in an analysis, we have developed a hypothetical case. The hypothetical case involves a major fixed guideway transit program consisting of 12 miles of elevated tracks and the related stations and equipment.

### Construction Costs

Construction costs for a fixed guideway transit project are estimated as described in EXAMPLE III above. The project spans over a five year period and the total cost including escalation factors is estimated as $1,205 million. Furthermore, the project budget has been distributed between years using the project schedule and is as given in the spreadsheet of Table 5.5. Each of these annual budgets are assumed to follow a normal distribution and for every year a contingency budget has been calculated such that the probability of cost overrun is kept to less than one third (33%). The total project contingency is $97.5 million that provides a confidence level of about 83% against cost overrun. In other words, there is a one chance in six that a cost overrun will occur. A CDF of the total project cost was given in Fig. 5.10 above.



### Project Financing

The project is financed from three primary sources of funds: federal grants, excise tax revenues, and proceeds from bond issues.

The amount derived from federal sources is assumed to be certain and is distributed as displayed in Table 5.5. The serial bonds issued here are considered revenue bonds. In other words, the sales tax revenues assumed here win be used to service the repayment of principal and interest of the bonds issued.

Sales tax revenues in later years will be used to repay the debt and interest expense associated with the bond issues. These revenues are assumed to grow at a mean annual rate of 2.5%. Growth rates are drawn from a truncated normal distribution with a mean of 2.5%, standard deviation of 2.5% between -2.5% and 7.5%. This growth rate reflects assumptions regarding income of underlying regional economy, population trends, and expansion of the regional job base.

Interest Rates: Interest rates are modeled as the inflation rate plus a time premium that increases with the bond's maturity. The inflation rate itself is assumed to follow a truncated normal distribution with a mean of 3.25% and a standard deviation of 3.25% truncated between 0 and 6.5% (Bodie, et. al., 1992). Mean interest rates for the serial bond issues used in this example are displayed in Table 5.6. Another relevant interest rate is the rate the owner can achieve from the surplus cash balances generated during the project's life. This rate is modeled as the inflation rate plus 1.0%.

Timing of Bond Issues: In this example, three serial bond issues are employed in years 1995, 1997, and 1999. These issues are timed to provide positive cash flows during the construction phase of the project. Bonds are issued according to the schedule displayed in Table 5.6 and have a total face value of $490 million. Interest rates for the bond issues are tied to their longevity and to variations in inflation rates. An upward sloping yield curve is assumed. This means that longer term bonds carry a higher interest rate than shorter term bonds. Tax revenues are not large enough to provide sufficient financing during construction. After construction, bond principal and interest are offset by sales tax revenues. The cash flows that result from this financing strategy are robust in early years and sufficient in later years. In practice, more complex bond issues would be used to minimize the surplus cash balances in early years. However, the simplified financing structure in this model captures the essence of cash flow management reasonably well.



Click HERE for graphic.

Simulation Analysis

It is assumed that FTA will provide $765 million distributed over a period of 5 years as given in the spreadsheet of Table 5.5. This amounts to about 60% of the total construction estate plus contingency. This ratio appears to be reasonable given current circumstances. $490 million is to be raised by issuing a series of revenue bonds.

Random Variables: Several items in the spreadsheet of Table 5.5 show potential for chance variations. Construction expenditures for every year are modeled according to normal distributions as discussed earlier Sales tax is a function of growth rate and inflation; interest income and debt service are modeled as functions of interest rate which itself is a function of inflation. As the inflation and growth rates are modeled probabilistically, sales tax, interest income, and debt service become probabilistic variables too.

Analysis of Results: A Monte Carlo simulation analysis was conducted on the spreadsheet. This was accomplished by generating random numbers according to specified probabilistic models for 2,000 iterations. The number of iterations was chosen sufficiently large to allow the simulation results to converge to their theoretical values. There are several important issues that have to be studied in this spreadsheet. First the planners have to make sure that the construction budget is sufficient and the contingency reserve is sufficient to meet unexpected cost variations. This issue was discussed throughout this paper and specifically in EXAMPLE III above.

Second, the ending cash balances should be positive throughout the spreadsheet. A negative value in any year means a cash shortfall that can create financial hardships and complications in the construction process. Simulation helps to assess the probability of having negative cash



balances throughout the project. Fig. 5.12 shows a Distribution Summary Graph for ending cash balances.

Click HERE for graphic.

Click HERE for graphic.

Table 5.7 provides summary statistics for this parameter. As can be seen the probability of having a negative cash balance increases in the later years. This is expected because of the modeling approach used in this example. For every iteration, a random value for inflation and growth rate is generated for the first year. In subsequent years, the generated values for the previous year will serve as the mean of the normal distribution used to model growth rate and inflation rate. In other words, the value of growth rate and the inflation will depend on their values in the previous year and will show a variance around the previous year's value. Tax revenues, interest income and bond proceeds are calculated m every iteration based on the generated growth and inflation rates. There are several alternatives to this approach; one can generate the values of tax revenues independently for various years or one can model inflation and growth rates as functions of an initially specified random variable that increases every year at a constant rate. More complicated models based on probabilistic treatment of population trend, local income, etc. can be conceived. It should be noted that one should set a limit to model complexity, otherwise interpretation and analysis of results may become difficult. Also the model may become intimidating to the experienced personnel that may be contribute to the planning effort by drawing upon their knowledge and past experience.

As can be seen (Table 5.7) there is a 31.3% chance that the project may sustain a cash shortfall in Year 2005. This probability is 24.6% for the Year 2004. For earlier years this probability is significantly lower and never exceeds 8.9%. Fig. 5.13 gives the ending cash flow distribution for the Year 2005. Depending on the planners' tolerance for risk, they may have to deal with this situation. One option would be to consider issuing more bonds when needed. This option should be considered in conjunction with the ability of the local economy to repay the debt. Another option would be to increase the sales tax rate. Either option could be pursued before the project is undertaken or during the project when the funds are needed.

Click HERE for graphic.



Another item of interest can be the growth of sales tax and its variations. As the sales tax is the major source of servicing the debt in this example, the project's sensitivity regarding the variations in growth rate should be studied. This can be done at

two levels. In one method, one can deterministically change the values of growth rate and for each scenario study the impact on the project's viability. In another method, a sensitivity analysis can be conducted while assuming a probabilistic model for the growth rate. This second model, though a bit more complex, is more realistic because it provides a measure of uncertainty for every scenario studied.

Click HERE for graphic.

SUMMARY

The objective of this chapter was to introduce methods and procedures for quantifying cost and schedule risks. First, the risk perception from the viewpoint of the owner and the contractor was discussed. Then, the concept of project contingency was covered. The techniques used in risk and modeling were divided into two major categories: deterministic and probabilistic. Deterministic contingency and sensitivity analysis were described. Then probabilistic risk measurement using analytical and Monte Carlo simulation approaches were explained. Issues and difficulties involved in probabilistic risk measurement such as the choice of statistical distribution and the mathematical model used for predicting total project cost or schedule were covered. Also the problem of variable correlation was addressed and some



guidelines were suggested. Several tools and software systems used in risk measurement were introduced and their strengths and shortcomings reviewed. Application examples were provided to show how the procedures presented were applied in practice. These examples covered schedule and cost risks. One example in particular, analyzed the interaction between financial and construction risks. It was shown that while probabilistic approach is in general mom complicated than the traditional methods of risk measurement, the additional information that results from an effective probabilistic analysis clearly makes it the better choice. Furthermore, availability of easy to use software and recent increase in the use of these methods have improved the understanding of the professional community.

