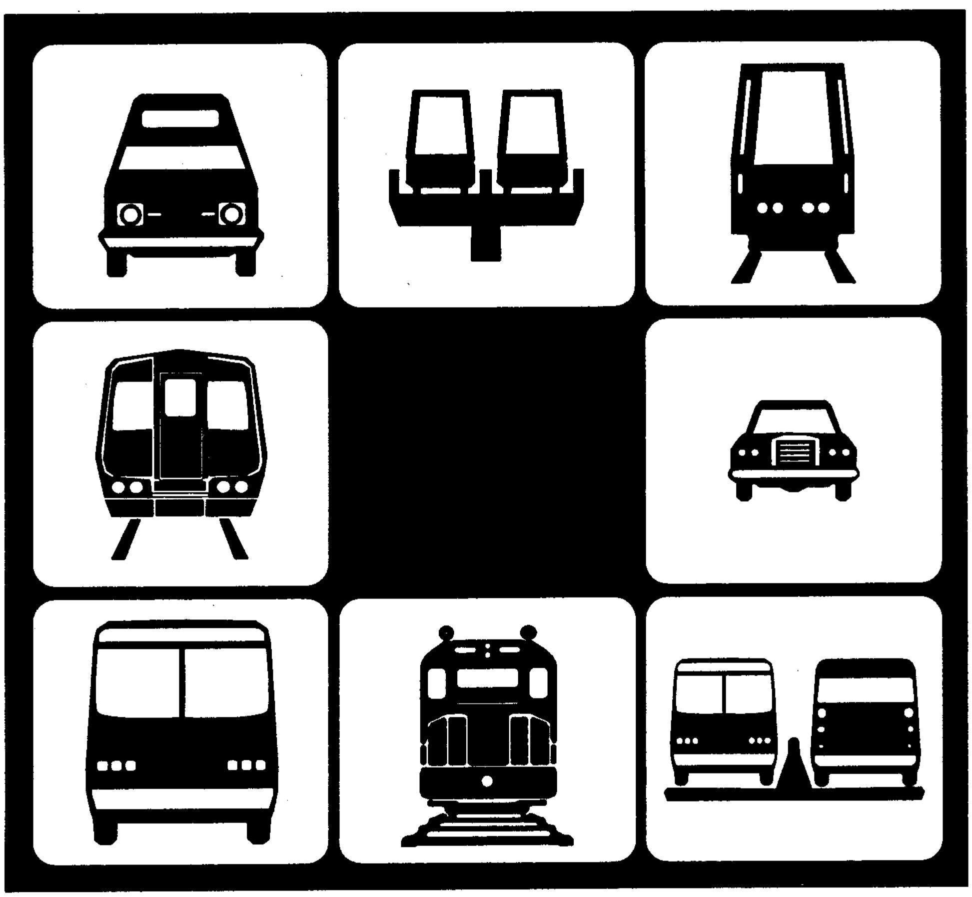
U.S. Department
of Transportation

Probabilistic Risk Analysis for Turnkey Construction: A Case Study

June 1996



Office of Planning

Probabilistic Risk Analysis for Turnkey Construction: A Case Study

Final Report
June 1996

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PREFACE

This study examines use of the probabilistic method, a multivariate, simulation-based statistical technique, to perform risk analysis for large turnkey transportation infrastructure projects. Turnkey contracting is an innovative procurement method whereby a single contractor is responsible for the design, construction, and possibly the operation of the public transit facility being built. Turnkey contracting encourages cost and risk sharing with the private sector, while the public entity retains ownership of the project. Two turnkey projects served as case studies:

- Tinker Air Force Base Extend Alternate Runway Project; and
- Baltimore Mass Transit Authority Central Light Rail Phase II.

The study is sponsored by the U.S. Department of Transportation, Federal Transit Administration, the Office of Planning, and is performed by Abacus Technology Corporation under contract DTFT60-94-C-41010. Ali Touran, PhD., P.E., served as technical consultant for the Central Light Rail Phase II probabilistic risk analysis.

Abacus Technology wishes to thank personnel from each of the case study agencies, for their cooperation and participation in this study. Many thanks go to Mr. Bob McCollum, U.S. Army Corps of Engineers (Tulsa, OK district); Mr. Denis Cournoyer, MTA Manager of Consultant Services; and Mr. John Coard, Project Director for MTA Phase II, for allowing us access to project information, and for giving us their time and attention. Finally, special thanks go to the Federal Transit Administration's Office of Planning: this study could not have been done without the considerable guidance and assistance of Mr. Edward Thomas, Ms. Nancy Strine, and Ms. Effie Stallsmith. Their support and enthusiasm has enabled this work from the beginning, and their comments on the draft report were most helpful.

EXECUTIVE SUMMARY

The Federal Transit Administration (FTA) Office of Planning has sponsored this study to examine the use of the probabilistic method, an innovative statistical technique, to perform risk analysis for large transportation capital projects. Turnkey construction, or design-build, is also a special focus of the investigation. Two case studies, both turnkey, provided the opportunity to apply probabilistic risk analysis to actual infrastructure projects which are currently being built.

Exhibit ES-1 is a general overview of the study participants. The remainder of this executive summary provides an overview of the study, key findings, study recommendations, and concluding remarks.

EXHIBIT ES-1
Overview of Study Participants

STUDY PARTICIPANTS	Project Budget (millions)	Sponsor	Percent Complete	Turnkey Award Date	Turnkey Contract Completion Date	Project Management
* *Extend Alternate Runway* Tinker Air Force Base Midwest City, OK	$10.8	U.S. Air Force	90% design 2% construction	July 1995	Dec 1996	U.S. Army Corps of Engineers (USACE)
** *Central Light Rail Phase II* Maryland Mass Transit Administration (MTA) • Hunt Valley Extension • BWI Airport Extension • Penn Station Extension	$106.3	80% FTA/ 20% local	98% design 30% construction	Sept 1994	Feb 1997	MTA

* *Due to unexpected delays during December 1995, study data required to perform a probabilistic risk analysis was unavailable for this project. Therefore, this case investigation is limited to project management findings in the specific area of risk avoidance.*

** *This project is a participant in FTA's Turnkey Demonstration Program.*

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OVERVIEW OF THE STUDY

The primary impetus for this investigation is the FTA's Turnkey Demonstration Program. The Intermodal Surface Transportation Efficiency Act (ISTEA) funded this program in 1991, to "determine the degree to which turnkey system procurement can reduce the time and lower the cost of transit capital project development."[1]

[1] U.S. Congress, Intermodal Surface Transportation Efficiency Act, Washington, D.C., U.S. Government Printing Office, December 18, 1991.

Potential benefits of turnkey contracting include:

- Lessened contractor claims (lawsuits) for changed conditions and design deficiencies, due to single-point design and construction responsibilities;

- Greater schedule efficiencies, due to the overlap of concurrent design and construction activities, and the elimination of administrative redundancies which are normally present in traditional design-bid-build contracting;

- Lower "soft costs," such as engineering services and project management, and lower interest and inflation adjustment(s) due to accelerated delivery;

- Project financing innovations such as vendor financing, extended payment terms, and contractor capitalization of leases;

- Creativity in design, methods and materials for construction, and access to proprietary technology.

This project is assisting the Turnkey Demonstration Program in its efforts to evaluate risk in turnkey construction. The ***objective*** of the study is to use probabilistic risk analysis to highlight risk mitigation techniques for two large turnkey transportation projects. In the context of this study, risk mitigation is any activity which is designed or intended to diminish project risk. Risk mitigation includes analyses designed to identify risk. Specifically, the study examines project contingencies, or risk premium amounts, in order to evaluate the risk of cost and schedule overrun. Cost and schedule activities are analyzed, and a determination of project risk is made, based on the probabilistic estimate developed and performed in the study. Risk mitigation techniques are reviewed for each case study, in the specific context of turnkey contracting.

The ***technical approach*** of the investigation included: (i) identifying critical risk variables for cost and schedule, for each project; (ii) identifying the appropriate probability distribution to model the cost and schedule variables; (iii) assigning "range" values to the critical variables, to form the (input) data points for the probabilistic model; (iv) using special, probabilistic software to perform a Monte Carlo simulation; (v) using the simulation output to assess project risk premiums, or contingencies; and (vi) using the results of the probabilistic estimate to review risk mitigation techniques for turnkey transit construction projects.

FINDINGS

The key study findings mainly cover results for the two cases:

1. **Turnkey Contracting by the U.S. Army Corps of Engineers (USACE) is a Formalized and Highly Disciplined Process.**

   The Tinker Air Force Base Extend Alternate Runway project shows that risk mitigation for military turnkey includes a high level of project definition at bid time, and careful construction of project contingencies prior to turnkey contractor award. Design review for turnkey construction is currently an area of significant uncertainty for USACE projects, and developments in this area are marked by frequent adjustments to contractor Notice to Proceed criteria.[2]

2. **The Baltimore Central Light Rail Line, Phase II, is a Low Risk Project.**

   A probabilistic risk analysis was performed for the Baltimore Phase II light rail extensions. Results indicate that Phase II will most likely overrun schedule for the turnkey construction contract. However, the probabilistic analysis shows a 96% level of confidence that the total project will not overrun its budget of $106 million, due to the substantial project contingencies. These results characterize the Phase II project as "low risk."

KEY STUDY OBSERVATIONS

1. **For Turnkey Construction, the Focus for Risk Analysis is Needed at the Bid Phase of the Project.**

   Project definition activities and subsequent risk diversification need extensive analysis, in order to construct clear and equitable project contingencies (risk premium amounts) for turnkey construction fixed-price award.

2. **Quality Assurance/Quality Control (QA/QC) Activities are Critical for Turnkey Projects.**

   Configuration management[3] for design, inspection, and testing of the ongoing construction work are "new frontiers" for turnkey contracting. Baltimore uses owner-audits and spot field inspections to oversee the turnkey contractor's QA/QC function.

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[2] The study data requirements for the *Extend Alternate Runway* case were not met on time, and so a probabilistic risk analysis was unable to be performed for the Tinker Air Force Base project.

[3] *Configuration Management* is the discipline of maintaining and controlling specifications and documentation related to the construction project's design. Configuration management includes manual and electronic drawings files, and record of authorization for (any and all) project design changes.

3. **Project Control and Project Oversight Decisions are Critical for Turnkey Projects.**

A formalized project management control system is normally designed by both owner and contractor, for turnkey construction projects. This synthesis is one example of a major and innovative by-product of turnkey contracting: the integration of owner and contractor management systems.

4. **Schedule is a Key Variable for Turnkey Project Risk.**

Construction lead times are frequently difficult to anticipate; and while project contingencies may be adequate at the unit cost and quantity level, schedule variations will tend to affect the turnkey budget by more than line item variations. This is mainly due to turnkey's intrinsic "overlapping" assumptions for the design and build phases. The study observes that there can be significant uncertainty (risk) in turnkey's schedule assumptions.

RECOMMENDATIONS

This study provided an in-depth opportunity to observe turnkey construction in practice, from bid through build phases. Due to the thorough risk analysis which was performed for Baltimore Phase II, this turnkey project in particular is valuable as a basis for the study's recommendations. Specific study recommendations are as follows:

1. **Document "Lessons Learned" for Turnkey Project, While Work is in Progress.**

Efforts should be made at the start of the turnkey project to describe (i) the integration of the owner and contractor's management systems, (ii) turnkey design review experience, and (iii) the cost impact and results (outcome) of contractor incentives and penalties.

2. **Direct More Risk Assessment Activities to the Bid Period.**

A "bid breakdown" should be developed by the owner, to detail and summarize the owner's conceptual estimate, and also serve as the basis for contract negotiations and subsequent project control.

3. **Tailor the Turnkey Procurement to the Project, and to Local and Regional Conditions.**

Public transit agencies should consider hybrid and superturnkey forms, and encouragement should be given to small business participation in turnkey. Also, the concept of re-competing multi-year awards should be evaluated for each project.

4. **Perform a Follow-on Evaluation to Assess Baltimore Mass Transit Administration (MTA) Phase II Cost and Schedule Performance at Project Completion.**

To fully evaluate the cost and schedule projections for the Baltimore Phase II project, further study is recommended to compare the probabilistic forecast obtained in this study, with actual project results in 1997, when Phase II is scheduled to be complete.

5. **Perform a Full-Scale Evaluation, to Address Goodness-of-Fit for the Probabilistic Method as a Potential Means to Perform Risk Analysis for the Larger Public Transit Industry.**

This study employed the probabilistic method to perform risk analysis for one ongoing public transit capital project, Baltimore Central Light Rail Line Phase II. A further evaluation is recommended to determine whether the probabilistic method is an effective means of measuring risk for a broader sample of transit projects. A representative study sample is recommended for selection, to assess the usefulness of the probabilistic method as an integral part of effective transit capital planning.

CONCLUSIONS

Turnkey contracting, because it is new and largely untested in the public sector, exposes both the owner and the turnkey contractor to much uncertainty, or risk. Risk identification and risk diversification activities are critical to turnkey, and this study, through its demonstration of the probabilistic method, provides one tool for identifying and assessing risk. Probabilistic risk analysis, though potentially intimidating due to its reliance on statistical results, is an extremely effective predictor of project risk. Major limitations to the method are obtaining quality data and modeling variable correlations.

This study finds that risk measurement is simply the first step in turnkey risk mitigation. Review of project management techniques, and risk communication for turnkey projects are the logical follow-on to risk measurement.

Further research is recommended, to demonstrate a broader base of applicability within transit, for the special expertise provided in probabilistic risk analysis. A probabilistic risk model uses deterministic[4] information to forecast relative risk. Full use of the probabilistic method, including data quality considerations and appropriate methodology, is the next logical step in developing and refining technology-assisted management tools for public transit planning and capital development.

[4] Deterministic information is generally defined as fact-based, analytical, management information which is non-probabilistic, and which may be used to analyze and forecast results by means of intuitive judgment or standard mathematical analysis.

1.0 INTRODUCTION

The Federal Transit Administration (FTA) has undertaken this study to assess the usefulness of probabilistic risk analysis methodology in measuring risk for federal transit construction, in the specific context of two contemporary non-traditional acquisitions: one military and one public transit turnkey. In addition, project management techniques and risk communication are examined to maximize the opportunity this study presents to appraise two non-traditional procurements across industry segments. This chapter describes the impetus for the study, and study objectives, study participants, and methodology.

1.1 IMPETUS FOR THE STUDY

Risk analysis has historically been practiced in some form, in planning for and implementing public transit construction projects. The usual, traditional methods have been deterministic models, whereby several variables are iteratively modified until some project target bottom-line value is achieved. This study examines the usefulness of the probabilistic method of measuring risk. Impetus for this investigation is chiefly attributed to the following:

- Transit construction is heavily capitalized by the Federal Government.
- Turnkey projects may bear special contingencies due to the early-bid, fixed price nature of these large contracts.
- Previous research has established a base of credibility for probabilistic risk analysis within the transit construction community.

1.1.1 Federal Investment in Transit Construction is Considerable

The FTA sponsors transit construction projects which are large, complex, and expensive. In fiscal year (FY) 1995, $6.4 billion was obligated by FTA for various grants[1], with 85% programmed for capital purposes. The total amount of flexible funds transferred to FTA for the Federal Highway Administration (FHWA) for mass transit projects in FY 1995 was $802 million. For FY 1995, the two largest FTA programs are Section 5309 Capital Program[2], and Section 5307 Urbanized Area Formula Program[3]. Section 5309 (formerly Section 3) capital obligations for FY 1995 were $2.6 billion, with 48% budgeted for new

[1] FY 1995 FTA obligations as cited include funds for operations ($857 billion) and planning ($100 billion).

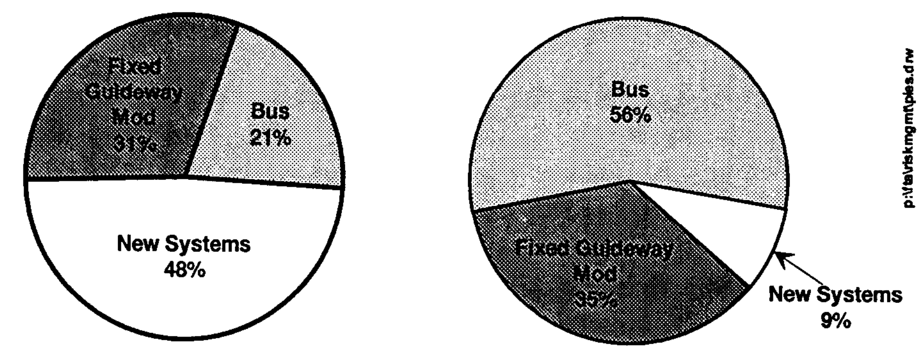
[2] Section 5309 provides capital funding for fixed guideway modernization, new systems, and bus and bus related projects.