The objective of this chapter is to help the owner to allocate the risks identified in the first step of the risk management process (Fit. 1.1) to various parties involved in the project. The owner should be doing this with a knowledge of the magnitude of risk (quantifies in step two, Fig. 1.1), because the risk magnitude can impact its optimal distribution.

In this chapter, we have considered most of the items identified in the risk checklist (Chapter 2). While many items deal with project planning, a large number of risk factors pertain to the construction process. These construction related items are usually allocated through clauses of the construction contract. Because of this, developing a fair and careful construction contract is of utmost importance for effectively distributing risks and keeping the probability of cost and schedule overruns low.

## INTRODUCTION

One risk have been identified and measured, the process of risk allocation amongst the parties involved in the construction project may begin. Since the owner is the one who provides the money, it is his privilege to assign responsibilities. Accordingly, he has the opportunity to reduce the total project cost through effective allocation of financial, design, and construction risks.

Publicly funded projects are usually awarded on a lumpsum basis through competitive bidding. Although objectives and specific requirements of major fixed guideway transit systems are generally defined carefully, not all of the project details are known in advance. A good portion of these contracts involve construction of underground facilities and tunnels where ground behavior cannot be predicted with great accuracy. Also, some of these projects are so complex that there are few eligible contenders to bid on the job. The traditional lumpsum approach where the total risk is placed on the contractor's shoulders through rigid contractual language is not necessarily optimal (Business Roundtable, 1982; CII Publ. 5-3, 1988). Contract clauses that place an inequitable risk share on the contractor are not cost effective for the owner (Dunlop, et al, 1988). Gross inequities in risk sharing promote negative working relationships and increase disputes (CII Publ. 5-3, 1988).

One example of risk allocation is the handling of contaminated material. This is especially relevant in underground construction and tunneling, where quantity and extent of contamination is not clear until the project is underway. Massachusetts Bay Transit Authority (MBTA) for example, uses a unit-price contracting method

where the contractor is required to submit separate unit-prices



for disposal of contaminated and uncontaminated material. In this way, the contractor would be compensated for the handling of the contaminated material and does not have to include a large contingency in the bid to cope with the potential high cost of dealing with an unknown quantity of contaminated material. Although the owner does not have the benefit of a fixed price, it only pays the extra cost if and when excessive amounts of contaminated material are detected. So both parties, contractor and the owner, benefit from this contractual agreement.

Construction Industry Institute (CII), a research group at the University of Texas, conducted a study in 1988 to examine various aspects of risk allocation in construction projects. In lumpsum construction contracts, the following clauses were found to be extremely important:

- Indemnity
- Consequential damages
- Differing conditions
- Delay

Depending upon who will be held responsible for each of the above issues, project performance (cost, schedule, quality, and safety) and the working relationship between owner and the contractor will be greatly affected. The study was concluded by making a number of specific recommendations on the preparation of contract clauses regarding risk allocation. Most of these recommendations pointed to some middle ground between the extreme cases of either placing the total risk on the contractor or keeping him completely insulated from risk. The study was conducted by collecting questionnaires from 36 contractors (many were designer/constructors) and interviewing them later to fine tune the results of the analysis. Another similar study (CII, Publ. 51, 1986) has shown that owners and contractors frequently interpret risk allocation clauses differently and this also leads to dispute. So it is be important to spend effort clarifying any ambiguity and promoting a spirit of cooperation and understanding among the parties to the contract.

## PRINCIPLES OF RISK ALLOCATION

Experience has shown that it is the owner who ultimately bears the burden of risks, whether he originally accepts them, whether he assigns them to the contractor and receives them back in the form

of higher bid contingencies and change orders, whether he receives no proposals because he transfers all risk to the contractor, or whether he pays for them via court decree (Riggs, 1979; Kuesel, 1979). Contract documents should be prepared by the owner's legal staff with full knowledge of construction management and engineering as to how the risks will be allocated with adequate time for the selection of the appropriate language, and with sufficient time for review (Riggs, 1979). With reference to optimal risk allocation, there are several tenets which owners should follow when instructing the legal staff. The primary doctrines of risk allocation are:



- Allocate the risk to the party who is in the best position to control it 1(Diekmann et al, 1988; Thompson & Perry, 1992; Bramble et al, 1990, Wideman, 1992)
- Which party is in the best position to accept the risk if it cannot be controlled? (Mompson & Perry; Wideman, 1992)
- Consider the ability of the party receiving the risk to survive the consequences if the risk occurs (Bramble et al, 1990; Thompson & Perry, 1992; Diekmann et al, 1988; Nadel, 1979)
- Consider whether the dollar premium charged by the transferee will be acceptable and reasonable (Thompson & Perry, 1992)
- Do not penalize a party for accepting a risk; for example, do not use a no damages for owner caused delay clause in conjunction with a liquidated damages clause (Bramble et al, 1990)
- Evaluate the potential for new risks being transferred back to the owner when initial allocations are made (Thompson & Perry, 1992; Wideman, 1992)

## RISK MANAGEMENT STRATEGIES

### Background

Various experts have developed risk management strategies to help the owner select the most suitable option for a given risk. Since many options appear simultaneously in various references, we first delineate each recommendation in a succinct form and then explain the common interpretation of all possible options. Subsequently, we shall present our selection of the best options and the reasons why they were chosen. The references chosen here have used several references themselves, so the following is the result of numerous studies, projects, and individual expertise. In short, this synthesis conveys the state of knowledge on risk allocation at this time.

Diekmann et al, (1988) propose the following alternative risk

mitigation tactics and suggest that the owner select the most appropriate alternative(s):

"- Eliminate the risk by banning the activity, process, or material
- Reduce the risk by substituting a less risky method, process or material
- Transfer the risk to another party
- Share the risk
- Retain the risk uninsured."

Wideman (1992) classifies risk mitigation measures as follows:

---

1Who is in the best position to control the events that may lead to the risk event? For example. when a railway alignment is proposed to transverse a densely populated urban area, vibrations from a passing train are likely to impact adjacent buildings. Since the designer is in the best position to minimize the likelihood of these vibration, he should be allocated such a responsibility.



"- Unrecognized, unmanaged or ignored (by default)
- Recognized but no action taken (absorbed as a matter of policy)
- Avoided (by taking appropriate steps)
- Reduced (by an alternative approach)
- Shared (with others, e.g., by joint ventures)
- Transferred (to others through contract or insurance)
- Retained and absorbed (by prudent allowances)
- Handled by a combination of the above."

Al-Bahar and Crandall (1990) suggest that the project risks can be mitigated through risk avoidance, loss reduction and risk prevention, risk retention, risk transfer (noninsurance or contractual) and insurance.

Lasdy, the C.I.I. publication 6-8 "Management of Project Risk and Uncertainties" (1989) proposed that risk control actions fall into two wide categories: Advanced Planning Actions and Risk Containment Actions, the first of which is applicable here and consists of risk avoidance, risk sharing, risk reduction, risk transfer, insurance, risk acceptance with contingency, and risk acceptance without contingency.

RISK MITIGATION MEASURES

Based on the foregoing studies and other extensive research, we have concluded that risks may be allocated by one or more of die following options:

- Risk acceptance
- Risk reduction
- Risk sharing
- Risk transfer
- Risk avoidance

Thee list has been organized such that responsibility and ultimate control that the owner retains for a particular risk changes from high to low. For example, if the owner accepts the risk of inflation, he has relieved the contractor of the risk burden altogether. He has placed himself in the position of controlling the inflation risk and must consider options such as contingency, currency futures, or interest bearing investments. At the other end of the spectrum, an owner may choose to avoid a risk. As a result, he will hope to have no responsibility for it and have little control over it (other than to continue to avoid it). These five options, while covering all methods of risk mitigation, consolidates some mitigation measures suggested by others. For example, insurance is generally considered as a risk transfer measure. So there is no need to have both insurance and risk transfer as independent mitigation measures; rather, insurance is treated as a subcategory of risk transfer. Similarly, risk acceptance with contingency and risk acceptance without contingency are both methods of accepting the risk and can be treated under one mitigation measure. Now, we further elaborate on each of these alternatives. It should be noted that in many cases, a combination of these measures are called for to properly allocate and mitigate a certain risk.



Risk Acceptance: Risk acceptance connotes that the owner will assume the whole or a portion of the monetary impact of the risk. Note that acceptance may be planned or uncontemplated. A planned risk acceptance indicates that. the owner has thoughtfully investigated and deliberately chosen to retain an identified risk (Al-Bahar & Crandall, 1990). In order for a risk to be accepted it will generally comply with one of the following conditions:

"A. It is voluntarily assumed
B. No alternative is available
C. The risky outcome is unknown with certainty
D. Exposure is essential
E. The negative consequences are ordinary" (Diekmann et at, 1988)

An uncontemplated risk acceptance occurs when the owner fails to identify or recognize the risk, and therefore unknowingly accepts the risk that may happen. Generally, such instances occur when the owner fails to perform a thorough risk identification analysis, and by default, passively retains the risk and this is when it is most costly to the owner. Alternately, uncontemplated risk acceptance occurs when the owner correctly identifies a risk, but fails to or cannot properly assess the size of the potential losses. (Al-Bahar & Crandall, 1990)

Risk acceptance may be made with contingency or without contingency. Contingency is a sum of money or period of time set aside from the general construction funds to pay for losses that actually occur. As described in Chapter 5, the total contingency budget will be the sum of the contingencies calculated for various risk components in the project. To the extent that total project costs do not exceed the planned budget with the planned contingency sums, the owner will not have to search for additional funding. Risk acceptance without contingency should only be considered when funding limitations preclude a properly implemented contingency account. This however, is a risky strategy. If such an instance should occur, the accepted risk items should have a low probability of occurrence or low potential impact.

Risk Reduction: In the context of this report, risk reduction implies that the owner has accepted the risk but has taken certain defensive planning actions to lower its potential impact. This may be accomplished in two ways: 1) lowering the probability of a risk, and/or 2) lowering the dollar impact of the risk if it does occur. Examples of specific actions that project management may pursue are listed below:

"- Qualified personnel
- Qualified subcontractors
- Safety/loss control program
- Responsibility allocation
- Strong project controls
- Constructability analysis
- Pareto's law control
- Critical items reporting
- Contingency account management



- Substance abuse program
- Training programs
- Project labor agreement
- Risk re-evaluation
- Crisis management" (C.I.I.- Pub 6-8,1989)

Risk reduction may also be accomplished by selection of an alternative which possesses a lower risk. The alternative may be a different process, material, or method that still accomplishes the same goal (Dielanann et al, 1988). Alternates are often engendered by constructability reviews, alternative bids, and value engineering.

Risk Sharing: When it is impossible or impractical for one party to control a specific risk, the task may be better managed by dividing it such that two or more parties manage the portion that they are best able to control individually. An excellent example of risk sharing is the development of a joint venture by contractors. A joint venture is the result of the unification of two or more contracting firms to build a single project. These types of organizations are often extremely well suited for the pooling of complimentary resources and facilities, for spreading construction risks, and for accomplishing tasks greater than any individual firm acting alone can undertake. For example, in a major fixed guideway transit project, a heavy construction company and a mechanical/electrical contractor may join forces to accomplish the project.

At a risk item level, an owner may share inflationary risks with a contractor in projects with long durations. In this way both parties will be exposed to a risk item none of whom have much control over.

At the contractual level, risks may be shared through the use of a Guaranteed Maximum Price (GMP) Contract. With this type of contract, the contractor is reimbursed for costs incurred plus a fee up to the contract ceiling. If the project costs exceed the guaranteed maximum, the owner is exposed to risks for the costs below the ceiling. It should be noted however, that cost plus contracts are not commonly used in public works contracting. Because of this, we will not be investigating this option in great detail.

Risk Transfer: Risk transfer may be accomplished by allocating the risk contractually to either of two major groups: 1) contractor, designer, material supplier, subcontractor, etc., or 2) insurance and bonding. When allocating risk to the first group, the owner will achieve the best overall result by recognizing the doctrines of risk allocation set forth earlier in this section. In those instances where the amount of transferred risk results in low competition or high bid prices, the owner should elect to utilize the services of professional risk insurers. The following is a list of risks which may be insured:

"1 DIRECT PROPERTY DAMAGE
- Resulting from auto collision or other auto events
- To equipment, in transit or handling, etc.
- To project materials, including theft

2 INDIRECT CONSEQUENTIAL LOSS
- Cost of removing direct loss debris
- Equipment replacement
- Rental income loss
- Business interruption
- Increased financing

3 LEGAL LIABILITY
- Public bodily harm
- Property damage arising from negligence of others
- Damage to the project entity due to:
    Design errors
    Excavation errors
    Project failure to perform as specified

4 PERSONNEL-RELATED
- Employee bodily injury
- Cost to replace employee
- Resulting business loss" (Wideman, 1992)

Risk Avoidance: One obvious measure to avoid risks is not to proceed with the project at all. This option may not be always available. However, it is still possible to avoid certain risky tasks, materials, or processes. For example, use of a new technology, although potentially attractive, may result in costly complications; a traditional technology in such a case would avoid the risk of using that new technology altogether. As various phases of project planning and design such an Alternatives Analysis, Draft and Final Environmental Impact Statements are completed and approved, the ability to avoid risks diminishes. In such cases, other mitigation measures are usually used to limit the owner's exposure to risk.

## RISK ALLOCATION TABLE

In our research, we found out that although a great deal of effort had been expended on various methods of risk allocation and mitigation, most of the research was fragmented and specific to a single or a few risk items. The notable exception was tunneling and underground construction. Because of the nature of these projects and the extent of uncertainty involved, several concerted

efforts in this area have resulted in a few high quality publications.



In our view, it is valuable to use these various references and compile them in a tabular format; this will bring together the results of the research and experience in the past two decades in the area of risk allocation and mitigation.

The following risk allocation table is a compilation of numerous procedures employed and suggested by industry professionals and educators. It is organized with the same format as the risk checklist presented earlier in this report. Oftentimes, the reader is given more than one allocation option. This has been done because no one solution is appropriate for all projects. Owing to the uniqueness of every project, management must select from among the mitigation techniques for the most appropriate. Every action or reason provided in the table is referenced to one or more publication. A list of publications referenced in the table is given at the end of this chapter.



Click HERE for graphic.

---

1 The numbers in parentheses refer to references given at the end of the Risk Allocation Table.

2 One solution may be the inclusion of a specific "Suspension" clause for political events.



Click HERE for graphic.

---

3 By requiring labor agreements for the period of contract from the contractor



Click HERE for graphic.

---

4 The owner may also require a detailed bid breakdown from the lowest apparent bidder.

5 It is probably wise to accept the risk when project duration > 24 months.

6 Other measures may include issuing of interim NTP's and receiving authorization for distinct project phases.



Click HERE for graphic.