[3] Section 5307 provides funding for capital, planning, and operating projects for urbanized areas (50,000 or more population).

systems. The Section 5307 program achieved a total of $3.2 billion in obligations for FY 1995, with 74% programmed for capital projects. Exhibit 1-1 shows the relative distribution of FY 1995 Section 5309 and Section 5307 obligated capital funds, exclusive of operations and planning.

EXHIBIT 1-1
FY 1994 FTA Capital Obligations

SECTION 5309: $2,608,491,948 **SECTION 5307: $2,340,590,170 ***



* Excludes amounts for Operation ($763,894,416) and Planning ($45,836,539).

The Federal Transit Act of 1991 requires that federal assistance for new systems and fixed guideway development be supported by evidence of adequate project reserves, dependable revenue streams, and ongoing financial capacity of the contractor. This financial capacity requirement mandates a sophisticated yet understandable and useful method to assess and mitigate risk in transit construction. Transit practitioners report that tight funding and emerging technologies are rapidly serving to advance the methodology which is applied to transit risk analysis. Also, there is greater uncertainty due to tax-based revenue sources for capital planning.[4] Thus, to assist transit systems in containing cost for large capital projects, FTA is providing practical tools and guidelines for financial risk management to minimize exposure to loss. This study addresses the need for useful, innovative risk management techniques in transit construction by evaluating the usefulness of probabilistic methodology as a viable risk measurement tool. Other risk management strategies and the broad area of risk communication are also addressed in the study, by observing and documenting project management methodology in the specific context of the two case studies of ongoing projects.

1.1.2 FTA's Turnkey Demonstration Program is Aimed at Cost Reduction

As a result of Section 3019 of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, the transit industry has moved into expanded relationships with the private

[4] Conversation with Doug Wentworth, Sacramento RT, April 1995.

sector in building and operating fixed guideway facilities. Turnkey contracting is an innovative procurement method which may benefit a public agency (the "owner") by exploiting the inherent profit-motive incentives for schedule and cost efficiency, by assigning more risk (and reward) to a private contractor or consortium. ISTEA has provided the impetus for the FTA's Turnkey Demonstration Program, which will test the potential for innovative procurements to improve upon traditional practices in building large transit fixed guideway systems.

Exhibit 1-2 provides a comparison of "one-step" turnkey versus traditional project development activities. Four turnkey demonstration sites were announced in Spring 1993:

- Baltimore Mass Transit Administration (MTA) Light Rail, Phase II;
- San Francisco BART Airport Extension;
- San Juan Tren Urbano (urban train), Phase I; and
- Los Angeles El Segundo Del Norte Station (Green Line).

The objective of the demonstration is to determine if, through the turnkey process, costs can be contained, change orders can be reduced, and financial risk can be reduced. ISTEA states that the goals of the Turnkey Demonstration Program are to "advance new technologies and lower the cost of constructing new transit systems," and to "determine the degree to which turnkey system procurement can reduce the time and lower the cost of transit capital project development."[5] Potential benefits from turnkey or design-build project implementation strategies include:[6]

- *Permit Federal cash flows to be managed more effectively*
  For example: extended payment terms, access to lease financing

- *Minimize project costs*
  For example: accelerate implementation, utilize private sector project management capabilities

- *Control project completion and overrun risks*
  For example: negotiate fixed-price contracts for capital and operating costs, develop system-level performance criteria

- *Attract new sources of funding*
  For example: vendor financing, joint development, leasing.

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[5] U.S. Congress, Intermodal Surface Transportation Efficiency Act, Washington, D.C., U.S. Government Printing Office, December 18, 1991.

[6] Luglio, Thomas J., and Jeffrey A. Parker, Turnkey Procurement: Opportunities and Issues, prepared for U.S. Department of Transportation, Federal Transit Administration (DOT/FTA), Washington, D.C., June 1992.

Turnkey procurement is typically characterized by lower "soft costs" such as engineering services and project management, and lower interest and inflation adjustment(s) due to accelerated delivery. Schedule improvements are achieved through elimination of many procedural duplications, overlapping activities, and administrative redundancies which are inherent in traditional, multiple compete bidding.

EXHIBIT 1-2
Turnkey Versus Traditional Contracting Activities

Project Procurement Method	Project Development Activity						
	Service Decision	Financing	Design	Construction	Joint Development	Ownership	Operations & Maintenance
Traditional	Public	Public	Public	Public	Public	Public	Public
Turnkey Projects	Public	Public	Private	Private	Public	Public	Either
Privatization	Public	Private	Private	Private	Private	Private	Private
Franchise	Private	Private	Private	Private	Private	Private	Private

Source: Luglio, Thomas J., and Jeffrey A. Parker, Turnkey Procurement: Opportunities and Issues, prepared for U.S. DOT/FTA, Washington, D.C, June 1992.

Turnkey projects are expected to achieve close-to-budget completion because of lessened contractor claims for changed conditions due to their design-build involvement. Touran comments: "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 the [Major Investment Study] phase will increase the contingency accordingly . . . in case the project design and construction do not proceed as directed."[7] Thus, a primary goal for the analytical or risk measurement phase of this study is to provide FTA with a guideline for developing an accurate and objective assessment of contingency (risk premium) for the turnkey project budget.

1.1.3 This Study Builds on Previous FTA-Sponsored Work

A recent study[8] was sponsored by FTA to examine contemporary risk management practices of the transit construction industry. Case studies of five large projects under traditional construction were examined. Financial control systems and risk management practices were reviewed and examined in the context of the ongoing projects.

[7] Touran, Ali, et al., Risk Assessment in Fixed Guideway Construction, January 1994, p.55.

[8] Feiner, Joseph, EG&G Dynatrend, Assessment of Financial Control Systems and Risk in the Transit Construction Industry, December 1994. This draft final report is currently pending FTA publication.

Project reserves were noted, and traditional risk management techniques such as value engineering and decision tree modeling were described in all applicable cases. Risk was described as "any factor that can impact the ability to complete a project on budget and on time." The report concludes with several observations and recommendations on risk management practices in transit construction, and introduces the technique of probabilistic risk analysis.

The subject draft report defines probabilistic risk analysis as ". . . a highly sophisticated form of analysis where multiple elements of risk can be treated as random variables and computer simulations are utilized to generate a most likely outcome based on thousands of computer generated *what-if* scenarios."[9] The report states that probabilistic risk analysis is effective not only as a model for quantitative decision-making, but that it is also a powerful qualitative tool with special importance for communications and marketing presentations to audiences with vested interest in the project. For example, such project "stakeholders" can include the transit-impacted general public and special civic interest groups; the business community, including property developers and capital sources and agents; all technical project participants, including building contractors, and architectural and engineering design firms; and cognizant governmental representatives for the project.

The current study builds on the earlier draft report by utilizing two case studies to examine the usefulness of the probabilistic method for risk analysis and risk communication. The study therefore intends to establish a base of credibility for probabilistic risk analysis.

1.2 STUDY OBJECTIVES

The primary focus of this study is to evaluate risk mitigation techniques for two large transportation capital projects which are under construction at the time of this study, and which are both non-traditional procurement. One case study is a military project and one is public transit. The study initially focuses on risk measurement, achieved through use of the probabilistic risk methodology. Risk management strategies and risk communication methods are then reviewed, as implemented at the two projects.

Specifically, the study objectives are to:

- Review the applicability of the probabilistic risk analysis method to large transit capital projects;

- Utilize the probabilistic risk analysis method in two non-traditional or turnkey construction case studies to perform risk assessment;

[9] Ibid., p. 10-9.

- Review and document risk management strategies applied by program management in the two case studies;

- Review and document risk communication strategies applied by management in the two case studies; and

- Develop recommendations for the use of risk assessment techniques, risk management, and risk communication in large transit construction projects.

1.3 STUDY PARTICIPANTS

The chief participants in the study are the U.S. Army Corps of Engineers (USACE) and the Maryland MTA. The two organizations and their projects are described below.

1.3.1 U.S. Army Corps of Engineers

1.3.1.1 Project Description

USACE is currently managing construction of the runway extension at Tinker Air Force Base in Oklahoma City, OK. This project is design-build and was bid at 35% preliminary design. This percentage represents Tinker program management's designation of the extent of completion of the design package, i.e., drawings and specifications necessary for construction, at the point of submittal of the construction cost bid.

The alternate runway at Tinker Air Force Base will be lengthened by 2,160 linear feet, and the adjacent taxiway will be lengthened by 1,800 feet. In addition to the planned runway extension, the existing keel section will be replaced with 3,500 feet of pavement. Widened paved shoulders of 25 feet each side will also be added to the full length of the existing 7,840-foot alternate runway. The entire project includes relocation of aircraft arresting barriers; approach lighting system and runway edge lighting; instrument landing system provisions; two 1,000-foot paved overruns at each end of the alternate runway; drainage; battle damage repair pad; and all necessary support. The air base will be shut down for 30 days, during the summer of 1996, while the runway intersection is constructed.

1.3.1.2 Schedule

The project is estimated to take a total of 18 months for the entire design-build process. Construction is scheduled to begin by February 1996 and to be complete by February 1997. Final design activities will precede construction. For a complete discussion of current project status, see Chapter 3.

1.3.1.3 Budget

The estimated budget for this total construction project is $10,800,000.

1.3.1.4 Key Personnel

Bob McCollum, USACE, Tulsa district, is the point of contact for this case study. Mr. McCollum is the project manager for the Tinker Air Force Base runway extension project.

1.3.2 Maryland Mass Transit Administration

1.3.2.1 Project Description

MTA is constructing an extension to the existing 22-mile light rail system. This extension is known as Central Light Rail Line Phase II, or Phase II. The project includes one true extension and two spurs off the existing main line as follows:

- 4.5-mile extension on the North line, from Timonium to Hunt Valley; the jurisdiction is Baltimore County.
- 2.7-mile spur off of the South main line to Baltimore Washington International airport; the jurisdiction is Anne Arundel County.
- 0.3-mile North to South spur off of the main line into Penn Station; the jurisdiction is Baltimore City.

This is an FTA turnkey demonstration project which was bid at approximately 30% design for civil construction of the guideway, and at a somewhat higher (but variable) percent design for electrical systems components. Whiting-Turner is the turnkey contractor responsible for final design, civil construction, and electrical systems design and installation.

1.3.2.2 Schedule

The Baltimore project began in August 1993 with FTA grant approval and initial right-of-way acquisition, and is scheduled to be ready for revenue service by the summer of 1997.

1.3.2.3 Budget

The Phase II total project is valued at $106,338,000. The design-build contract is for $55,750,000. These amounts include all "soft cost," such as administrative services and right-of-way permits. Federal capital funding of this project is 80%.

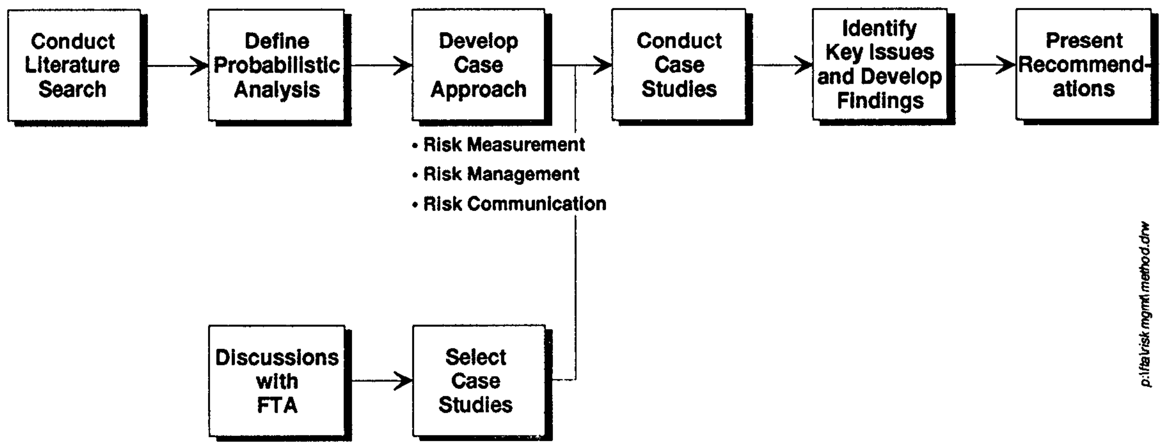
1.3.2.4 Key Personnel

John Coard, MTA Project Director, is the point of contact for the light rail extension project.

1.4 METHODOLOGY

An overview of the study methodology is shown in Exhibit 1-3. The study began with a survey of the literature and identification of key prior studies. The two projects to be used for the case studies were selected following a definition of probabilistic analysis and technical approach, and discussions with FTA.

EXHIBIT 1-3
Study Methodology



Each case study examines risk mitigation techniques in the context of the developing project, and the management structure in place at each of the organizations at the time of the study. The case investigations focused on risk measurement, risk management, and risk communication. The following section reviews the general methodology which was used to perform the risk analyses for the two case studies.

1.4.1 Risk Measurement

1.4.1.1 Project Contingencies

Contingencies are "risk premium" amounts which are added to budget line-items (cost contingencies) and schedule activities (duration contingencies) by both owner and contractor, to allow for uncertainty in the project. Contingencies objectify or quantify the risk in a project, and provide the measurable means for all contracting parties to diversify or to share the risk.

This study uses probabilistic risk methodology to assess the unallocated and allocated contingency amounts in each case study. For cost items, the *unallocated contingency* is a provisional fund which is formally set aside by the contractor in the project budget, to allow for cost overruns and, perhaps, revenue shortfalls. Unallocated contingency amounts are typically set to a percentage of the contract bottom line, and the funds are normally invested in an interest bearing account until they are used. *Allocated contingency* amounts are those risk premiums which are distributed to (included in) specific project line items.

1.4.1.2 Application of the Probabilistic Method

A probabilistic estimate was made for the MTA Phase II case study, for both cost and schedule variables. This estimate was then used as the basis for a risk analysis, or contingency evaluation for the case.

Cost and schedule data was obtained for the project, and critical (highly variable) cost and schedule activities were identified. Contingencies were removed from study data prior to performing the probabilistic analysis, since a probabilistic estimate is most advantageously conducted at bid time, when the level of line-item and unallocated contingencies, as well as total project budget, is being reviewed and negotiated.

Next, a probability distribution was selected to model each critical variable.[10] Once the probability distribution was defined, then the critical variables were "ranged," that is, data values were assigned to estimated distribution points. For triangular distribution,[11] the ranging consisted of identifying high, low, and most likely variable values. The definition of the high and the low point (i.e., 95% and 5%; 100% and 0%; or some other estimation for data point locations within the distribution) is documented and explained in the study.

Monte Carlo simulation was employed over many trials (iterations). The probabilistic output consisted of summary statistics which show cumulative probabilities from 0% to 100%, for achieving some level of estimated cost or activity duration, as a result of the Monte Carlo simulation. Project contingencies were then evaluated against the probabilistic output.

To illustrate the end result of a typical risk analysis: if an 85% level of confidence is required for total project budget, then the needed contingency amount for the project would be calculated as follows:

*Contingency = 85% budget level (from probabilistic output) less Base Cost**

** Base cost is source data used for the analysis, and does not include contingencies.*

Exhibit 1-4 shows a very simple example of a project cost contingency calculation, resulting from application of the probabilistic method.

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[10] Construction data are normally asymmetrical, have confined ends, take mainly positive values, and are unimodal (there is a single point of highest frequency within the distribution).

[11] *Triangular* is one of many forms or types of probability distributions. Triangular distributions are defined by three points: the lower bound, the upper bound, and the most likely value or mode.

EXHIBIT 1-4
Example of Cost Contingency
Measured Through Use of the Probabilistic Method

	Basis for Probabilistic Estimate (Owner's Estimate)[1]	Results of Probabilistic Estimate at 85%[2]	Required Contingency[3]
Total $000's	$50	$60	$10

NOTES:

(1) Base cost, total project expense or "owner's estimate." Contingencies are excluded.

(2) 85% probability is the area of the distribution for total cost which contains all values of the total cost which have 85% chance or less of being attained. 85% is selected in this demonstration case as a "margin of safety" in order to compute a conservative contingency. That is, there is only a 15% chance, given the results of this particular probabilistic simulation, that the total cost will be more than this value.

(3) This value represents the amount of contingency funds which are required in order to achieve an 85% level of assurance that the project will not experience a cost overrun. If this logic (and degree of safety) is adopted by the owner, then the required contingency is added to project cost. In this example, $50 + $10 = $60 is the amount needed to provide an 85% level of confidence that the project will remain within budget.

1.4.2 Risk Management

This study provides an opportunity to review and document risk mitigation methods utilized by the Army Corps of Engineers and the Baltimore MTA. Special attention is given to documenting risk management strategies which were utilized by project management at the two public agencies at the time of the study.

Typical elements of a program management "risk checklist" are listed below:

- How is the structure and content of the Request for Proposal (RFP) characterized? Is it prescriptive or open? Are construction methods, configurations, and materials specified? Are innovative design solutions encouraged? Are performance and functional characteristics given in the RFP? How are they conveyed?

- What is the process for vendor rating and selection? Is this process fully described in the RFP? Which committee, groups, or person(s) decide the rating and weighting method which will be used to evaluate the bids? Who has oversight for this process?

- How is the Government's conceptual (pre-bid) cost proposal developed? Who has input into this process and to what extent are bids evaluated relative to this document?

- When is advance right-of-way purchase made or easement rights secured? When are utility provisions fulfilled? Describe this process.

- To what extent are community and political support solidified? Which committee, groups, or person(s) are responsible for monitoring and responding to developments in this area?

- Describe the financial management control systems which are put in place throughout the contract. How often is payment made to the contractor? What documentation is needed before payment is authorized? Who authorizes payment?

- Describe schedule control systems which are in place throughout the contract. Are there any schedule or completion incentives in this contract? Which committee, group, or person(s) reviews and authorizes schedule documentation?

- Describe procedures for value engineering, configuration management, and constructability reviews during design and construction.

- How is the insurance program implemented, including surety evaluation and bonding for the contractor? Give coverage type(s) and levels.

- How is financial capability of the contractor determined? Describe this process and evaluation method(s).

- Describe project financing. Include a full description of all sources of funds; give debt service levels and required reserves, as applicable.

- How are quality control measures for testing, inspection, and safety performed? Describe all required documentation and authorizations.

- How does the contractor manage subcontractor oversight? Is there accountability in the (prime) contract for performance standards in this area?

- Describe terms and provisions for contract change order and modification procedures, including owner-initiated changes. Does the contract include any counter-incentives (penalties) in this area?

- List all contract deliverables (generic) and progress meetings which are not covered in the discussion points above. Which specific office has responsibility for maintaining the formal file of contract deliverables?

- Please describe procedures and certifications required for contract closeout.

The checklist above was utilized as a guideline to obtain information regarding project risk strategies for the two case studies. Not all points in the above checklist were covered for each project.

1.4.3 <u>Risk Communication</u>

For public transit, risk management must include communication to many and various interested parties, including the general public, about the nature of the values and assumptions which underlie important capital decisions. Frequently these values and assumptions are qualitative. Risk communication should add value by conveying "net benefit" to vested parties. Risk communication should couple quantitative and qualitative risk "analysis," and in so doing, facilitate the iterative and complex contracting process of transit construction.

1.4.3.1 Risk Communication for Transit Construction

The literature on risk communication clearly indicates that the way information is presented affects the way it is received; yet there is no consensus about how to communicate risk concepts well. Risk communication for public transit is present throughout the Major Investment Studies (MIS) process[12], and the ensuing project development and construction phases of guideway contracting:

- Developing ridership forecasts;
- Selection of the Locally Preferred Alternative;
- Developing conceptual project cost, and funding availability;
- Assessment of environmental impacts[13];

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[12] The FTA/FHWA Major Investment Studies (MIS) process evaluates the overall effectiveness and cost-effectiveness of alternative investment strategies for U.S. transportation infrastructure. MIS integrates the planning and environmental (NEPA, 1987) processes. The purpose of MIS is to address major regional transportation problems, analyze solutions, and to effectively present this information to decisionmakers and "stakeholders" or vested parties. Each MIS should be conducted in a way which adapts to the public involvement process for (each) Metropolitan Planning Organization (MPO). MIS should consider factors such as direct and indirect costs of the alternatives, mobility and accessibility improvements, and impacts on the social, economic, environmental, and safety concerns of the region, as well as project operating efficiencies, land-use, financing, and energy consumption (Source: *A Guide to Metropolitan Planning Under ISTEA -- How the Pieces Fit Together*, FHWA-PD-95-031). The project scope and conceptual and preliminary design are the end result of MIS, through a regionally-specific process of collaborative public involvement.

[13] The National Environmental Protection Act (NEPA) of 1987 requires preparation of a Draft Environmental Impact Statement (DEIS) and a Final Environmental Impact Statement (FEIS), when a determination is made that the project is likely to cause significant impacts on the human or natural environment(s). There are many

- Selection review board contractor ratings and decision(s);
- Bonding against contractor risk; and
- Managing contract modifications for fixed-price bids.

1.4.3.2 Risk Communication and Probabilistic Analysis

Sandman[14], who discusses risk communication in the context of siting controversy for construction of a hazardous waste facility, points out that "Uncertain risks are less acceptable than certain risks. Most people loathe uncertainty. While probabilistic statements are bad enough, zones of uncertainty surrounding the probabilities are worse. Disagreements among experts about the probabilities are worst of all."

Probabilistic risk analysis can be useful in community forums, focus groups, and in negotiations where all parties have an incentive to estimate risk accurately. Cumulative probability functions resulting from a probabilistic analysis can usefully adapt to a "Which shall we do?" approach versus a potentially confrontational "How about this?" However, Sandman believes that people are less interested in risk estimation than risk reduction. Probabilistic risk assessment, therefore, may be a particularly useful tool to facilitate risk communication, through its ability to measure risk continuously or probabilistically -- there is no presumption of a single right answer -- and thereby clarify risk quantification.

Throughout the MIS process, probabilistic risk analysis can add value by assisting and enhancing the collaborative nature of MIS. Traditional planning procedures (pre-ISTEA) have generally considered the direct input of communities only in the final stages of a linear decision-making process, in which a cognizant state agency prepares a plan and then justifies it to various constituents. With MIS, the transportation plan is developed with integral community input from the start[15]. FTA's revised planning regulation (23 CFR 450.316(b)(1)) requires Metropolitan Planning Organizations to have "a proactive public involvement process that provides complete information, timely public notice, full public access to key decisions, and supports early and continuing involvement of the public." Probabilistic risk analysis has the dual ability (i) to model variables simultaneously, through application of Monte Carlo techniques which rely on input from selected probability distributions; and (ii) to express results of the risk analysis in easy-to-interpret cumulative

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linkages with the NEPA process and the MIS documentation process, and FTA continues to integrate and streamline both sets of procedures. Presently, *MIS/Option I* produces an MIS report to identify the locally preferred transit alternative, and then develops the DEIS and the FEIS as a result of further project scoping; *MIS/Option II* performs scoping and the DEIS prior to selection of the locally preferred alternative, then, like Option I, produces the FEIS at the end of the (MIS) planning process.

[14] Sandman, Peter M., "Getting to Maybe: Some Communications Aspects of Siting Hazardous Waste Facilities," Seton Hall Legislative Journal, Vol. 9, 1985.

[15] Regional or corridor planning studies are generally the beginning phases of MIS; the Transportation Improvement Plan (TIP) is an intermediate result of MIS, with NEPA documentation and project development to follow.

probability curves. These qualities make probabilistic risk analysis an excellent tool for facilitating the MIS decision process embodied in the planning regulation. Project decision-makers and stakeholders (vested parties) can effectively use probabilistic risk analysis to define and quantify the uncertainty in a project's budget[16] and schedule, and then develop realistic alternatives which are "modeled" robustly. These key features of probabilistic risk analysis foster group collaboration and goal-directed consensus building, elements which embody the letter and spirit of MIS.

1.4.3.3 Risk Communication and the Case Studies

Of particular interest to the study are the following characteristics of risk communication, observed in the context of each case study:

- Is information presented quantitatively or qualitatively?
- Is information presented in a directive format or in a format which encourages judgment and evaluation?
- To what extent are perceived risks consistent with objective measures of risk?
- Are there standards for "communicative accuracy," i.e., formal or informal guidelines or instructions regarding which details will be omitted and which will be included?
- Is information presented in a simple and clear way, and without distortion or bias?
- How readable are presentations? How comprehensible?
- Which media are used in presentations (formal reports, pamphlets, brochure, other)?

More generally, information flow channels, such as formalized community and public media events, are observed and documented if they are applicable to the project. Characteristics of salient communication channels are reviewed and described, and management observations are included regarding the useful and negligible features of each.

[16] MIS requires a *financially constrained plan* to be developed prior to project implementation. Financial constraint requirements do not prohibit the exclusion of projects where funding is uncertain, but do require that such projects be linked to reasonable funding sources, and that a capital provision strategy be included in the plan.

2.0 REVIEW OF PROBABILISTIC RISK ANALYSIS

This chapter provides a description of probabilistic risk analysis, and implications for its use in transit capital development projects. The following sections include a description of the probabilistic method, current uses in private industry and government, and comments on the method's particular suitability for the transit capital development project. The chapter concludes with a discussion of the salient risk elements for transit capital development. Major elements or categories of transit construction risk are shown, and specific examples of transit risk items are described.

2.1 DESCRIPTION OF THE METHOD

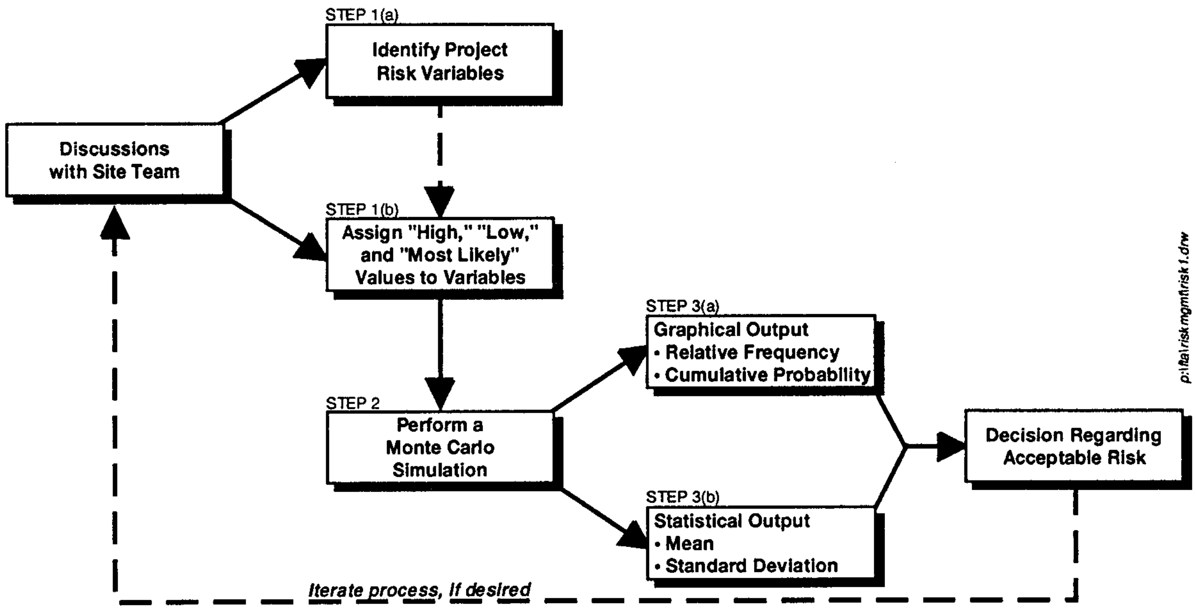
Probabilistic risk analysis is a decision tool which can be effectively used in a risk mitigation program for large, public capital development projects such as public transit, where investment is high, benefits are very slowly manifested, and complexities abound. Probabilistic risk analysis is most useful when the method is coupled with other, more conventional risk management strategies which are embodied in a disciplined and formalized project management approach. Risk communication is a natural adjunct to a risk mitigation program which begins with probabilistic risk analysis. The method is particularly well suited to facilitate communication by fostering high participation of vested parties, a collaborative orientation, and descriptive, intuitively appealing graphics which convey simultaneous complexities in a sure, straightforward manner. Probabilistic risk analysis models realistic outcomes, and effectively conveys the results of input from all parties in the decision-making process.

2.1.1 The Three Stages of Probabilistic Risk Analysis

Exhibit 2-1 describes the sequence of activities in the probabilistic risk analysis process. Identification of project risk variables is followed by performing the probabilistic analysis, using computer software to conduct a Monte Carlo simulation. Next, results of the analysis are interpreted and a decision is made regarding acceptable risk. This process may be iterated if desired by the site team.

The first step in the probabilistic approach is to assess risk or measure the probability of cost or schedule overrun/underrun by identifying project variables which are expected to vary greatly. These variables have especially large and volatile ranges, hence, much uncertainty. In the case of project budget, these variables are "cost drivers" which critically impact the project bottom-line by virtue of their variability, or probability distributions. The triangular distribution is frequently selected for use with probabilistic modeling, because of its simplicity and its ease of use. Use of a triangular distribution requires the identification of *high*, *low*, and *most likely* values for each selected variable. The resultant data points form the basis for the triangular, or three-point distribution.

EXHIBIT 2-1
Probabilistic Risk Analysis Process



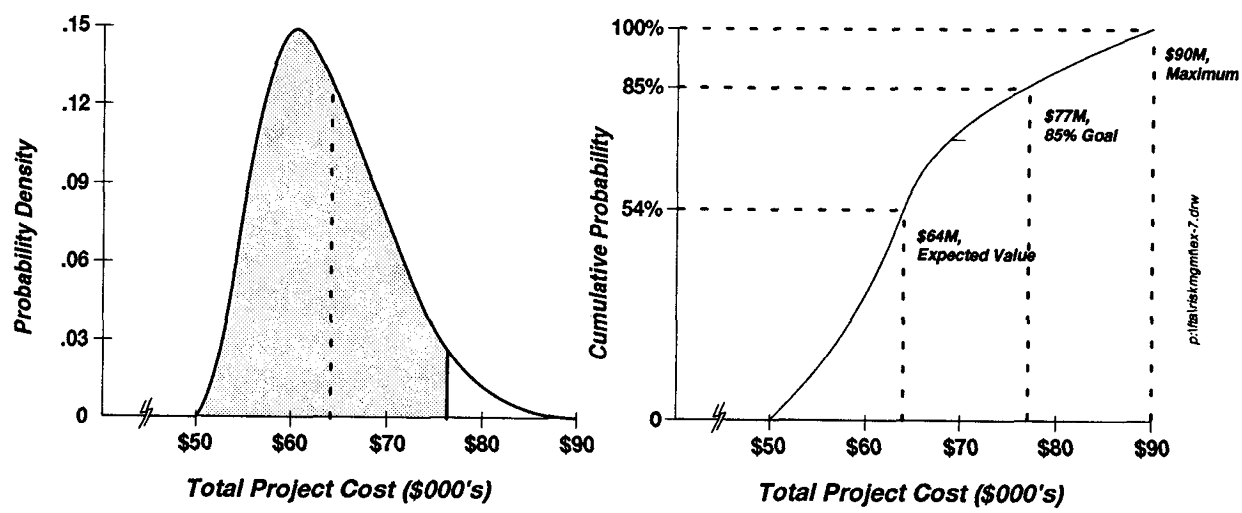
The second stage of a probabilistic risk analysis is the use of computer software to conduct Monte Carlo simulation on the total project budget, including the risk variables which have been identified and "ranged" as described in the paragraph above. Monte Carlo simulation uses the selected, user-defined probability distributions of the identified project risk variables to perform random modeling; that is, given the unique distribution of each project risk variable, the simulation produces repeated variable values ("x") by simulating or "performing" many random repetitions or trials. Total cost is defined as a function of various random variables, "x." Each time a set of "x's" are randomly generated in the simulation process, a value for total cost is calculated. Once the simulation is complete, a distribution for total project cost is obtained. The precision of the approximation improves as the number of simulation trials increases. Monte Carlo simulation is thus able to replicate real-life occurrences, in its ability to "model" projected events and generate an expected value for the objective function (e.g., total cost or total schedule) under study. For example, the simulation results may indicate an 83% likelihood (relatively high probability) that a project will need to use its contingency reserve in order to avoid a funding overrun; or, results may show a 65% probability (relatively low) that the project will be complete within the budgeted schedule duration.