7 Use of Value Engineering clauses may also be effective.



Click HERE for graphic.

8 The owner may require the contractor to provide alternate bid prices with various completion times.

9 It is good practice to specigy a method for determing time extensions.

10 Require that changed conditions be reported prior to proceeding with affected work.



Click HERE for graphic.

11 Assigning too much risk to Engineering may result in expensive overdesigns.

100

Click HERE for graphic.

---

12 It is recommended that the site be videotaped prior to the bid to reduce claims of changed conditions, etc.

101

Click HERE for graphic.

---

13 For example, in case where there is a potential for hazardous materials, the owner may ask the bidders to provide unit prices contingent on encountering such materials. This would generally not affect the total bid but will come into effect if indeed the contractor encounters hazardous material during construction.

14 It is prudent to clearly specify bases for bid rejection and withdrawal

102

Click HERE for graphic.

---

15 This method of contractinf is not common in public works projects.

103

Click HERE for graphic.

---

16 Some of the economic factors that contractors consider in deciding on the level of markup in a lumpsum contract would be the amount of their backlog (generally, the larger the backlog, the higher the level of markup), the number and the identity of competitors, and general economic conditions (in slow times markup tends to be lower).

17 For example, the MBTA (Massachusetts) prequalifies bidders for contracts over $1 million.

104

Click HERE for graphic.

105

Click HERE for graphic.

106

Click HERE for graphic.

---

18 One has to make sure that using wrap-up insurance will not benefit unsafe contractors.

107

Click HERE for graphic.

108

Click HERE for graphic.

---

19 Because it may not be cost effective to shift this risk to the contractor.

109

Click HERE for graphic.

---

20 The owner may consider establishing penalties for noncompliance with DBE rules.

21 By using a turnkey approach all the weather risk could be allocated to the contractor except where governed by state laws(34).

110

Click HERE for graphic.

111

Click HERE for graphic.

112

Click HERE for graphic.

---

22 Defensive engineering refers to the situation where the Engineer, feeling threatened by the perceived high level of risk in the design contract, attempts to design the project conservatively and hence often expensively.

23 XCU: collapse of buildings, blasting, damage to underground property.

113

Click HERE for graphic.

Click HERE for graphic.



12. Clough, R., Construction Contracting, 5th Ed., John Wiley and Sons, New York, NY, 1986.

13. "Contracting Practices for the Underground Construction of the Superconducting Super Collider," U.S. National Committee on Tunneling Technology, National Research Council, National Academy Press, Washington, D.C

14. Contract Risk Allocation and Cost Effectiveness, Construction Industry Institute, Publication 5-3, University of Texas, Austin, Texas, Nov. 1988.

15. Diekmann, James E., Sewester, E.E., and Taher, K., Risk Management in Capital Projects, University of Colorado at Boulder, Oct. 1988.

16. Hack, Samuel L, "Project Management and Contractual Relationships," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

17. Hanunond, David G., "Minimizing Risks and Mitigating Losses," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

18. Hancher, Donn E., et. a]., "Bond and Insurance Coverages for Highway Construction Contractors," NCHRP Synthesis Report 341, Transportation Research Board, National Research Council, Washington, D.C., 1991.

19. Hayes, Ross W., John G. Perry, Peter A. Thompson, and Gillian Willmer, Risk Management in Engineering Construction: Implications for project managers, Thomas Telford Limited, London, December 1986.

20. Hinze, J., Construction Contracts, McGraw-Hill, Inc., New York, NY, 1993.

21. "I.T.A. Recommendations on the Contractual Sharing of Risks," Tunneling and Underground Space Technology, 1988.

22. Impact of Various Construction Contract Types and Clauses on

Project Performance, Construction Industry Institute, Publication 5-1, University of Texas, Austin, Texas, July 1986.

23. Kuesel, Thomas R., "Allocation of Risks," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

24. Management of Project Risks and Uncertainties, Construction Industry Institute, Publication 6-8, University of Texas, Austin, Texas, Oct. 1989.

25. Nadel, Norman A., "Allocation of Risks - A Contractors View," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.



26. Owner's Guide to Saving Money by Risk Allocation, Associated General Contractors of America, Inc., Washington, D.C., 1991.

27. Ribakoff, Solomon, "Construction Contract Arrangements," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

28. Riggs, Louis W., "Contractual Arrangements For Construction," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

29. Ryland, V. Wallace, "Minimizing Risks/Mitigating Losses," Proc.,Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

30. "Standard Insurance Specifications for MBTA Construction Contracts," MBTA, Boston, Mass., February, 1992.

31. Strauss, M.W., "Risk and Liability Sharing: The Owner's View," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

32. Thompson, P., and J. Perry, Engineering Construction Risks, Thomas Telford, London, UK, 1992.

33. Wideman, R., Max, Project and Program Risk Management, Project management Institute, Drexel Hill, Pa., 1992.

34. Yarema, G.S., "The Next Step in the FTA Turnkey Demonstration Program: Developing an Effective Contract," FTA/APTA Turnkey Workshop, USDOT/FTA, Miami, Florida, June 10, 1993.

# APPENDIX A - REFERENCES

Al-Bahar, Jamal F. and Crandall, Keith C., "Systematic Risk Management Approach for Construction Projects," Journal of Construction Engineering and Management, ASCE, Vol. 116, No. 3, Sept. 1990,533-546.

Alldredge, William S., "Allocation of Risks," Proceedings, Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

Altman, E.T., Corporate Financial Distress, John Wiley & Sons, New York, New York, 1983.

Altman, E.I., "Financial Ratios, Discriminant Analysis, and the Prediction of Corporate Bankruptcy," Journal of Finance, September 1968, 589-609.

Avoiding and Resolving Disputes During Construction, Technical Committee on Contracting Practices of the Underground Technology Research Council, A.S.C.E., New York, N.Y., 1991.

Barnes, Martin, "How To Allocate Risks in Construction Contracts," Project Management, Butterworth & Co., Ltd., 1983.

Barrie, D., and B.C. Paulson, Jr., Professional Construction Management, 3rd Ed., McGraw-Hill, Inc., New York, N.Y., 1992.

Bates, G.S., "Minimizing Risks and Mitigating Losses," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

Best's Insurance Reports - Property-Casualty, A.M. Best Company, Oldwick, N.J., 1992.

"Better Contracting for Underground Construction," U.S. National Committee on Tunneling Technology, National Academy of Sciences, Washington, D.C., 1974.

Bickelhaupt, David, L., General Insurance, 11th Ed., Richard D. Irwin, Inc., Homewood, Ill., 1983.

Bodie, Z., A. Kane, and A.J. Marcus, Investments, Irwin, Inc., Boston, Mass., 1993.

Booz-Allen and Hamilton, Inc., Light Rail Transit Capital Cost Study, Urban Mass Transportation Administration, U.S. Department of Transportation, Washington, D.C., 1991.

Bramble, B., M. D'Onofiio, and J.B. Stetson, Avoiding and Resolving Construction Claims, R.S. Means, Inc., Kingston, Mass., 1990.

Burtch, Chauncey E., "Concept To Commissioning: How Risky The Trip?," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

Casey, J. Joseph, "Identification and Nature of Risks in Construction Projects: A contractor's Perspective," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications, U.S. Department of Transportation, Federal Highway Administration, 1985.

Clough, Richard, Construction Contracting, John Wiley and Sons, New York, New York, 1986.