The third and final stage of probabilistic risk analysis is interpretative and may need to be iterated, or run again. The results of this stage may be used to generate or "feed" another round of analysis beginning with a fresh look at stage one, i.e., re-examining the triangular or range input values for the critical project risk variables which are selected by the project site team. The interpretative stage of the probabilistic method relies on graphical tools such as histograms (relative frequency polygons), ogives (cumulative frequency polygons), and may include "tornado graphs"[1] which describe calculated sensitivities for critical variables generated from the information which is produced as a result of the Monte Carlo simulation. Visual output is quite software-dependent, but it typically includes probability density functions and statistical parameters such as expected value (mean), standard deviation, upper and lower limits, and graphic confidence intervals for a given region (probability) expressed as a percent between 0% and 100%.

2.1.2 <u>Probabilistic Risk Analysis Output</u>

Exhibit 2-2 gives an example of standard output for a probabilistic risk analysis. A cumulative probability function or ogive is utilized in the probabilistic analysis to display the likelihood of achieving any given, desired target. If, for example, an 85% certainty level is desired to achieve on-target completion for a construction project, then the required contingency is the project value at 85% cumulative distribution, less the total project cost without contingency ("owner's estimate"). Exhibit 2-2 shows the visual and probabilistic basis for these observations.

EXHIBIT 2-2
Example of Probabilistic Risk Analysis Output



Minimum	**$50**
Mean (dotted line)	**$64**
Maximum	**$90**

Shaded region represents 85% confidence level.

If Owner's Estimate* = $60M and an 85% likelihood is desired to avoid a cost overrun, then the contingency amount will need to be valued at: $77M - $60M = $17M.

*** Cost estimate without contingency.**

[1] <u>Analytical Power Tools</u>, a reference manual of statistically-based analytical software published by Palisade Corporation, Vol. 3, No. 1, p. 4.

Desired targets will naturally represent various degrees of risk aversion, and so one clear advantage of using the probabilistic method is its innate ability to offer alternative choice options for resource-directing decisions. In turn, the strength of this advantage is based upon the sound statistical practice of "vibrating" all assumptions, both probabilistic and constant, simultaneously via the Monte Carlo technique.

2.2 CURRENT USES IN PRIVATE INDUSTRY AND GOVERNMENT

2.2.1 Gas & Oil Industry

Probabilistic analysis has been used to measure risk in private industry for decades. Applications for probabilistic studies have perhaps been most notable in gas & oil exploration activities, and probabilistic analysis in this area has been widely reported within the subtext of operations research. Seismic data, field-size distributions, ranges of pay thicknesses, and recovery per acre are some of many risk variables which have been modeled probabilistically. In addition, competitive bidding for gas & oil leases almost always involves great uncertainty and greater opportunity for loss than competitive bidding in other industries.[2] Exploration is a process that commits funds to unknown futures, and well reserves are notably difficult to estimate. Probabilistic analysis has been used extensively to support exploratory studies in the gas & oil industry, since the beginning of federal offshore sales in the Outer Continental Shelf and Alaska in 1954. Speaking with regard to the inordinately high risks which are present in the gas & oil industry, Robert Megill states: "Granted there are uncertainties in a bid for constructing a building, laying a pipeline or obtaining a fuel contract; the difference is one of degree."[3]

Megill recommends triangular distributions for uncertain variables with many possible answers, although he cautions that exploratory problems frequently imply lognormality.[4] Megill gives thorough treatment to the statistical characteristics of triangular distributions, the full scope of which is beyond this study. He notes that triangular maxima and minima are *absolute* values, i.e., their relative frequencies are set to zero. Megill further notes that many explorationists falsely assume that the triangular distribution allows for some small probability of occurrence of the minimum and maximum values.

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[2] Megill, Robert E., An Introduction to Risk Analysis, Second Edition, PennWell Books, 1984, p. 173.

[3] Ibid.

[4] If the logarithm of a variable versus frequency plots as normal (bell curve) distribution, then it is considered to be a lognormal distribution.

2.2.2 Other Applications for Probabilistic Analysis

In addition to the gas & oil industry, probabilistic risk analysis is currently applied in a variety of business, engineering, and scientific situations in government, private industry, and academia. Numerous specific applications of probabilistic analysis are reported:[5]

- Litigation awards modeling;
- Nuclear reactor safety analysis;
- Genetic counseling;
- Wargame simulations;
- Mergers and acquisitions; and
- Traffic flow analysis.

2.2.3 Status of Limits for Probabilistic Analysis

Historically, a significant limitation for potential application of probabilistic analysis has been the dearth of accessible computer software needed to perform Monte Carlo simulation. Since the early 1990s, this limitation has been largely alleviated by the ready market availability of numerous programs which perform probabilistic risk analysis on a variety of platforms. These programs are, for the most part, inexpensive and fairly easy to use. Some probabilistic software are stand-alone programs and some are spreadsheet add-ins. Many have excellent graphics and are quite user-friendly. Importantly, an advanced degree in statistics is not required to use and interpret these programs. What is needed is a thorough grounding in the fundamental concepts of probabilistic technique, which are introduced in the explanations and exhibits in this study. The power of probabilistic analysis is currently available to anyone who has a personal computer.

2.3 APPLICABILITY FOR TRANSIT DEVELOPMENT

Probabilistic risk analysis is a contemporary decision tool which is especially well suited to infrastructure applications in public transit. In its ability to analyze information continuously or probabilistically, and to present this information meaningfully, probabilistic risk analysis fosters a collaborative approach for transit capital planning which engages "stakeholders" or vested groups in a productive discussion of the full spectrum of possibilities for resource direction. In this manner, probabilistic analysis encourages creativity within the realm of achievable decisions. This approach is in significant contrast to the classic combativeness evidenced in "toe to toe" alternative evaluation, which, at best, can process decision-making in a logical but piecemeal way, and holds potential for worsening already-existing animosity and group polarization.

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[5] This information is obtained from Palisade Corporation of Newfield, New York, the authorized retailer for @RISK tools for performing probabilistic analysis.

David Lewis[6] states that a primary advantage of probabilistic analysis is that ". . . stakeholders are never drawn into a debate about who is right and who is wrong . . . . Risk analysis . . . embraces virtually any reasoned view, albeit with different degrees of probability. Experience demonstrates that the process results in consensus not because of clever group manipulation, but because of its authenticity in dealing with the realities of uncertainty in engineering, environmental science and economic theories."

2.3.1 Transit Infrastructure's Volatility of Estimates

Transit capital development is characterized by marked volatility throughout the course of the selection and estimating process. Complex and ever-changing scenarios are the rule. In its special ability to "vibrate" critical risk variables simultaneously, probabilistic analysis provides a unique capability to calculate and present a true mid-range scenario. This attribute is very useful in the transit development process, where ridership, financing, and the full range of construction cost estimates are subject to many influences and much deviation. In probabilistic analysis, important risk variables are analyzed probabilistically, and results are based on a simulation achieved over many trials.

Intuitively, probabilistic analysis is easy to grasp and the results are conveyed in the context of confidence intervals. Moreover, the probabilistic approach can be combined with more conventional and commonly used methods of appraising "riskiness." Deterministic models such as standard spreadsheet analyses are able to sequentially iterate a decision situation through use of a "what if" approach. That is, variables are continually adjusted in these deterministic models, in order to eventually achieve some target or bottom-line performance values. Probabilistic analysis uses expert (project team) estimates to form triangular distributions for each risk variable. This stage of probabilistic analysis is most similar to the more familiar deterministic method. Probabilistic analysis is intuitive or subjective in this regard, and, most importantly, it is experientially based. That is, by opting to pursue a probabilistic approach to transit capital evaluation, there is no need to dispense with the older, comfortable method of using subjective information in the decision process. Subjective information is the basis for the probability distribution of each risk variable. However, probabilistic analysis' strong advantage and particular suitability for transit is mainly due to the method's ability to enhance the deterministic methodology by performing three key tasks:

- Probabilistic analysis *simultaneously models multiple attributes* of a decision paradigm.
- Probabilistic analysis *replicates real-world events* through Monte Carlo modeling.
- Probabilistic analysis *presents meaningful information in an understandable format* through use of cumulative probability charts.

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[6] Lewis, David, "The Future of Forecasting: Risk Analysis as a Philosophy of Transportation Planning," TR News, March-April 1995, p. 6.

2.3.2 Probabilistic Analysis as a Policy Tool

Transit capital planning is complex and expensive. The Major Investment Studies (MIS) planning process includes many diverse groups or "stakeholders" to the process:

- "Owners" or government agency representatives who influence and administer public project funding, which may leverage private investment;

- Other local, state and federal agencies who are operationally impacted by the MIS (transportation plan);

- Elected officials, who represent the voting public and who enact laws to enable project development and project funding;

- The general public, including representatives of special interest and community groups which are organized and authorized to represent the economic and cultural diversity of the metropolitan area, and who act on behalf of special segments of the regional tax base;

- The business community, which may partner with government to fund capital transportation projects in order to develop a regional land-use mix which is beneficial to the general public, and consistent with the metropolitan area's long range plan;

- Technical experts or consultants, with knowledge and skills unique to the processes, proprietary technology, and characteristics of the special purpose environment which constitute the transit project; and

- Contractors, who are motivated by the profit incentive.

Within a diverse arena, probabilistic analysis embodies a shareholder approach with a "net-benefit" bottom-line. That is, because all critical decision factors are varied simultaneously, the probabilistic method facilitates communication, compromise, and action. Probabilistic analysis shifts the debate from unproductive controversy over ownership of "the facts" to a constructive view of the possible and the probable. Decision forums are thus able to convert from a combative to a collaborative mode, and move on to an effective deliberation of policy and action. For example, regional business interests which represent capital markets may "buy into" a transit project, only after reviewing results of the probabilistic forecast for expected regional population and related ridership. The forecast reflects community perception of regional development, as well as expert evaluation, and the input variables are collaboratively fitted to a suitable probability distribution in the model. Such an analysis yields results which are understandable and useable, and the decision-making process can effectively proceed to the next step.

2.4 RISK ELEMENTS IN TRANSIT DEVELOPMENT

Risk on a major capital project encompasses any factor that can impact a transit system's ability to complete a project on time and within budget. The probabilistic analysis process begins by having representatives of the project team identify critical risk variables. Variables are considered critical if they can be expected to vary greatly, and impact the project bottom-line significantly. Criticality assessment is left to expert project consensus in the probabilistic risk measurement process.

Risk elements in transit development may, depending on assessment of the project team, include any of the factors below:

Examples of Transit Development Risk Items

- *Political Risk* - Legislative initiatives and electoral results at all levels of government -- federal, state and local -- can impact a transit project, especially in the early stages of planning. Environmental regulations and requirements; licenses, permits, and approvals; taxes; and all sources and forms of public project financing are subject to political or constituency risk.

- *Economic Risk* - Ridership forecast and fare analysis; inflation rate; consumer sales; bond ratings; funding portfolio or mix; debt management ratio and capitalization policy; and cash flow projections are some of the economic feasibility variables which are present in transit construction.

- *Social Risk* - Urban sprawl, land use analysis, population growth, and demographic attributes such as income and age are some social indicators which may pose some risk, particularly in long-range transit planning.

- *Engineering Risk* - Project performance characteristics and design standards, design complexity, system integration, constructability, life cycle cost analysis, data/drawing quality, technology, and patents are examples of engineering risk variables present in transit development.

- *Construction Risk* - This category of risk is so broad that it can be broken down into four distinct elements:

  - *Site Risk* - Access, underground soil and water conditions, abutting structures, utilities, hazardous waste, archeological finds, security, disruption to the public, noise, fumes, and dust;

  - *Labor Risk* - Labor availability and local wage scales; unions; workmens compensation; substance abuse; and managing sabotage, theft, and waste on the site;

- *Materials Risk* - Sources of materials and services and the management of these sources; and

- *Schedule Risk* - Formalized project management techniques including site, labor, and materials protocols, quality assurance, and procedures for the timely procuring of licenses, permits, and approvals.

• Other Risk - Weather, fire, and natural disasters can impact the timely completion of a transit project.

In summary, probabilistic risk analysis measures uncertainty in construction contracts by treating project components with a high potential for variability as random variables. These variables are then modeled probabilistically and a cumulative distribution function is calculated for total cost or schedule. This cumulative distribution function is used to assess desired contingency rates. This becomes a subjective exercise in management desires, styles, and needs. Risk communication techniques come to the forefront, with major emphasis on communicating the results of probabilistic risk analysis in a way that fosters understanding and resolution.

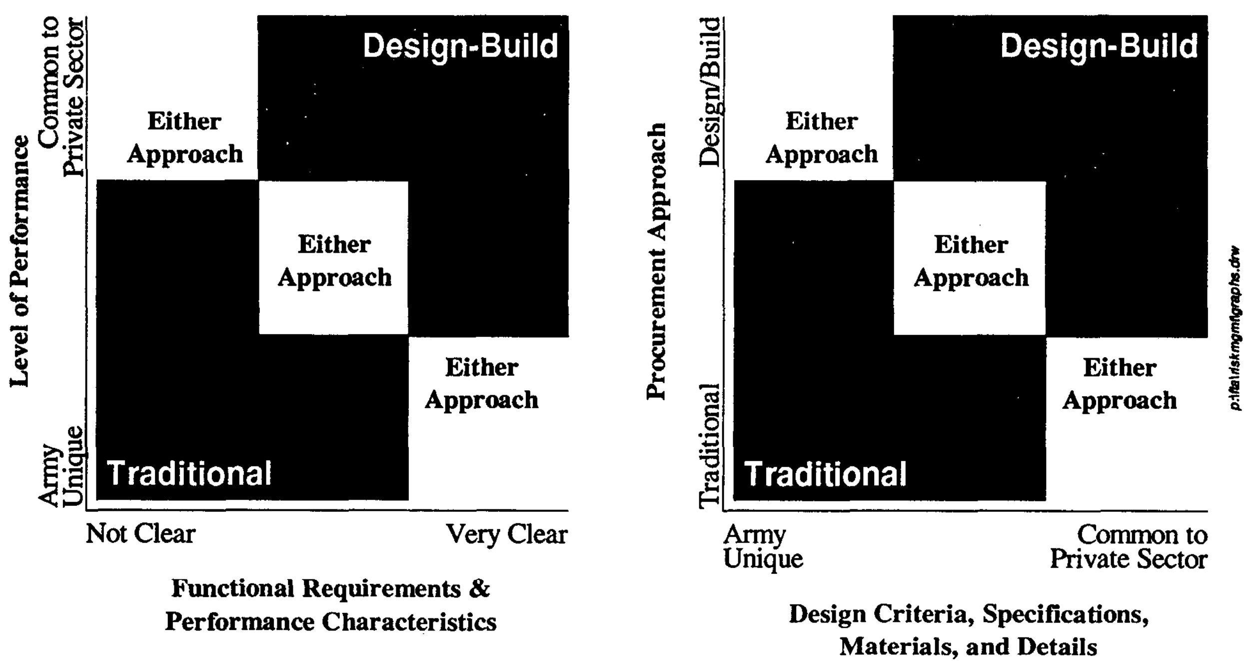
Probabilistic analysis requires an appropriate statistical distribution for each risk variable, and should consider correlation among variables. These are the two main technical obstacles to using the method. However, contemporary software is readily available to assist the user in fitting a reasonable distribution for modeling a particular variable, and careful review of risk variables by the site team can isolate and combine variables in such a way that statistical dependency is minimized. A skilled risk moderator can be of significant assistance to the project team, in guiding the selection of variables or variable groups, and interpreting cumulative probabilities which result from the probabilistic analysis.

If addressed thoughtfully, the technical considerations and requirements of probabilistic risk analysis will not be problematic in practice. The utility of simultaneous, multivariate modeling coupled with understandable, useful results through analysis of the cumulative probability function is a strong indicator of probabilisitic risk methodology's unique advantage in measuring risk for transit capital development projects.

3.0 CASE STUDY "A" -- TINKER AIR FORCE BASE RUNWAY EXTENSION

This case study uses the Extend Alternate Runway project at Tinker Air Force Base in Oklahoma City, Oklahoma to perform a risk analysis for cost. This project is design-build. Sverdrup Civil[1] is the design-build contractor, and the U.S. Army Corps of Engineers (USACE, "the Corps") - Tulsa District has project management and oversight authority. Exhibit 3-1 shows the key decision criteria used by the Corps when making a determination for design-build or traditional procurement. The Extend Alternate Runway project is work which is common to the private sector in terms of design criteria, technical specifications, materials and methods; and the functional requirements and performance characteristics are able to be clearly specified in the Request for Proposal.