"Companies Holding Certificates of Authority as Acceptable Sureties on Federal Bonds and as Acceptable Reinsuring Companies," Circular 570, Federal Register, Department of the Treasury, July 1, 1992.

Constructability - A Primer, Publication 3-1, Constructability Task Force, CII, Austin, Texas, 1986.

"Contracting Practices for the Underground Construction of the Superconducting Super Collider," U.S. National Committee on Tunneling Technology, National Research Council, National Academy Press, Washington, D.C.

"Contract Risk Allocation and Cost Effectiveness," Publication 5-3, Construction Industry Institute, University of Texas, Austin, Texas, Nov. 1988.

"Contractual Arrangements," Report A-7, Construction Industry Cost Effectiveness Report, The Business Roundtable, October, 1982.

Crystal Ball, Decisioneering, Inc., Boulder, Colorado, 1992.

Curran, M.W., "Range Estimating," Cost Estimating, No.3, Vol.31, March, 1989, 18-26.

Curran, M.W., "Range Estimating reduces Iatrogenic Risk," Proceedings, American Assoc. of Cost Eng., Boston, Mass., June, 1990, k.3.1-k.3.3.

D'Eramo, D.E., and R. Martinez, "The Old Colony Railroad Rehabilitation Project," Civil Engineering Practice, Vol. 6, No. 2, Fall, 1991, 55-72.



Devore, J.L., Probability and Statistics for Engineering and the Sciences, 3rd Ed., Brooks/Cole Publishing Co., Pacific Grove, Calif, 1991.

Diekmann, James E., Sewester, E.E., and Taher, K., Risk Management,,in Capital Projects, University of Colorado at Boulder, Oct. 1988.

Dielanann, J.E., "Probabilistic Estimating: Mathematics and Applications," Journal of Construction Eng. and Management, ASCE, Vol. 109, No.3, September, 1983, 297-308.

Dunlop, J.R., M.M. Parker, and D.B. Ashley, "The Impact of Risk Allocation and Equity in Construction Contracts: An Overview of Indemnity, Consequential Damage, Differing Conditions and Delay Clauses," The University of Texas at Austin, May, 1988.

Duns Analytical Services, Dunn and Bradstreet, 1987-1991.

Economic Report of the President, Council of Economic Advisors, Washington, D.C., 1993.

"Final Environmental Impact Statement," City and County of Honolulu, Department of Transportation Services, Federal Transit Administration, Honolulu, Hawaii, July 1992.

Gaarslev, A., "Stochastic Models to Estimate the Production of Material Handling Systems in the Construction Industry," Technical Report No.111, Construction Institute, Stanford University, Stanford, Calif., August, 1969.

Gilly, B.A., A. Touran, and T. Asai, "Quality Control Circles in Construction," Journal of Construction Engineering and Management, ASCE, Vol. 113, No. 3, September, 1987, 427-439.

Hack, Samuel L., "Project Management and Contractual Relationships," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

Hackney, J.W., "Applied Contingency Analysis," AACE Transactions, 1985, B.2.1-B.2-4.

Halpin, D.W. and R.W. Woodhead, Construction Management, John Wiley and Sons, Inc., New York, New York, 1980.

Hammond, David G., "Minimizing Risks and Mitigating Losses," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

Hancher, Donn E., D. Burke, and Z. Goff, "Bond and Insurance Coverages for Highway Construction Contractors," NCHRP Synthesis Report 341, Transportation Research Board, National Research Council, Washington, D.C., 1991.



Hayes, Ross W., John G. Perry, Peter A. Thompson, and Gillian Willmer, Risk Management in Engineering Construction: Implications for project managers, Thomas Telford Limited, London, December 1986.

Hinze, Jimmie, Construction Contracts, McGraw-Hill Inc., New York, New York, 1992.

Hutchens, Peyton E., "Risk Reduction Through Indemnification Contract Clauses," Journal of Management in Engineering, Vol.8, ASCE, New York, N.Y., July 1992.

"I.T.A. Recommendations on the Contractual Sharing of Risks," Tunneling and Underground Space Technology, 1988.

Iman, R.L. and W.J. Conover, "A Distribution-Free Approach to Inducing Rank Correlation Among Input Variables," Communications on Statistics: Simulation and Computing, Vol.11, No.3. 1982, 311-334.

Impact of Various Construction Contract Types and Clauses on Proect Performance, Publication 5-1, Construction Industry Institute, University of Texas, Austin, Texas, July 1986.

"Instructions, Construction Contract Risk Analysis Weighted Guidelines," Mass. Highway Dept., Boston, Mass., 1992.

Jackson, R.L., J.W. Kinsey, W.E.Cotton, and S.K.Moore, "The Why and How of Contingency Management," Transactions, AACE, 9th Annual Meeting, Denver, Colo., 1985, N.0.1-N.0.5.

Johnson, M.E., and J.S.Ramberg, "Transformations of the

Multivariate Normal Distribution with Applications to Simulation," Los Alamos Sci. Lab. Tech. Report LA-UR-77-2595, Los Alamos, N.M., 1978.

Keown, A., D. Scott, J. Petty, and J. Martin, Basic Financial Management, 6th Ed., Prentice-Hall, Englewood Cliffs, N.J., 1993.

Kim, Y.W.,"Decision Support Framework in Adaptable Tunneling," dissertation submitted to the Dept. of Civil Eng. of Massachusetts Institute of Technology, in partial fulfillment of the requirements for the Degree of Doctor of Philosophy, Boston, Mass., April., 1984.

Kuesel, Thomas R., "Allocation of Risks," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

Luglio, Thomas J. Jr., and Parker, Jeffrey A., Turnkey Procurement: Opportunities and Issues, Dept. of Transportation, Federal Transit Administration, 1992.

Mak, Stephen, and Raftery, John, "Risk Attitude and Systematic Bias in Estimating and Forecasting," Construction Management and Economics, July 1992, Vol 10, pp 303-320.



Management of Project Risks and Uncertainties, Construction Industry Institute, Publication 6-8, University of Texas, Austin, Texas, Oct. 1989.

McOllough, P.R., "Eisenhower Memorial Tunnel- How Colorado Department of Highways Improved Contracting Practices and Management," Proceedings, Rapid Excavation and Tunnelling Conference, 1981.

Miller, R.W., Schedule, Cost and Profit Control with PERT, McGraw-Hill Inc., New York, New York, 1963.

Mlakar, P.F., and LM.Bryant, "Direct Range Cost Estimating," Proceedings, AACE, Boston, Mass., June 1990, K.4.1-k.4.4.

Moder, J.J., C.R.Phillips, and E.W.Davis, Project Management with CPM, PERT, and Precedence Diagramming, 3rd Ed., Van Nostrand Reinhold Co., New York, New York, 1983.

Monte CarloTM, Ver. 2.0, Primavera Systems, Inc., Bala Cynwyd, Penn., 1993.

Moody's Bond Record, Moody's Investor Services, New York, New York, various issues.

Moody's Municipal Credit Record, Moody's Investor Services, New York, N.Y., various issues.

Morgan, M.G. and M. Henrion, Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis, Cambridge University Press, New York, New York, 1990.

"Old Colony Railroad Rehabilitation Project from Boston to Lakeville, Plymouth and Scituate, Massachusetts," Draft Environmental Impact Statement Report, UMTA and MBTA, May 1990.

Nadel, Norman A., "Allocation of Risks - A Contractors View," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

Needles, B.E., Jr., Financial Accounting, Third Edition, Houghton Mifflin Co., Boston, Mass., 1989.