EXHIBIT 3-1
U.S. Army Corps of Engineers
Design-Build Decision Criteria



Source: U.S. Army Corps of Engineers

[1] The Sverdrup Corporation Transportation and Public Works Division is located in Maryland Heights, Missouri.

Funding for this project is via the Air Force Material Command at Wright-Patterson Air Force Base in Ohio. Total contract value is $10,847,558. The build phase for Extend Alternate Runway is scheduled to begin in March 1996 and to be complete in December 1996.[2] Primary contacts for the case study are:

- Bob McCollum, USACE Program Manager for Tinker Air Force Base; and
- Jim Fulk, Sverdrup Program Manager for Tinker Extend Alternate Runway.

Project background, data, technical approach, and study findings are presented below.

3.1 PROJECT BACKGROUND

This section describes relevant background information, gives an overview of the actual construction work, and describes contractor selection for the project. Current status of the project is also provided.

3.1.1 Background and Construction

Tinker Air Force Base is the training and operating base for E-3 and E-6 aircraft, and provides depot support for B-1s, B-52s, C/KC-135s, and an F-16 squadron. The primary runway at Tinker is currently adequate for all of these missions, but is deteriorating rapidly and will require nearly complete replacement within the next five years. This renovation will necessitate closure of the runway for eight to ten months, during which time all aircraft departures and arrivals must be from the alternate runway. However, the alternate runway is not wide enough to accommodate B-52s, not long enough for E-3s, E-6s and B-1s, and it does not have the Instrument Landing System capability needed for F-16s.

The construction project for the case study consists of the final design and construction for the lengthening, widening, and upgrade of the alternate runway at Tinker Air Force Base. Lengthening consists of an extension of approximately 2,200 linear feet by 200 feet wide surface to the end of the runway. Widening consists of an additional 25 feet surface to each runway edge. The upgrade work includes taxiway extension, Aircraft Battle Damage Repair pad and 5,000 gallon underground storage tank, concrete box culvert extension, runway overruns, new taxiway shoulders, runway edge lighting, Approach Lighting System, site provisions for Government furnished/Government installed Instrument Landing System, generator backup power, and grading. Relocation work includes utility relocations, the relocation of Precision Approach Path Indicator lighting, and the two Aircraft Arresting Systems with the associated portable building which houses the rewind mechanism for the system. Exhibit 3-2 shows the construction area site plan for the Extend Alternate Runway project.

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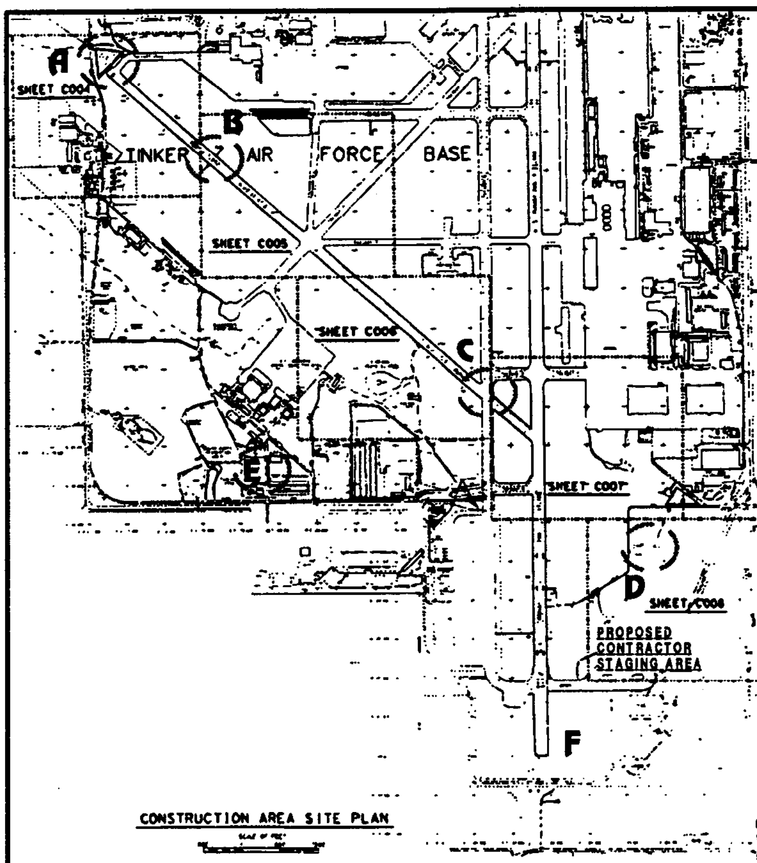
[2] Sverdrup Civil, *Preliminary Draft Schedule*, September 10, 1995 (Pre-design conference at Tinker Air Force Base).

EXHIBIT 3-2
Tinker Air Force Base
Construction Area Site Plan for Extend Alternate Runway



DRAWING INDEX

VOL. I of II: CONSTRUCTION DRAWINGS

GENERAL SHEETS -

G001	PROJECT LOCATION MAP, CONTRUCTION AREAS AND DRAWING INDEX	
G002	SURVEY FEATURES LEGEND AND SYMBOLS	

CIVIL SHEETS -

C001	DEMOLITION SITE PLAN AND SECTIONS	
C002	GENERAL CONSTRUCTION SITE PLAN	
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C004	AREA 2 - SURVEY	
C005	AREA 3 - SURVEY	
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C007	AREA 5 - SURVEY	
C008	AREA 6 - SURVEY	
E001	AIRFIELD LIGHTING PLAN - SURVEY	

VOL. II of II: (DRAWINGS PROVIDED FOR REFERENCE ONLY)

SET 1: REPLACE SE-1000 FT. RUNWAY 12/30

G-1	COVER SHEET	DE-F-94032-1
C-1	EXISTING & NEW JOINT LAYOUTS AND UNDERDRAIN PLAN	DE-F-94032-2
C-2	PROFILE PLAN	DE-F-94032-3
C-3	DETAILS	DE-F-94032-4

SET 2: REPLACE ALL VASI AIRFIELD LIGHTING SYSTEMS (100%)

G-1	TITLE SHEET	DE-F-94048-01
E-1	ELECTRICAL SITE PLAN	DE-F-94048-02
E-2	AIRFIELD LIGHTING VAULT	DE-F-94048-03
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SET 4: INSTALL TWO BAK-12 ARRESTING SYSTEMS

•	PLANS	DE-F-7662-1
•	PLAN PROFILE AND DETAILS	DE-F-7662-2
•	ENGINE PAD DETAILS	DE-F-7662-3
•	DECK SHEAVE FOUNDATION DETAIL	DE-F-7662-4
•	DETAILS	DE-F-7662-5

SET 5: INSTALL BAK-12 ON RUNWAY (12/30)

C-1	SITE PLAN AND LOCATION MAP	DE-F-85052-1
C-2	PLAN, PROFILES AND DETAILS	DE-F-85052-2
A-1	BUILDING STRUCTURAL AND ELECTRICAL PLAN, ELEVATION & DETAILS	DE-F-85052-3
A-2	BUILDING FOUNDATION AND DETAILS	DE-F-85052-4

SET 6: SURVEY. CORPS OF ENGINEERS 3 JULY 1985
RUNWAY EXTENSION RUNWAY 12/30, TINKER AFB
SHEETS 1 THROUGH 9

SET 7: SURVEY. CORPS OF ENGINEERS 3 JULY 1985
RUNWAY EXTENSION RUNWAY 12/30, TINKER AFB
SHEETS 1 THROUGH 5

SET 8: INSTRUMENT LANDING SYSTEM (ILS) LOCALIZE
12 SHEETS TOTAL

Legend:

A - extend alternate NW-SE runway; extend 2-barrel reinforced concrete box culvert

B - BAK12 Aircraft Arresting System (AAS); relocate 200 feet NE

C - pendant cable and chain aircraft arrester; relocate to 98+00

D - Aircraft Battle Damage Repair Pod (ABDR)

E - relocate ABDR and install new 5,000 gallon underground storage tank

F - this is the southern portion of the main N-S runway

p:\tsk\risk mgmt\case-a.drw

Source: U.S. Army Corps Engineers IFB# DACA56-95-R-0004

3.1.2 Contractor Selection

The Tinker project was bid at a stage where 30% of design was complete. Design-build for USACE work is accomplished in six phases, which are depicted in Exhibit 3-3. A source selection board advises the contracting officer[3] and performs specific roles throughout the project's development and execution. The board is composed of professionals from management, contracting and counsel.[4] Exhibit 3-4 displays the steps for evaluating proposals and awarding the contract.

Sverdrup was awarded the design-build contract on August 25, 1995. The design-build contract is for $9,687,864. Rating points for the bid covered managerial and technical performance elements. Technical evaluation included offeror experience and past performance. The main rating criteria for technical performance elements were:

- Experience with relevant projects;
- Experience with design-build;
- Three industry references in the disciplines of design, construction, and design-build;
- Management commitment or corporate level of support;
- Resource commitment: staff, vendors, and technology; and
- Financial capacity, including financial audits, bonding, and lawsuits pending.

Special contract provisions for the design-build contract include a liquidated damages clause for the runway intersection work, which was originally scheduled for July 1996. The intersection work has currently been re-scheduled to August 1996. During this construction phase, the air base will be shut down. Liquidated damages of $91,350 per day will be assessed the contractor, for each day of air base shut-down which is needed beyond a maximum of 30 days.

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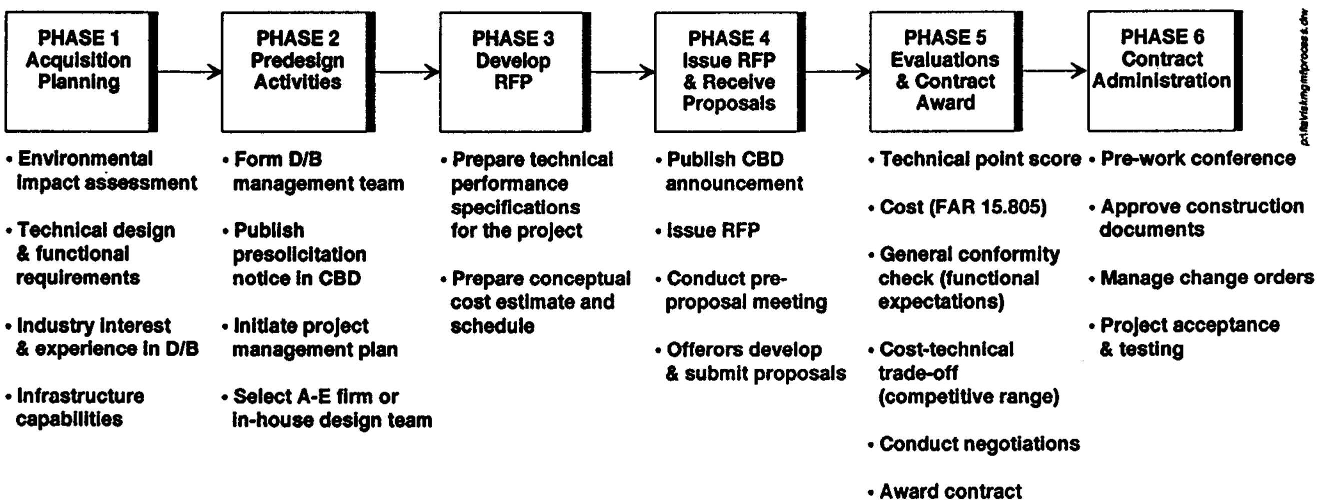
[3] The contracting officer for the Extend Runway project at Tinker Air Force Base is R.L Hedrick of the Tulsa District USACE office.

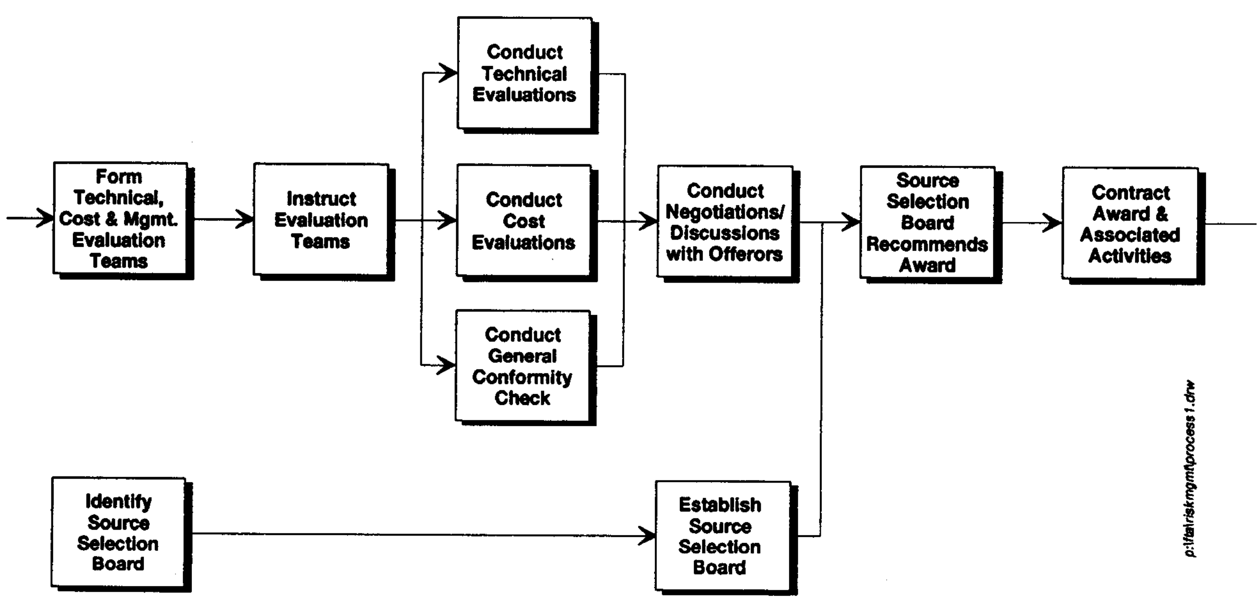
[4] Duncan, Daniel, Design-Build Instructions (DBI) for Military Construction, Headquarters U.S. Army Corps of Engineers, October 29, 1994, pp. 2-3.

EXHIBIT 3-3
Tinker Extend Alternate Runway
Design-Build Process



Source: U.S. Army Corps of Engineers

EXHIBIT 3-4
Tinker Extend Alternate Runway
Proposal Evaluation Process



Source: U.S. Army Corps of Engineers

On September 6, the Air Force issued a Notice to Proceed (NTP) for Sverdrup to perform up to 60% of the design. A pre-design conference was held onsite at Tinker at that time[5]. This NTP culminated with a Preliminary Design Submittal by Sverdrup. At the pre-design conference, USACE requested that a computerized Critical Path Network diagram[6] be ready at completion of preliminary design; but for various reasons the availability of this cost-loaded network was delayed until February 1996. This delay prevented completion of the probabilistic risk analysis. As a result of the delay, a cursory risk analysis was performed for this project, including a simple description of project cost contingencies, relative to the total design-build contract.

3.1.3 Current Project Status

A second NTP was issued by the Air Force on November 27, authorizing Sverdrup to complete 100% of the design and to begin preliminary sitework including surveying and geotechnical investigation. A pre-work conference was scheduled for January 31, at which time a construction NTP may be issued. The Air Force requested that the USACE obtain the contractor's schedule as soon as possible, due to air base planning needs for aircraft operation and maintenance.

Sverdrup submitted two cost reduction proposals in the period prior to beginning construction. One proposal was for re-grading the concrete box culvert, and the other was to re-site the Aircraft Battle Damage Repair pad and cover over the related well. The Air Force rejected the box culvert modification, and was considering the second (Aircraft Battle Damage Repair pad) mod.

3.2 DATA

The contractor's cost-loaded network, necessary for probabilistic analysis, was unavailable in time to perform a quantitative cost and schedule risk analysis for the Tinker project. This network was initially required of the contractor by USACE in November 1995, and was delayed until February due to Sverdrup priorities. The network, received by Abacus Technology in late February 1996 just prior to completion of the Abacus Technology draft final report to FTA, is available upon request in hard-copy format. See Appendix A for instructions to obtain a copy of the Sverdrup cost-loaded network.

3.3 TECHNICAL APPROACH

Although a probabilistic risk analysis has not been performed, the contingency detail provided below highlights USACE risk mitigation techniques for design-build.