O'Shea, J.B., G.N.Slutkin, L.R.Shaffer, "An Application of the Theory of Queues to the Forecasting of Shovel-Truck Fleet Productions," Construction Research Series, No.3, Dept. of Civil Eng., University of Illinois, Urbana, Ill., June 1964.

Owner's Guide to Saving Money by Risk Allocation, Associated General Contractors of America, Inc., Washington, D.C., 1991.



Pegden, C.D., R.E. Shannon, and R.P. Sadowski, Introduction to Simulation using SIMAN, McGraw-Hill Inc., New York, NY, 1990.

PERT Cost Systems Design, DOD and NASA Guide, The Office of the Secretary of Defense and the National Aeronautics and Space Administration, U.S. Government Printing Office, Washington, D.C., June 1962.

Pickrell, Don H., Urban Rail Transit Projects - Forecast Versus Actual Ridership and Cost, Transportation Systems Center, U.S. Department of Transportation, Cambridge, Ma., 1990.

Platt, H., and M. Platt, "Development of a Class of Stable Predictive Variables: The Case of Bankruptcy Prediction," Journal of Business Finance and Accounting, Spring 1990, 31-51.

Pritsker, A.A.B., Introduction to Simulation and SLAM-II, 3rd Ed., Systems Publishing Corp., West Lafayette, Ind., 1986.

Pritsker, A.A.B., C.E. Segal, and R.D.J. Hammersfahr, SLAM-II Network Models for Decision Support, Prentice-Hall, Englewood Cliffs, NJ., 1989.

"Project Development Process for Major Transit Investments," FTA Pamphlet, Washington, D.C.

"Regulations Governing Surety Companies Doing Business with the United States," Treasury Circular 297, Revised 9/1/1978, Dept. of the Treasury, Washington, D.C., 1978.

Remmen, Albert, The Contract Bond Book, National Underwriter Publications, 1980.

Ribakoff, Solomon, "Construction Contract Arrangements," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

Riggs, Louis W., "Contractual Arrangements For Construction," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

@RISK: Risk Analysis and Modeling User's Guide, Palisade, Inc. , Newfield, NY., 1992.

Robert Morris Associates, '91 R.M.A. Annual Statement Studies, Philadelphia, Pa., 1989.

Ross, S.A., R.W. Westerfield, and B.D. Jordan, Fundamentals of Corporate Finance, Irwin, Inc., Homewood, Illinois, 1992.

Rowe, William D., An Anatomy of Risk, John Wiley & Sons, Inc., New York, N.Y., 1977.

Russell, Alan D. and Ranasinghe, Malik, "Analytical Approach for Economic Risk Quantification of Large Engineering Projects," Construction Management and Economics, Vol.10, 1992, pp 277-301.



Russell, Jeffrey S., "Underwriting Process for Construction Contract Bonds," Journal of Management in Engineering, Vol.8, ASCE, New York, N.Y., Jan. 1992, pp 63-80.

Russell, Jeffrey S., "Construction Contract Bonds," Journal of

Management in Engineering, Vol.7. ASCE, New York, N.Y., July 1991.

Russell, Jeffrey S., "Surety Industry: Overview," Journal of Management in Engineering, ASCE, Vol.6, No.3, July, 1990, 323 341.

Ryland, V. Wallace, "Minimizing Risks/Mitigating Losses," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

Schwartzkopf, W., R. Tasker, and M.J. Sugar, "Using the Claims Consultant to handle Fidelity and Surety Claims," in Handling Fidelity, Surety, and Financial Risk Clairm, 2nd Ed., Wiley Law Publications, John Wiley and Sons, New York, NY, 1990.

Spooner, J.E., "Probabilistic Estimating," Journal of Construction Eng. and Management, ASCE, Vol.100, NO.COI, March, 1974,65-77.

"Standard Insurance Specifications for MBTA Construction Contracts," MBTA, Boston, Mass., February, 1992.

Strauss, Max W., "Risk and Liability Sharing: The Owners View," Proc., Construction Risks and Liability Sharing Conference, ASCE, Scottsdale, Arizona, 1979.

Teicholz, P., "A Simulation Approach to the Selection of Construction Equipment," Technical Report No.26, Construction Institute, Stanford University, Stanford, Calif., 1963.

Thompson, P., and J. Perry, Engineering Construction Risks, Thomas Telford, London, UK, 1992.

Touran, A. and D. Ladick, "Application of Robotics in Bridge Deck Fabrication," Journal of Construction Engineering and Management, Vol. 1 15, No. 1, March, 1989, 35-52.

Touran, Ali, "Risk Modeling and Measurement in Construction," Civil Engineering Practice, Boston Society of Civil Engineers, Spring 1992, pp. 29-46.

Touran, A. and E.P. Wiser, "Monte Carlo Technique with Correlated Random Variables," Journal of Construction Eng. and Management, ASCE, Vol. 1 18, No.2, June 1992.

Touran, A., "Probabilistic Cost Estimating with Subjective Correlations," Journal of Construction Engineering and Management, ASCE, Vol. 1 19, No. 1, March 1993, 58-7 1.

"Tunnel Risk Assessment," Concept Design Report, Metcalf and Eddy, Inc., Boston, Mass., June 1989.

Wideman, R., Max, Project and Program Risk Management, Project management Institute, Drexel Hill, Pa., 1992.

Yarema, G.S., "The Next Step in the FTA Turnkey Demonstration Program: Developing an Effective Contract," FTA/APTA Turnkey Workshop, USDOT/FTA, Miami, Florida, June 1993.



# APPENDIX B - SUPPLEMENTARY COMMENTS ON THE RISK CHECKLIST

This Appendix contains supplementary comments on most of the risk items presented in Chapter 2. These comments are included to further clarify risk items and to highlight important issues. Not every item in the checklist is explained here; rather, we have focused on more sensitive items or those that we felt needed clarification. Although the risk checklist was developed from the owner's point of view, many of the comments given here reflect contractor's concerns also.

## I. PROJECT FEASIBILITY

### A. Technical Feasibility

The degree to which the plans call for specialized personnel, methods, and equipment will impact the risks inherent in the project.

1) Is the technical process or design mature?

2) Are there portions of the project which contain non-standard design technology or highly technological elements with strict tolerances?

3) Will the design require the contractor to employ highly trained personnel and will the contractor be able to control the quality of their work?

4) Does the contract require the use of specialized equipment? For example, will such equipment be needed for excavation, shoring, survey and layout, measuring,

concrete formwork, concrete placement, erection, lifting, testing or safety? Moreover, what is the availability and reliability of such equipment?

5) Does the contract call for specialized methods to achieve the desired goals? Such methods may entail earth stabilization, underpinning methods, specialized excavation, environmental controls, steel erection and tensioning, marine specialties, all which may be beyond construction practice. Alternately, is the contractor allowed to select a method with which he is most familiar and still able to reach the chosen goal?



6) What is the magnitude to which the contract calls for several different craft disciplines to be working in close proximity to each other (i.e. electricians, laborers, mechanical, HVAC, millwrights, instrumentation, operating engineers, etc.)?

B. Long term viability

With the increasing budgetary constraints, the self-sufficiency of transit systems may become an increasing important issue.

1) To what extent will the project require long-term operating and maintenance subsidies?

2) What are the demographic projections for this area? That is, will the project serve smaller and smaller populations?

3) What is the future capacity of the system? Is the project designed such that it can be expanded easily?

4) Has a rigorous Alternatives Analysis been conducted?