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[5] The pre-design conference for the Extend Alternate Runway project was held on September 12, 1995.

[6] USACE uses the contractor's cost-loaded network as the basis for progress payments to the contractor for project work performed.

3.4 STUDY FINDINGS

The Extend Alternate Runway project is funded for a total value of $10,847,558. Of this amount, $550,812 (or 6%) are unallocated USACE project contingencies. The design-build contract itself (including the contractor's contingencies) is valued at $9,687,864. Thus:

$9,687,864	Design-Build Contract[7]
608,882	Salaries and Administration Expense[8]
550,812	6% Project Contingencies
$10,847,558	Total Extend Alternate Runway Project

The total contingency amount, $550,812, consists of four elements (four separate contingency values) which are explained as follows[9]:

- $266,417 or 2.75% for Management Reserve. This is held for Air Force (owner) requested changes, which is a sort of project "wish list" of desired, additional activities;

- $193,757 or 2% for unknown site conditions or market conditions, such as escalating wage rates and subcontractor issues, which would cause an owner-authorized contract cost increase, subsequent to contract award;

- $50,740 or .5% for Engineering and Design ("Post Award Engineering and Design") . This value covers engineering of any special items, during the construction phase of the project; and

- $39,898 or .4% for Other Cost Contingencies. This small amount is intended to cover design reviews for design-build. In traditional design-bid-build contracting, USACE conducts very short constructability reviews, and there is no formal review process as is the case with design-build[10]. This contingency line-item is therefore intended to supplement Salaries and Administration and Engineering and Design (above), which mainly cover costs which occur during the construction phase of the project.

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[7] The design-build contract includes the contractor's cost contingencies.

[8] Salaries and Administration expense covers U.S. Army Corps of Engineers area office supervision and overhead, quality assurance and inspection activities in support of the contract, and contractor payment administration.

[9] Conversation with Bob McCollum, USACE Project Manager for Extend Alternate Runway, on February 5, 1996.

[10] This formalized USACE review process is evidenced in the stepped NTP's which are required prior to work authorization for design-build.

The owner contingencies, displayed above, indicate that design-build is an evolving concept for USACE work. Design reviews for USACE design-build are generally paid for through "Other Cost Contingencies" at this time, rather than Corps Salaries and Administration; and contractor Notices to Proceed (NTPs) are used to evaluate each stage of design. Often, contract "phases" are utilized in conjunction with NTPs, to underscore the Corps disciplined design review function. Contingencies for unknown site conditions and out-of-scope design activities are intended to supplement the budget, in case of unforeseen events. Cost contingencies, NTPs, and contract phasing are several risk mitigation measures which are used by the U.S. Army Corps of Engineers in design-build contracting.

The Extend Alternate Runway project, a military design-build project, demonstrates that the Corps has put in place extensive controls to manage the design-build project concept. The study finds that such tight controls, especially during the final design phases of the contract, may serve to diminish one major advantage of design-build contracting, i.e., the ability of the contractor to perform final design and construction activities simultaneously. For Tinker Extend Alternate Runway, the contractor needed to be at a 100% complete level of design, before construction activities were allowed to begin (Phase II NTP).

The study also finds that, for Extend Alternate Runway, contractor activities for cost reduction proposal efforts (value engineering) which were performed during the final design period, significantly delayed critical activities such as preparation of the project master schedule and network, and the selection of key subcontractors. These delays, in turn, caused planned construction milestones to be pushed back, to the extent where the actual construction NTP was delayed for one month, and the planned airfield shutdown was moved from July to August[11]. The construction NTP was also authorized by USACE on January 30, 1996, without a contractor work plan or cost-loaded network on file. The contractor network was due on November 27, 1995.

In conclusion, the design-build concept for USACE is evolving. Contingencies are used to cover design-review activities, which are unique to USACE design-build, as well as unforeseen events. This case demonstrates that design-build controls may negatively affect the project schedule. It is the Corps' belief that stringent controls are needed for design-build, and that schedule efficiencies can be achieved during the construction phase of the project, because the project designer is also the builder.

[11] The airfield shutdown is due to the planned runway intersection work, originally scheduled for July 1996 but recently moved to August.

4.0 CASE STUDY "B" -- BALTIMORE MTA CENTRAL LIGHT RAIL LINE (PHASE II)

The main objective in this case study is to conduct a probabilistic analysis using Monte Carlo simulation to assess the risk of cost and schedule overrun for the Baltimore Central Light Rail Line Phase II (CLRL or "Phase II") project, which is currently being built by the Maryland Mass Transit Administration (MTA). The results of this case study will be used to evaluate the adequacy of contingencies and the probability of exceeding the project budget. Total contract value is $106,338,179, and project funding is 80% Federal Transit Administration (FTA)/20% State of Maryland. Ridership projections for the Central Rail Line, including the planned extensions, is for 33,000 passengers per day by the year 2010. The Phase II extensions are expected to be operational by the late spring or summer of 1997.

This analysis is based on the owner's (MTA's) estimate at the end of preliminary engineering, and will provide a range of potential cost and schedule variations that are of interest to the owner and the sponsor. It is understood that such an analysis should have been performed at an earlier date, preferably at the time when the project was going to bid, due to the capability the study provides to evaluate cost and schedule contingencies in the specific context of risk diversification. That is, this form of analysis serves the owner best when it is conducted before the contractor is chosen and the construction award is made. The assumptions used in this case study are mainly based on information which was available at the time of bidding.

The Phase II project is design-build, and MTA is a participant site in the FTA's current Turnkey Demonstration Program. The terms "design-build" and "turnkey" are synonymous for purposes of this case study. Turnkey denotes use of a private contractor by a public agency, for both design and construction services for a transit construction project. Turnkey procurements are generally firm fixed price contracts, usually guaranteed by a payment/performance bond.

Project identification, specification, and project development for MTA Phase II was accomplished within the following FTA planning process[1]:

(1) Regional/Corridor Planning
(2) Alternatives Analysis and Scoping
(3) Conceptual Engineering/Draft Environmental Impact Statement (DEIS)
(4) Preliminary Engineering/Final Environmental Impact Statement (FEIS)
(5) Final Design.

Exhibit 4-1 is a transit project implementation flow chart which shows timing of turnkey consideration for the public agency, at each point in the FTA traditional procurement process. *The MTA Phase II project was selected for turnkey procurement after FEIS, and before Final Design.*

The design-build contractor for Phase II is Whiting-Turner. The contractor is responsible for final design, construction, testing, and start-up. MTA has project management and project acceptance responsibility. Primary contacts for the case study are:

- John Coard, MTA Phase II Project Director
- Denis Cournoyer, MTA Manager, Consultant Services

Dr. Ali Touran[2] assisted Abacus Technology on the case study by guiding the cost and schedule risk analysis. Project background, data, technical approach, and study findings are presented below.

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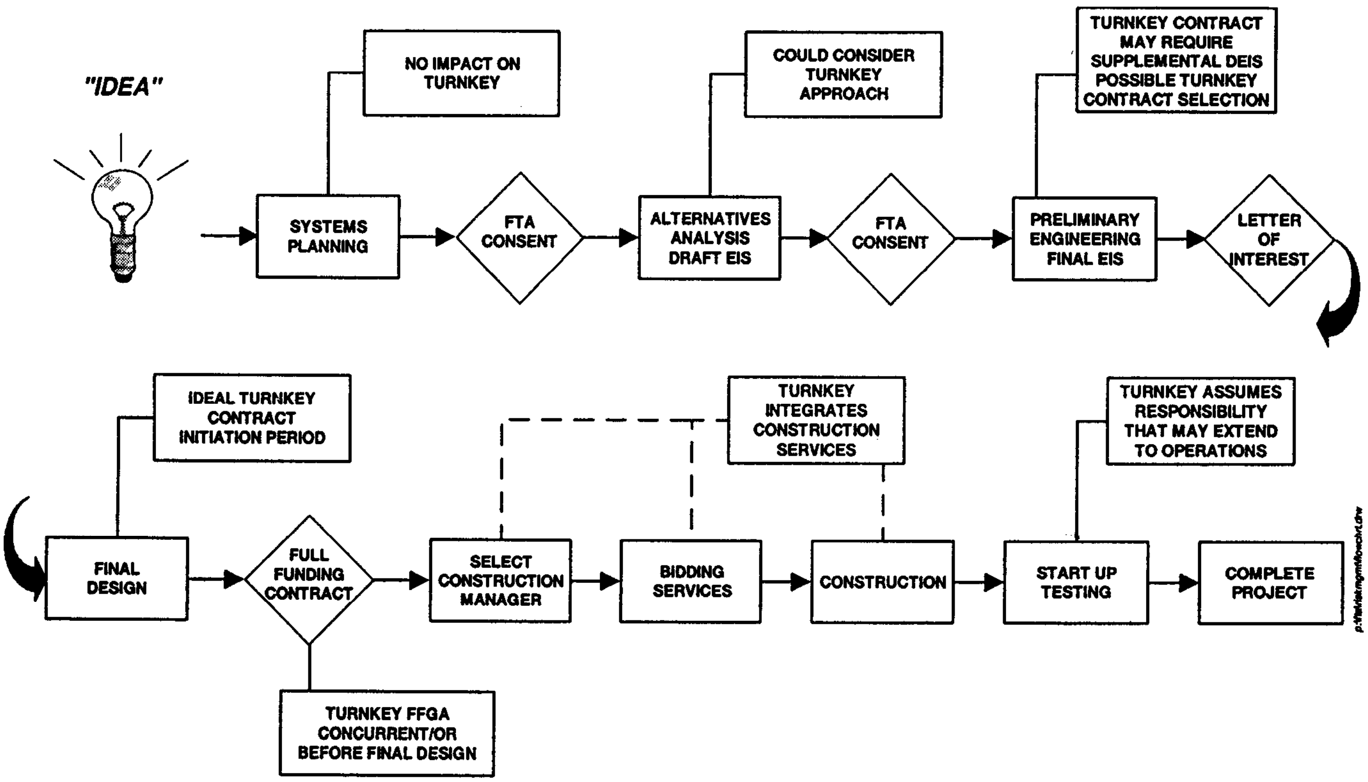
[1] With the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) legislation in 1991, regulatory changes were implemented which call for a modified capital planning process, different from the one utilized for the MTA Phase II project. This new planning process, known as Major Investment Study (MIS), is currently required for transit infrastructure projects, and is integrated with National Environmental Protection Act (NEPA) documentation requirements for DEIS and FEIS plans. MIS normally is developed in three steps or phases: (i) identify conceptual alternatives for improving mobility, or meeting the expressed regional/corridor need for transit improvement; (ii) narrow the list of alternatives to a workable number of six to eight, which will be the subject of further study; and (iii) select the preferred alternative after stakeholder review of the relevant technical, environmental, and financial information for each alternative. MIS can proceed under either Option I (MIS report leading to identification of preferred mobility plan, then project scoping/DEIS/FEIS), or Option II (scoping/DEIS leading to identification of preferred mobility plan, then FEIS). *For more information on MIS in this study, see also Section 1.4.3 Risk Communication and Section 2.3.2 Probabilistic Analysis as a Policy Tool.*

[2] Ali Touran, Ph.D., P.E., is an Associate Professor in the Department of Civil & Environmental Engineering at Northeastern University in Boston, Massachusetts.

EXHIBIT 4-1
Transit Project Implementation Flow Chart for Baltimore MTA Phase II Central Light Rail Project



Source: Transit Turnkey Implementation, presented by William T. Thomson, P.E., FTA/APTA Workshop on Turnkey Development (Miami, FL), June 1993

4.1 PROJECT BACKGROUND

This section provides relevant background information, gives an overview of the actual construction work, and describes contractor selection for the project. The current status of the project is also provided.

4.1.1 Background and Construction

The Mass Transit Administration (MTA) of the Maryland Department of Transportation in 1964 initiated studies of mass transit options for the Baltimore region. This effort resulted in a plan for a regional fixed guideway system, including heavy and light rail lines.[3]

[3] Final Environmental Impact Study (three extensions), October 1993.

The original concept of the Central Light Rail Line Phase II (CLRL) project included 27 miles of light rail transit serving north and south corridors. Phase I of the CLRL is a 22-mile line connecting Dorsey Road in the south in Anne Arundel County, through Baltimore City, to Timonium in the north in Baltimore County. Construction was staged to allow for revenue operations on part of the line in April 1992, and all 22 miles were completed on Phase I in June 1993. The first phase was constructed using state and local funds exclusively.

Phase II will complete the system by extending the line in the north to the Hunt Valley business district, and to the southwest with a spur to Baltimore-Washington International Airport (BWI Extension). Additionally, a third extension will connect the CLRL to Amtrak's Pennsylvania Station for connection to the MARC Penn line and Amtrak trains. Exhibits 4-2, 4-3, and 4-4 depict the alignments for each of the three Phase II extensions. The construction work for the proposed extensions is described as follows:

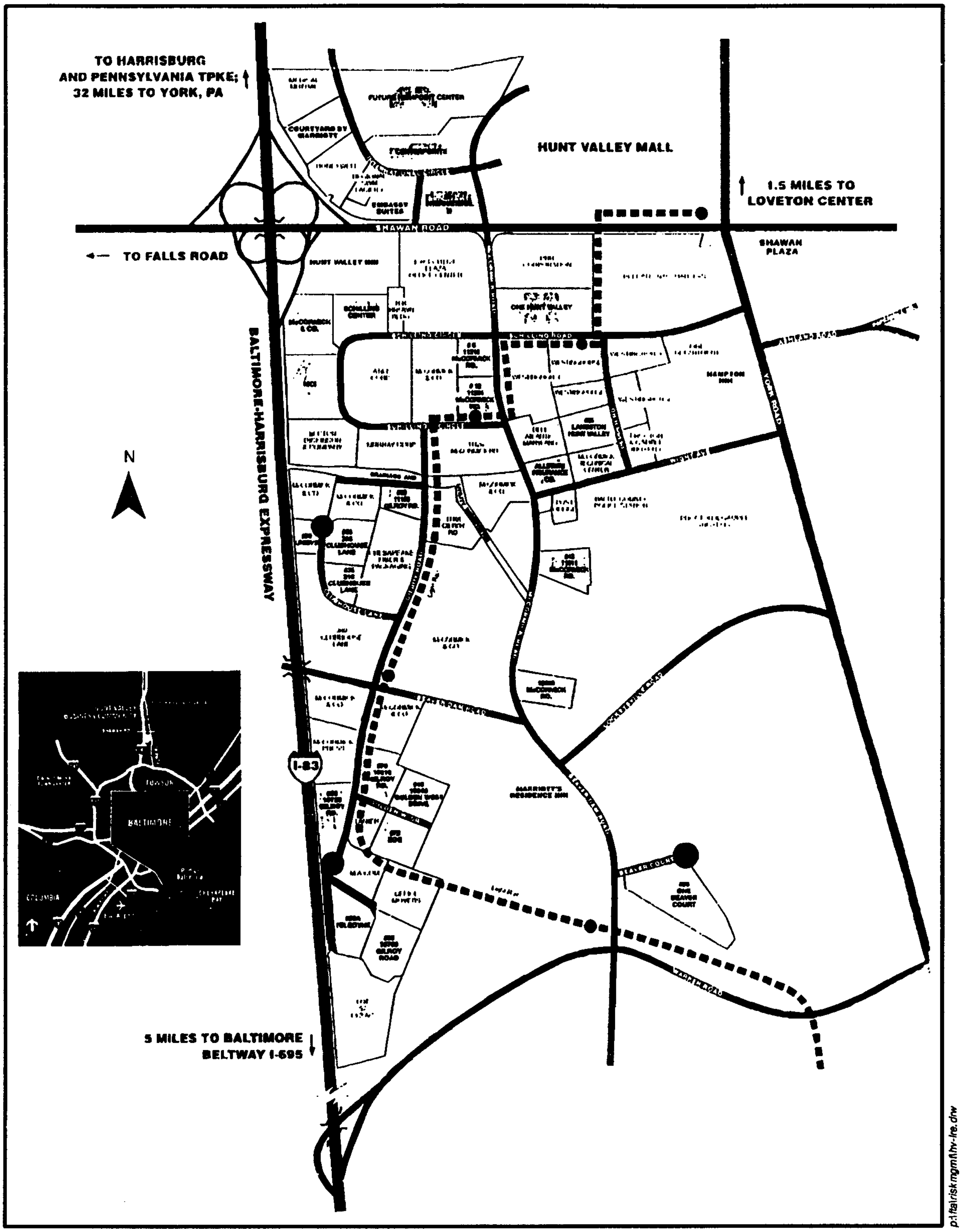
Hunt Valley Extension. A 4.5 mile extension is under construction from the current terminus in Timonium to the Hunt Valley Industrial Park in Baltimore County. There are five station stops planned: Warren Road, Gilroy Road (north of Beaver Dam Road), Schilling Circle (east of Gilroy), Pepper Road (southwest corner of Schilling at Pepper), and at the Hunt Valley Mall. An existing Conrail alignment was purchased for the CLRL. This right-of-way continues north from Timonium for almost three miles. Under agreement with the MTA, freight trains will continue to operate along the entire Conrail alignment, including the section from Timonium to Hunt Valley, during hours when the light rail train (LRT) is not in operation (from midnight to 5 a.m.). Baltimore County is performing civil and trackwork, including utility relocation and right-of-way acquisition, for a short segment (2,447 ft) of the line, from Timonium to Warren Road. The design-build contractor will do the systems work in this segment. The MTA plans no improvements to the railroad right-of-way north of Warren Road. At Warren Road, the new LRT alignment leaves the Conrail right-of-way and turns west.

BWI Extension. A 2.7 mile spur is being built from the existing Linthicum Station in Anne Arundel County to the BWI airport. This extension includes two station stops, one at MD Route 170 and Elkridge Landing Road, and a direct connection at the airport terminal. The Maryland Aviation Administration (MAA) is performing the civil facilities work, including trackwork, from the airport station to the transfer station, including utility relocations and right-of-way acquisition; the design-build contractor will do the systems work in this (MAA) segment. The line will pass through the runway protection zone (RPZ) of the BWI's northeast runway. The RPZ is that area where no permanent structures or stopped vehicles are permitted; however, light rail vehicles are permitted to cross through the RPZ.

Penn Station Extension. This extension consists of a .34 mile (1,795 feet) extension from the existing Mt. Royal station stop to Amtrak's Penn Station. A south leg of a new "Y-shaped" track will be built on an aerial structure spanning the Jones Falls Expressway (Interstate 83) to the new light rail station stop, which will connect the Penn Station lobby by stairs and elevator. Penn Station is currently served by 38 Amtrak long distance trains per day, 30 Amtrak Metroliner trains per weekday, and 30 Maryland Rail Commuter (MARC) trains per weekday. Amtrak/MARC is doing the trackwork and catenary relocations necessary at Penn Station. The Penn Station CLRL alignment traverses the 100-year flood plain of the Jones Falls, on aerial structure on column supports. Columns are being located to minimize adverse impact to the floodplain.

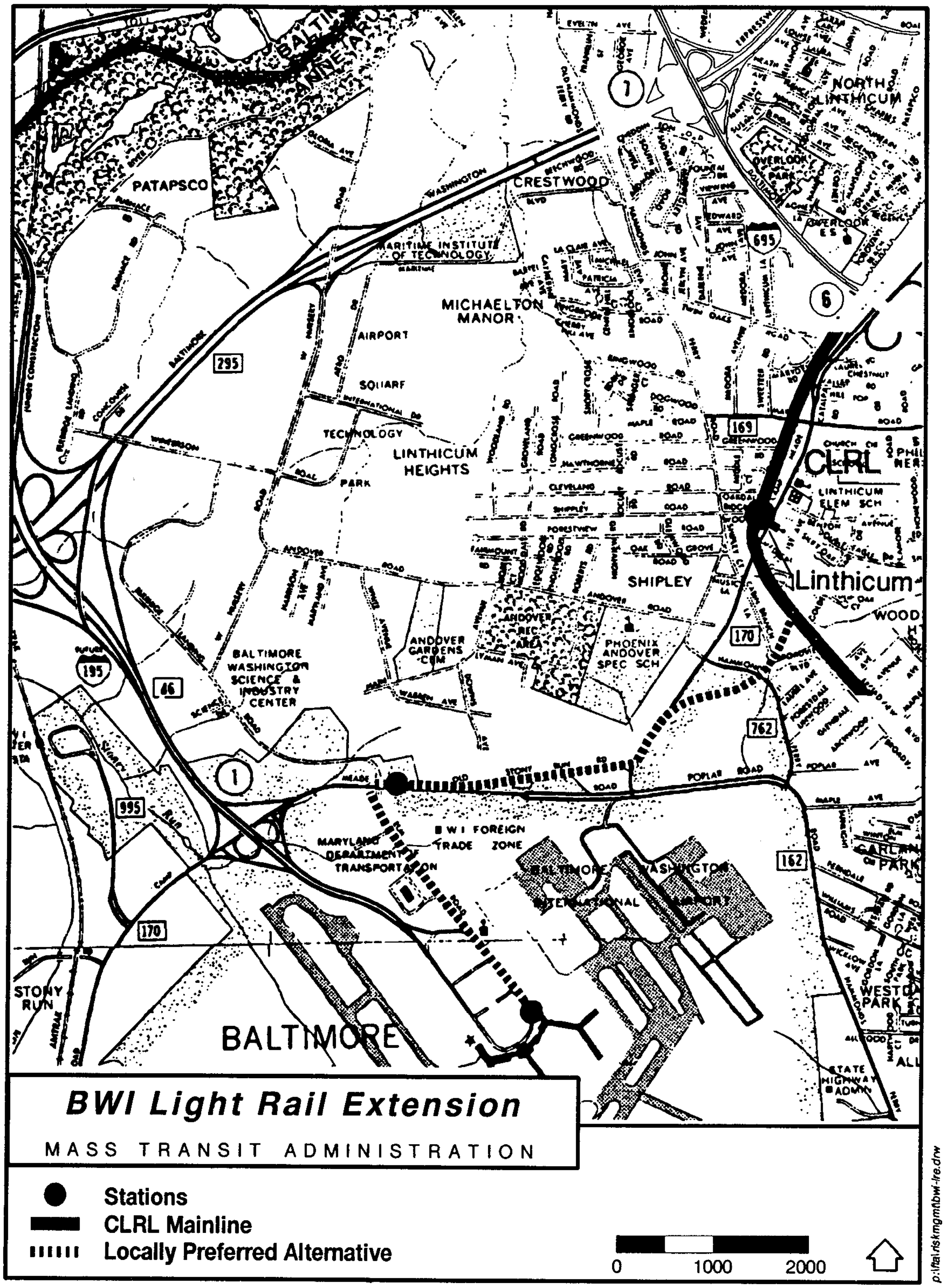
Light rail vehicles to be acquired for Phase II are 95 feet long, 9 feet 6 inches wide, and are composed of two body halves connected by a swiveling articulation joint. Operator cabs at each end of the vehicle allow bi-directional operation. Each car accommodates 85 seated passengers with a standee capacity of 35, for a total capacity of 120 passengers. Exhibit 4-5 depicts an MTA light rail vehicle.

EXHIBIT 4-2
Hunt Valley Light Rail Extension



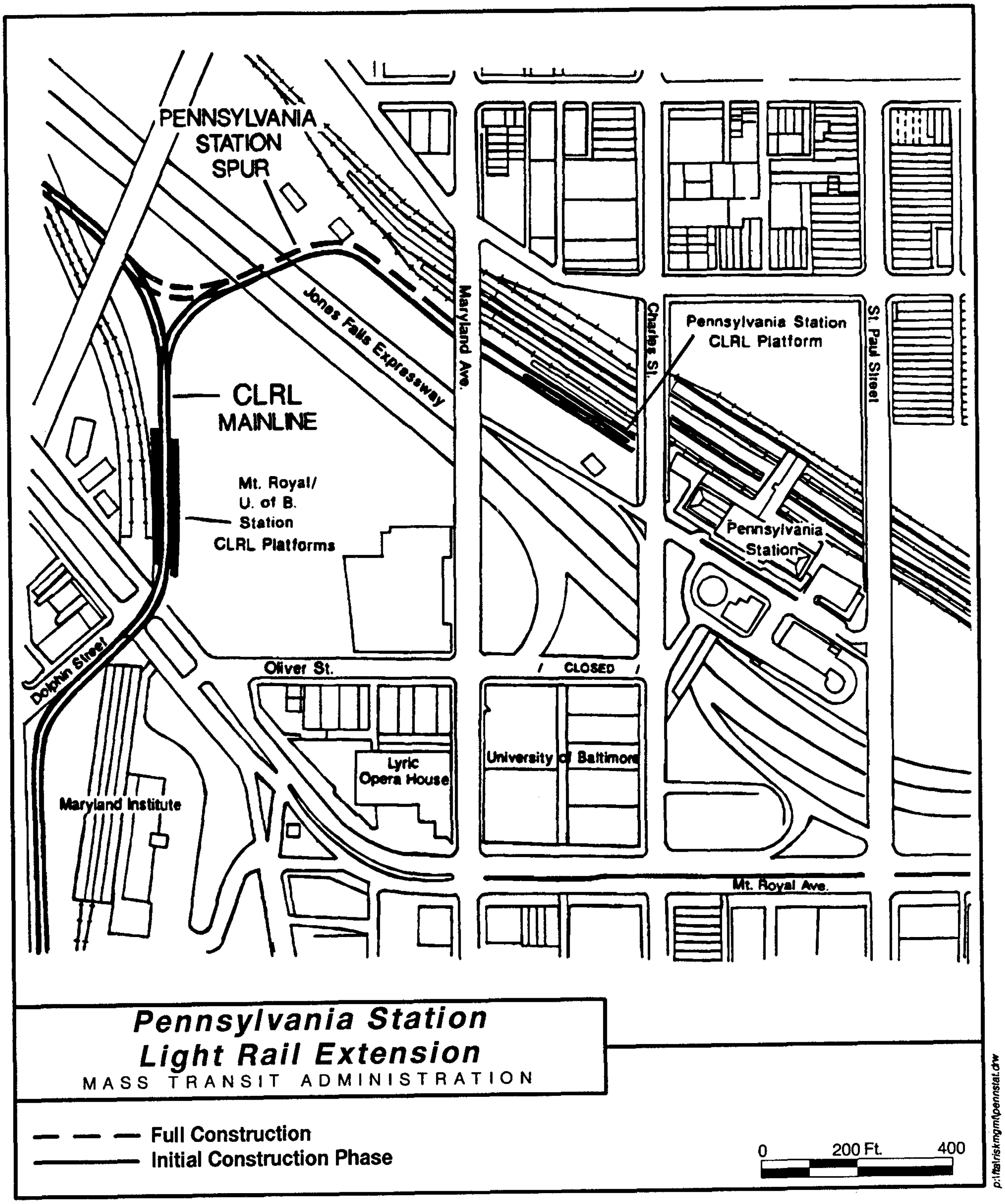
Source: MTA

EXHIBIT 4-3
BWI Light Rail Extension



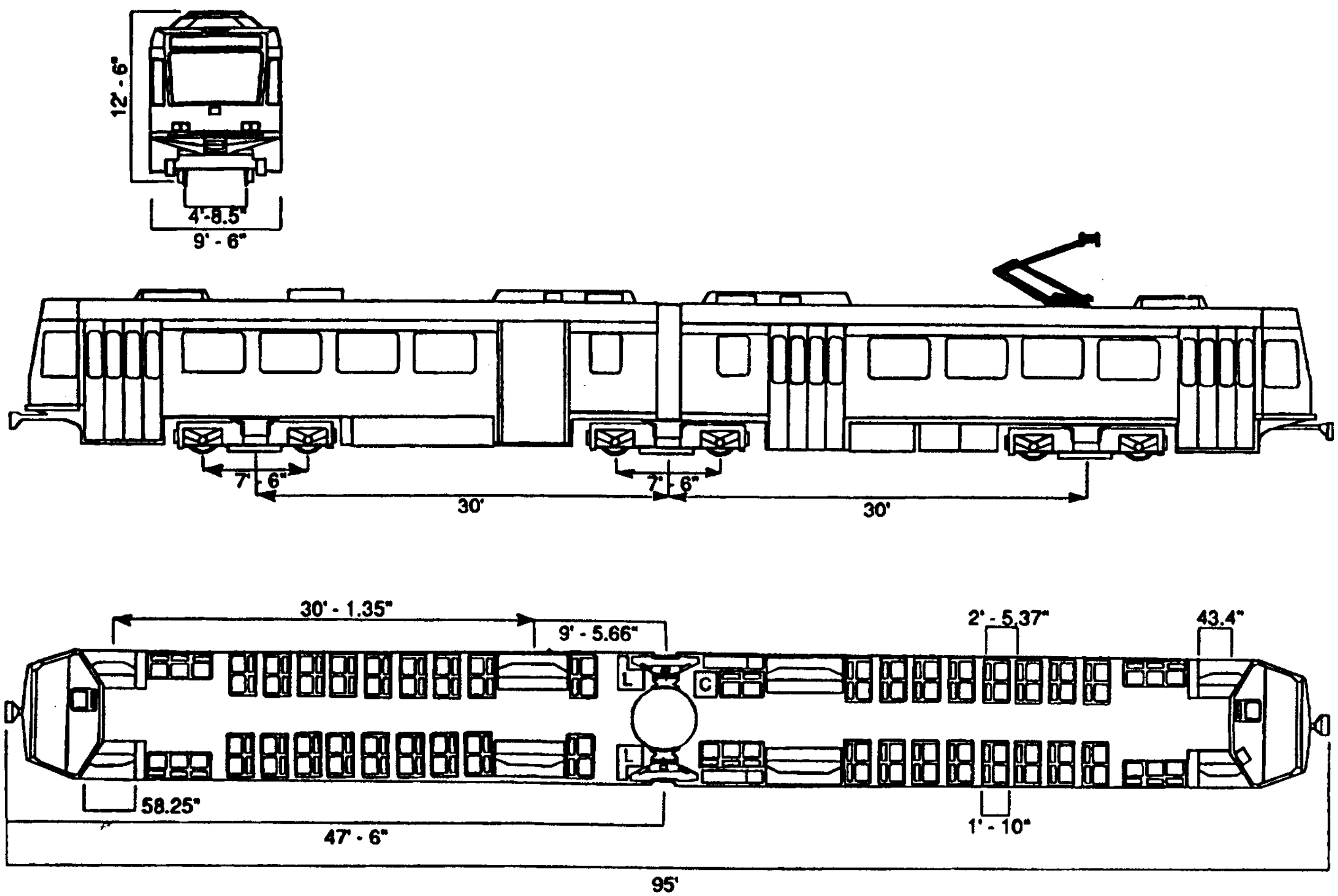
Source: <u>FEIS</u>, October 1993

EXHIBIT 4-4
Penn Station Light Rail Extension



Source: FEIS, October 1993

EXHIBIT 4-5
Baltimore Light Rail Vehicle



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Source: FEIS, October 1993

4.1.2 Contractor Selection

Contractor selection for Phase II was conducted using a two-step sealed bidding process. Prior to the commencement of this process, the decision was made early in 1994 to perform Phase II under a design-build award. This decision was largely guided by the availability of recent Phase I cost and design specifications data. The Invitation for Bid was developed in Spring 1994. Several MTA design consultants[4] prepared preliminary design provisions and directive drawings to fulfill a variable level of completion[5] for each of the major design disciplines (civil, structural, signal, power systems, and track). A Notice to Contractors was published in The Baltimore Sun, Engineering News Record, and Passenger Transport. The two-step process is as follows:

> *Step 1:* Proposals were evaluated by an MTA Proposal Evaluation Committee. Ratings were mainly based on experience, design and construction resources, key personnel, quality of the technical proposal, and management systems.
>
> *Step 2:* Bidders who were judged in Step 1 to be qualified then received an Invitation for Sealed Price Bids. The design-build contract was awarded to the lowest responsive bidder (the lowest price bidder).

Whiting-Turner was awarded the design-build contract in September 1994, and Notice to Proceed was granted in January 1995, when Phase II construction commenced. MTA's qualification package for the design-build awardee included the contractor Dunn & Bradstreet rating[6] as well as current projects and assets, pending judgments and lawsuits, and industry references. The value of the fixed price contract is $55,750,000, which is insured with a surety performance bond[7] for the full contract amount. As design-build contractor, Whiting-Turner is responsible for the following work:[8]

- Completion of design from the level of Extended Definition to 100%;
- Staging and coordination necessary to maintain existing light rail line, rail freight, and highway traffic;

[4] Chief design consultants for the MTA were Parsons Brinckerhoff/Morrison Knudsen (civil) and Parsons-DeLeuw (systems).

[5] This process was known as "Extended Definition" of the preliminary design.