C. Political Circumstances

1) Will there be unusual government intervention in any of the following?
   a. design standards
   b. environmental issues
   c. site location
   d. pricing
   e. reporting requirements
   f. permit issuance
   g. inspections
   h. customs

2) What are the chances for: riots, strikes, etc.?

3) What are the long term plans for the community?

## II. FUNDING

### A. Funding Sources

1) Federal share

2) Local government contribution



3) State contribution

4) Private Financing

5) Right of way development rights

6) Tax exemptions or concessions

7) Farebox revenues

How reliable am the sources of funding mentioned above? Can any surprises be expected in obtaining funds from any of the above sources that can drastically impact the project fate? How much coordination between various funding agencies will be required? Is joint development a viable alternative?

### B. Inflation and growth rates

1) Will the work be performed during periods of economic stability or will it be executed when the economy is experiencing variations? During the times of economic growth, the possibility of raising taxes and meeting project's financial obligations is greater.

2) Will the project last beyond the time that accurate predictions can be made about inflation?

3) Are suppliers willing to give fixed prices for goods and services that may not be delivered for several years?

4) Have reasonable allowances been made for inflation? How the regional growth rate is going to affect the local source of funding?

C. Accuracy of Cost and Contingency Analysis

1) Is the contingency amount simply added as a fixed percentage of the total project cost or has a serious effort been made to determine risks?

2) Is there a wide spread in the bids received?

3) Is there a large discrepancy between the engineers estimate and the bids received?

D. Cash Flow

1) Are the cash flow estimates reasonable and fundable?



2) Are there large discrepancies between the budget cash flow and the project construction expenditure plan? If so, who would be responsible for interim financing?

E. Exchange Rates

1) If foreign contractors are involved in the project, have fluctuations in "change rates been planned for?

F. Appropriation

1) Have the funds been appropriated or only authorized.?

2) Will there be adequate funding until completion? How is the allocated funds distributed throughout the project construction period? Also see issues under Cash Flow.

III. PLANNING

A. Scope

1) Is the scope clearly defined and understood by all parties involved so that chances for additional work orders are minimized?

B. Complexity of the Project

1) Is the project so complex that it will be difficult to see how all the parts fit together?

C. Technical Constraints

1) Refer to Technical Feasibility under Project Feasibility.

D. Sole Source Material or Service Providers

1) What is the possibility of project completion if a sole source supplier ceases operations? Have contingency plans been made to create a new company to replace a sole source supplier?

E. Constructabilty

1) Is an effort being made to make the design as constructable as possible? Are there plans to formally study design in order to improve and enhance construction process?



F. Milestones (Schedule)

1) How crucial is the completion of milestones with respect to the entire project?

2) How many critical paths have been created as a result of milestones?

3) What is the level of liquidated damages associated with project milestones?

G. Time To Complete (Schedule)

1) Condensed Schedule
   a. What is the extent to which schedule completion times have been shifted from the ideal to the minimum?
   b. How does the contract address multiple shift work due to schedule compression?
   c. Have allowances been made for changes in productivity due to compression?

2) Normal Schedule
   a. Will the project be of such a long duration that the risk of exposure to unknown conditions is high?

H. Synchronization of Work and Payment Schedules

1) Is there the possibility of front-end loading?

2) Is there any benefit to provide mobilization fund to the contractor? Is it possible to reduce retained

## IV. ENGINEERING

### A. Design and Performance Standards

### B. Unreliable Data

1) Is any aspect of the project information or technical data available to the engineers unreliable, incomplete, or inadequate?

### C. Complexity

1) Does this project have any components which have never been designed before?

### D. Completeness of Design

1) To what extent is design complete? This can be very important when soliciting turnkey proposals. What effect will this have on the contingency sums that the bids contain?



### E. Accountability For Design

1) Is the owner or the engineer willing to accept responsibility for errors and omissions in design?

2) What is the extent and rigorousness of the design review process?

### F. System Integration

1) Are design interface points being studied? Are these interface points compatible so that there will be 'a smooth transition?

## V. TYPE OF CONTRACT

### A. Lumpsum

The primary risk factors to the owner with this type of contract are:

1) Changes in scope resulting in payment adjustments on a non-competitive basis.

2) Unforeseen complexities in field conditions that may result in change in quantities.

3) Differing site conditions (DSC) i.e. conditions that have changed materially from those manifested by the contract documents and could not have been reasonably foreseen.

4) Excusable delay conditions - i.e. delays which are allowed within the contract, allowing the contractor more time and possibly more money.

5) If quality expectations are not clearly defined, the contractor will be tempted to take short cuts in order to complete the project as soon as possible.

B. Unit Price

The primary risk factors to the owner with this type of contract are:

1) Payment adjustments for quantity over-runs

2) Differing site conditions

3) Excusable delay conditions

4) Termination for convenience



C. Cost Plus

Although this type of contracts have not been widely used on public projects, they may provide vehicles for innovative procurement involving public-private partnerships.

VI. CONTRACTING ARRANGEMENT

A. Turnkey - when the contractor will design, build and start up the project.

B. Joint Venture - i.e. when two or more contractors pool their resources to build a project under one organization.

C. Single Prime Contractor - owner contracts with one company to

build the project

D. Several Prime Contractors - owner contracts with two or more distinct constructors.

E. Innovative Procurement Methods - a wide range of contracting arrangement related to involving public-private financing such as super turnkey, build-operate-transfer, etc. have been proposed that can be used under special circumstances and will have profound risk implications for the project.

VII. Regional and Local Business Conditions

A. Number of Bidders

B. Unemployment Rate in Construction Trades

C. Workload of Regional Contractors

These conditions directly impact the bid value submitted by the contractor. The traditional contractor decides on his markup based on his existing backlog, the competition, and the economic conditions. In times of economic hardship there is generally an increase in the number of bidders with a sharp decrease in the bid values. This can benefit the owner and can be considered as an important factor in planning and timing of major projects.

VIII. CONTRACTOR RELIABILITY

A. Contractor's Capability

1) How much experience does the contractor have on projects with the same goals and size?



2) What was the contractor's profit margins on similar projects (if possible)?

B. Contractor's Capacity

1) What is the contractor's work in progress?

2) What percentage of the contractor's total work volume will this project account for?

3) What else is the contractor bidding on and what are his chances for the award?

4) Does the contractor have the bonding capacity for this

project?

C. Contractor's Credit Worthiness

1) Profitability trend

2) Depth of bank support

3) Total Assets and equity

4) Aging of accounts receivable

5) Debt levels

D. Experience of Personnel

1) Years of experience of key personnel

2) What is the number of P.E.'s and the people with advanced degrees on the contractor's payroll?

3) What is the contractors reputation for integrity and quality of workmanship?

4) What is the background of the owner(s) of the contracting company? Are there any character issues with the owners or the contractor's key personnel?

IX. OWNER INVOLVEMENT

The extent to which the owner needs to become involved with any of the following factors in order to control risk.



A. Management of Project

1) How much time and effort will be required in the overall supervision of design, construction, scheduling, quality control, cost and scope may depend on the type of contract selected.

B. Supplying of Material

1) The owner may reduce project costs by purchasing some items directly from suppliers. This benefit is derived from mass purchasing power and the ability to make large payments without affecting cash flow.

2) What are the consequences if owner-furnished materials or equipment are late or unsuitable.

C. Testing and Inspection

1) What are the gains in time and quality if the owner utilizes his own testing and inspection facilities?

D. Safety Programs

1) Does owner involvement in worker and site safety minimize claims and risks? How does the contractor view this?

E. Communications and Problem Solving

1) To what extent is the owner willing and able to resolve problems rapidly, to avoid delays and antagonistic relationships?

2) Is a Dispute Resolution Board (DRB) being planned, especially for projects involving underground construction?

F. Partnering - This is a relatively new management approach that attempts to reduce adversarial relationship between project parties.

1) Are there any plans for utilizing partnering concept in the project?

G. Start-up Operations

1) What are the plans for the project start-up period? Do the owner's operating personnel have to interface with the contractor? Will this interface period be smooth?



X. REGULATORY CONDITIONS

A. Licenses and Permits

1) Obtaining permits in advance of construction will minimize delay claims. Permits required for the construction operations can best be obtained by the contractor though.

B. Environmental Regulations and Requirements

1) Are existing regulations overly conservative and require the use of extensive and expensive remedies?

C. Patent Infringement

1) Will the use of an existing patent create undue royalty payments or litigation? Is the cost of such use known in advance of the start of the project?

D. Taxes and Duties

1) Will an existing tax or duty unfairly rule out a superior foreign contractor or supplier?

E. DBE Involvement

1) What are the DBE requirements?

2) What is the probability of finding an adequate number of competent DBE firms that are available for work in the area?

3) What has been the experience of potential bidders with DBE firms in the region?

XI. ACTS OF GOD

XII. SITE

A. Access

1) Is the existing infrastructure capable of handling the construction traffic along with the normal volume?

2) How many times will the traffic have to be rerouted during the course of construction?



3) Do the existing roads and bridges have the weight capacity to handle construction tonnages?

4) Are the existing roads wide enough to accommodate the materials and equipment that must be moved into the area?

5) Is site access restricted by owner or prior contracts?

6) What is the nature and number of alternative routes available to the contractors?

7) Is access to the site limited to certain times of the day?

B. Congestion

1) Is there sufficient acreage for work staging and materials storage?

2) How much coordination between contractors will be required when the joint occupancy of the site increases?

3) Who will be responsible for coordinating the contractors?

4) Will any of the contracts have to be accelerated just to satisfy turn-over requirements for the storage area?

5) What is the proximity of the adjacent contractors work area? Who will make sure that the abutting contractor will provide a clear working area for the next contractor when his work starts?

6) What is the exposure to interaction with the public? i.e. how much distraction will there be for the workmen?

C. Underground Conditions

1) What is the extent of deep excavations or tunnels with complex support systems?

2) What is the history of the area for burying massive objects? This is especially important in older cities such as Boston.

3) What do the test borings reveal? Were there sufficient borings taken to extrapolate with any degree of accuracy the conditions between test holes? Were the holes drilled as deep as the proposed excavation?



4) What is the potential for encountering adverse groundwater conditions? If groundwater is known to be present, what are the acceptable means of removing it from the work area and where will it be pumped?

5) What is the extent of underground utilities at the construction site? Do the local utilities have accurate

records of abandoned lines as well as active lines?

6) What is the possibility of finding historical artifacts, ancient cemeteries, or other archeological finds?

7) What is the potential for encountering hazardous wastes?

8) What is the potential for encountering hazardous wastes that ut not identified or specifically located in the contract documents?

D. Noise, Fumes, Dust

1) How will the site location and soil type affect the need for noise, fume and dust abatement procedures?

E. Abutting Structures

1) As the number of abutting buildings owned by third parties increases, the potential for damage to these edifices may increase.

2) If buildings adjacent to the construction right-of-way begin to show signs of damage, the project may be subject to delays until such time that the causes of the damage are determined.

3) Are there any historical buildings near the site? Are these buildings on the National Register of Historic Places?

4) What is the nature and level of vibration mitigation requirements specified by the contract?

5) If the abutting structures are too close, the contractor may lose efficiency due to restricted site conditions.

F. Security

1) Will extra care be required to secure the site, as well as the storage of materials and equipment?



G. Disruption to Public

1) Is there potential for restricted work hours because of proximity to residential or business districts?

## XIII. LABOR

Most of the issues enumerated in the checklist will be of prime concern to the contractor. The owner should have an overall understanding of the potential impact of these parameters on project cost and schedule.

## XIV. LOSS OR DAMAGES

## XV. GUARANTEES

A. Schedule - delay clauses demarcate the time and money supplements to which either party may be due for delays created by the accountable party or force majeure.

B. Performance - performance clauses demarcate the time and money supplements to which either party may be due for failures to perform created by the accountable party or force majeure.

C. Consequential Losses - These are damages that originate as an indirect consequence of construction activities. Examples include loss of production, loss of goodwill, loss of profit or sales, and interest on debt service.

D. Liquidated Damages - These clauses define the monetary penalties to be assessed against the contractor in the event of failure to meet certain schedule criteria.



# APPENDIX C - LIST OF CONTRIBUTORS

Several individuals from FTA, engineering firms, construction companies, sureties, and State agencies have contributed to this effort by providing information. We would like to thank Marina Drancsak and Elizabeth Solomon of FTA for supporting us in all administrative aspects of grant management. Their prompt response and effective support are greatly appreciated. Edward Thomas of FTA, the technical director of the grant, cooperated and supported us throughout this effort by providing insight, feedback, and information about the functions and procedures of the FTA and the Agency's concerns and objectives. Without his support, this work would have not materialized. We appreciate his enthusiasm and energy and hope that we have been successful in addressing the FTA's needs in the area investigated.

The following is a listing of the individuals who have provided information or offered valuable comments on the findings of this project. Involvement of each individual varied in context and extensiveness. We sincerely thank them and apologize to anyone inadvertently not included in the list. We accept full responsibility for any errors or inaccuracies in the report.

David B. Ashley, Professor, University of California, Berkeley, California.
William R. Barry, Chief Estimator, Stone and Webster, Boston, Mass.
Anthony Branca, PI Assoc., independent consultant, Sharon, Mass.
Peter Butler, Budget Office, MBTA, Boston, Mass.
Mark Campa, Moody's Investors Service, New York, New York.
Jane Chmielinski, Director, Environmental Management Group, MBTA, Boston, Mass.
Domenic E. D'Eramo, Vice President, Sverdrup Corp., Boston, Mass.
James E. Diekmann, Professor, University of Colorado, Boulder, Colorado.
David J. Forkenbrock, Director, Public Policy Center, University of Iowa, Iowa City, IA.
Donna Hixon, Bond Underwriter, Reliance Insurance, Boston, Mass.
Michael Hurley, Construction Manager, Sverdrup Corp., Boston, Mass.
Thomas J. Luglio, Jr., EG&G Dynatrend, Bryn Mawr, Pa.
Donald McCarter, Underwriting Manager, Hartford Insurance Co., Boston, Mass.
Timothy C. McManus, Principal, PMA, Boston, Mass.
L.P.(Bud) Morrill, Chief Engineer, Estimating and Cost, Stone and Webster, Boston, Mass.
Joseph Philips, Underwriting Manager, SafeCo, Framingham, Mass.
John Powers, Project Manager, MBTA, Boston, Mass.
Sidney J. Wanel, Attorney at Law, Davis, Malm, and D'Agostine, Boston, Mass.
Glenn R. Whitehouse, Chief Estimator, Perini Corp., Farmingham, Mass.

NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

The United States Government does not endorse manufacturers or products. Trade names appear in the document only because they are essential to the content of the report.

This report is being distributed through the U.S. Department of

Transportation's Technology Sharing Program.

DOT-T-95-01

DOT-T-95-01

TECHNOLOGY SHARING
A Program of the U.S. Department of Transportation

---

Go Back to the FTA Home Page