[6] Dun & Bradstreet, an international solvency indexing service.

[7] Underwriter is United States Fidelity and Guaranty Company, which is headquartered in Baltimore, Maryland.

[8] MTA Central Light Rail Phase II Project Management Plan, June 1995, p. 7-1.

- Grading, paving, and drainage;

- Construction of structures and station stops including signage and graphics;

- Design and construction of modifications and relocations of municipal utilities;

- Procurement and installation of all track material including subgrade, sub-ballast and ballast;

- Procurement and installation of systems components for signals, catenary, and power;

- Installation of fare collection equipment; and

- Testing and start-up.

Major work outside the design-build contract is:

- Vehicles;
- Landscaping design and construction;
- Procurement of fare collection equipment;
- Communications;
- Real estate acquisition;
- Permits; and
- Utilities relocation for electric, gas, and telephone.

Exhibit 4-6 shows project risk allocation for MTA and Whiting-Turner.[9] The design-build contract also has a liquidated damages clause: for each day of total schedule overrun (delay) beyond NTP + 760 days, the following amounts will be assessed Whiting-Turner, per Phase II segment:

- Hunt Valley Extension, $3,350 per calendar day
- BWI Extension, $3,350 per calendar day
- Penn Station Extension, $2,900 per calendar day.

Maximum aggregate liquidated damages assessed for any one calendar day is limited to $9,000.

[9] Ibid., page 4-5.

EXHIBIT 4-6
Project Risk Allocation for Phase II

Risk Area	MTA	Whiting-Turner
Political	Full responsibility.	None.
Funding	Full responsibility.	None.
Right-of-way	Primary responsibility. The MTA will acquire all right-of-way as identified in the Extended Definition phase.	Partial. The Design-Build Contractor shall acquire any additional parcels required by his detailed design at no additional cost to the MTA.
Geotechnical	Available geotechnical information will be provided to the Design-Build Contractor.	Full responsibility.
Hazardous Materials	Full responsibility.	Design-Build Contractor shall, if encountered, remove and dispose of hazardous materials.
Utilities	MTA will be responsible for identifying utilities. MTA will be responsible for having private utilities relocated.	Design-Build Contractor shall be responsible for confirming contract document information for relocation of all City and County utilities and any and all utilities found following commencement of construction.
Inflation	MTA assumes full responsibility prior to bid opening.	Design-Build Contractor shall assume all responsibility after bid opening.
Federal and Local Requirements	MTA assumes responsibility for any changes to Federal and local requirements that occur after bid.	Design-Build Contractor shall be required to meet Federal and local requirements in place at time of bid, including Buy America, DBE, Davis-Bacon Wage Rates, and ADA.
Design and Integration	None. MTA will provide design monitoring and oversight to assure conformance with contract requirements.	Notwithstanding MTA design review, Design-Build Contractor shall be fully responsible for designs and design liability satisfying contract requirements.
Construction	None. MTA will provide construction monitoring and oversight to assure conformance with contract requirements.	Full responsibility.
Subsystem Testing	None. MTA will approve test plan and witness test to assure conformance with contract requirements.	Full responsibility.
Systems Integration and Testing	Prime. MTA will develop and carry out the test plan using MTA staff.	Participatory. Design-Build Contractor shall be required to support tests and to correct all identified deficiencies.
Schedule	Monitoring. MTA will be required to provide right-of-way, design comments, etc., on a timely basis.	Prime responsibility.
Quality Assurance/ Quality Control	Participatory. Actions necessary to ensure that quality requirements will be satisfied. MTA will perform spot checks and QA/QC audits.	Prime responsibility. Actions necessary to ensure that completed project meets requirements of the design criteria and final Design-Build design documents.
Construction Safety	None.	Full responsibility.
Site Security	None.	Full responsibility.
Insurance	None.	Full responsibility.

4.1.3 Current Project Status

MTA estimates that Phase II is currently about 30% complete. Design is almost totally complete, except for signal design which is less than 50% done but on-target. There have been no change orders, although one is expected for tactile edges[10], and the estimate here is for $75,000. There have been no disputes, and MTA estimates that the project will be ready for revenue service in May 1997. No delays are expected. In Hunt Valley, complete demonstration of the existing freight track has been completed, along with the resetting of steel on the Beaver Run Bridge. Caissons are complete at Penn Station, and pier and wall footings are coming out of the ground. Work on both sides of Interstate 83 is being accelerated in order to allow for any upcoming weather. The January 1996 blizzard delayed all work by about three to five days, but no long-term impact is expected at this time. At BWI, the deep cut in the runway protection zone is about 60% complete.[11]

4.2 DATA

The data used in the case study is organized for cost and schedule. The following sections describe the study data.

4.2.1 Cost Data

A variety of sources yielded cost data for the project. These sources include FTA reports, MTA cost studies, meetings with MTA personnel, and consultations with an independent cost estimator.

Cost information used in this study was mainly provided by the Project Management Oversight Consultant (PMOC) Budget Review report prepared by Sverdrup Civil, Inc. in May 1994. The Budget Review report contained MTA engineer's estimates, which were based upon actual costs incurred during the construction of the Central Light Rail Line Phase I Project. This report included comments by the Sverdrup's Project Management Oversight team regarding budget and schedule. The report was prepared when the project design was 30% complete (at the completion of the Preliminary Engineering phase), and represents the final cost estimate prior to the MTA advertising for contractor bidding. The MTA Phase II financial summary is included in Appendix B. Additional cost information was derived from two Final Environmental Impact Statement reports and a U.S. Army Corps of Engineers report produced by the FTA in October 1993.

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[10] *Tactile edges* are detectable warning surfaces consisting of small truncated domes at closely-spaced intervals. The Americans with Disabilities Act (ADA) calls for the use of distinctively-textured paving patterns as signaling and wayfinding devices, for the foot or cane of pedestrians who have vision impairments.

[11] Project status is taken from John Coard's comments, *Phase II Monthly Progress Report* for November 1995.

Two meetings were held with the MTA Phase II personnel. The first meeting, on December 18, 1995, yielded general project information, cost and schedule data, MTA's approach and philosophy for preparing contract documents and for selecting the turnkey approach, and a tour of each extension. The second meeting, on January 11, 1996, was used as a follow-up question and answer session for clarification of interim data.

Because the functional specifications of MTA Phase II are similar to those in Phase I of the Central Light Rail Line project, estimated work quantities, actual unit costs, and preliminary drawings from Phase I were used by MTA to estimate costs for Phase II. The engineer's Phase II estimates[12] included markups for various allocated contingencies and escalation factors, resulting in total cost estimates for the design-build contract and the total project. These contingency and escalation factors were removed from the cost line items prior to running the simulation models. Cumulative distribution functions resulting from simulation analysis were used to assess the adequacy of contingency levels assigned to the project.

A total budget of $106,338,179 was established for the project by the owner. Some items in the project budget were already contracted and therefore assumed to be constant. These items included four conceptual design contracts and vehicle costs which added up to $20 million (19% of the total project budget). The Phase II budget which was used for this probabilistic analysis is shown in Exhibit 4-7.

EXHIBIT 4-7
MTA Phase II Budget

	MTA	***Basis for Probabilistic Risk Analysis**	****Implied Contingency**
Design-Build Cost	$61.6 M	$44.2 M	39.4%
Total Cost	$106.3 M	$82.4 M	29.0%

* Without contingencies
** Includes allocated and unallocated contingencies

4.2.1.1 Development of the Cost Data

To prepare the MTA source data for the probabilistic analysis, the engineer's estimate from the PMOC Budget Review report was first analyzed and placed in a format compatible

[12] The *engineer's estimate* in this report, is the estimate prepared by MTA at the end of the Preliminary Engineering estimate, i.e., approximately April 1994.

with the @RISK tool[13]. An experienced construction cost estimator[14] assisted the technical oversight by reviewing the cost estimate of the PMOC Budget Review data. Cost contingencies and inflation escalators were removed from the MTA budget. Exhibit 4-8 (following Section 4.2.1.1.2) shows the Phase II budget, net of contingencies, prior to probabilistic analysis.

4.2.1.1.1 Organization of the Cost Data

The Phase II cost data was organized into four main data segments, prior to probabilistic analysis. Major areas of risk are noted below:

- *Penn Station Extension*
  Major risk items are bridge construction (under aerial structures) and piling (under excavation). The traffic maintenance budget is low, and there is no cost included for flagmen, a requirement for trackwork.

- *BWI Extension*
  Major risk is the crowded jobsite. Also, the Maryland Aviation Administration (MAA) has responsibility for part of the construction. This interface can potentially impact the project schedule and costs.

- *Hunt Valley Extension*
  Notable potential risk of subsidence, due to Genstar mining operations. MTA discounted this risk based upon current soil conditions and the depth of galleries and tunnels located in bedrock.

- *Utilities/agency, fare collection equipment, and landscaping.*

4.2.1.1.2 Estimation Observations Regarding the Cost Data

The following observations and comments pertain to the cost data obtained for the MTA risk analysis:

(1) The design budget for landscaping seems low.

(2) The unit cost of earthwork seems high, but it may include the cost of (potential) hazardous waste.

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[13] *@RISK* is the software which was used for the MTA Phase II probabilistic risk analysis. Because @RISK is a spreadsheet add-in, the analysis required that the Phase II data first be developed into discrete cost elements for preliminary design, systems engineering, construction, vehicles, landscaping, ticket vending machine equipment, and MTA administrative costs. Allocated contingency factors and economic cost escalators were removed from the Phase II cost data prior to the probabilistic analysis.

[14] Mr. William Barry of Boston, MA.

(3) The unit cost of concrete work seems low, especially given the scope of the bridge over Interstate 83. This shall be taken into consideration on the risk analysis.

(4) The traffic maintenance budget is low, but is a small item.

(5) The trackwork cost seems reasonable.

(6) The cost of signals seems in line with similar transit projects.

(7) There was some concern with the estimates for "Traction Power and Substations" and "Overhead Contact System." The substation is usually accompanied with switchgear and inverter. This could add up to more than $3 million per substation. The budget allocated for each substation is $535,000. The length of feeder cable and the length of ductbank is also low. The rationale for these low costs is that the more expensive ductbank will only be used at intersections and direct burial will be used in all other areas. The system design does not call for feeder lines along the full length of the track. These substation costs were compared to a similar project, the Regional Transit Metro of Sacramento (Light Rail Transit Capital Cost Study, 1991), and were similar to the costs in this estimate. Furthermore, systems cost were discussed with MTA Phase II staff, and Abacus Technology was assured that these estimates are accurate.

(8) The engineer's estimate does not contain a budget for Final Design, which is part of design-build. The cost for Final Design was estimated at 3% to 5% of the contract budget, for a project with these characteristics.

(9) The original project budget, as reported in the PMOC Budget Review report, did not include a "Communications" cost and a cost for "Warren Road Crossing." Both of these line-items are included in the final MTA financial summary for the project.

(10) The MTA Administration budget is low compared to other projects. Although most of the inspection and management will be assigned to the contractor, the budget is low as a perçentage of the total budget (1.99%). The Light Rail Transit Capital Cost Study (1991) cites costs of five projects in the U.S with Project Management and Project Management Oversight costs as a percentage of total costs, varying from 2.3% to over 5%.

EXHIBIT 4-8
Central Light Rail Line - Phase II
Basis for Probabilistic Analysis

	Hunt Valley	BWI	Penn Station
Excavation and Backfill	$1,698,378	$594,850	$376,118
Trackwork	7,877,574	2,451,137	1,011,678
Aerial Structures	300,900	0	2,280,910
Retaining Structures	666,704	297,700	857,006
Utilities	997,556	28,900	0
Stations and Parking	1,119,000	206,000	551,000
Station Work/Traffic/Landscape	330,600	20,000	80,000
Traction Pwr & Subst	3,478,339	2,052,639	99,756
Tract-Other Related Costs	0	0	0
OH Contact System	2,166,914	1,524,574	492,011
OCS-Other Related Costs	818,988	439,192	22,560
Signals	5,666,641	4,254,139	841,465
Signals-Other Related Cost	357,240	138,847	62,400
Total	$25,478,834	$12,007,978	$6,674,904
Total Design-Build Contract		$44,161,716	
Project Administration			
MTA Administration	$1,735,700		
Systems Start Up	1,160,000		
Design Engineering			
PB/MK (EIS/PE)**(MTA-0221)**	3,259,896		
PDI (EIS/PE)**(MTA-0225)**	91,773		
PB/MK (Ext. Dfn.)**(MTA-0221)**	1,600,000		
PDI (Ext. Dfn.)**(MTA-0225)**	800,000		
WBCM (Ext. Dfn.)	100,000		
STV/Lyon (Ext. Dfn.)	75,000		
Landscape Design	37,573		
Open End Consultant	2,777,000		
Communications	484,000		
Landscaping	481,612		
Fare Collection Equipment	912,000		
Agencies and Utilities	4,382,000		
Vehicles **(MTA-0244)**	14,311,513		
Warren Rd. Crossing	65,227		
Real Estate			
Appraisal/Acquisition	6,000,700		
Sum	$38,273,994		
Total Phase II Project		$82,435,710	

4.2.1.2 Escalation Factors

The engineer's estimate applied three years of escalation factors to Phase II cost, bringing the data to the midpoint of the contract for Phase II. The Engineering News Record (ENR) Building Cost Index (BCI) for Baltimore shows that, on average, there is a 3.5% rate of increase for labor and material costs. The Building Cost Index was used to escalate the total construction budget. Exhibit 4-9 shows values of Building Cost Index for Baltimore in recent years.

EXHIBIT 4-9
Baltimore Building Cost Indexes

Date	BCI and % Annual Change
December 1989	2432.35
December 1990	2579.90 (+6.1%)
December 1991	2508.06 (-2.8%)
December 1992	2607.76 (+4.0%)
December 1993	2787.51 (+6.9%)

Source: "Using ENR's Indexes," Engineering News Record, March 28, 1994, p. 50.

From 1989 to 1993, there has been a +14.6% growth in construction costs in Baltimore. This translates to +3.5% compounded annually. A uniformly distributed random variable was used to model annual cost escalation for this project. The uniform distribution chosen has a range of 3.5% to 5.5%. Exhibit 4-10 displays a uniform distribution.

EXHIBIT 4-10
Uniform Probability Distribution

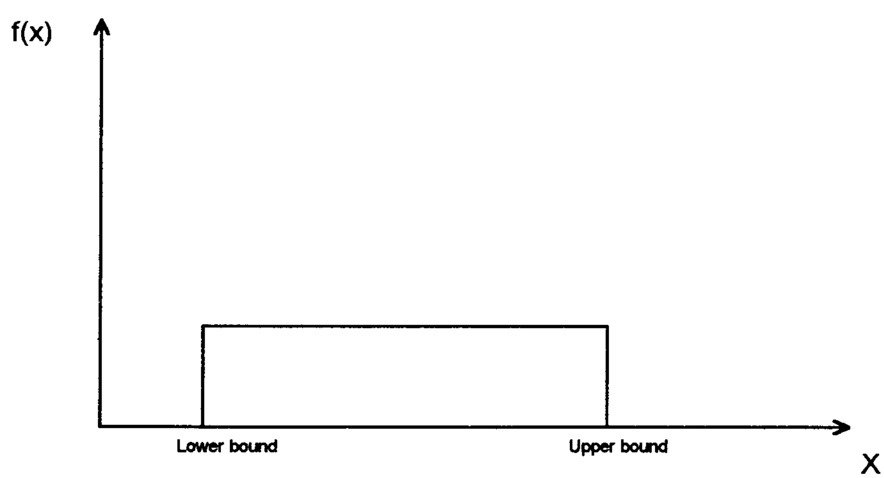


Exhibit 4-11 shows escalation factors for three years, for each cost category used by the MTA to reflect unit costs for October 1995.

EXHIBIT 4-11
MTA Escalation Factors

Cost Category	Escalation Factor
Civil-Trackwork	12.0%
Systems	15.1%
Fare Collection Equipment	12.4%
Landscaping	12.0%

4.2.1.3 Contingency Factors

Exhibit 4-12 lists the contingency factors used by the Engineer for each cost item.

EXHIBIT 4-12
MTA Contingency Factors

Cost Item	Contingency Factor
Civil-Trackwork	21.9%
Systems	15%
MTA Administration	21.9%
System Startup	12%
Landscape Design	25%
Open End Consultant	15%
Landscaping	21.9%
Fare Collection Equipment	5%
Agencies and Utilities	21.9%
Real Estate	21.9%

The choice of contingency factors reported above follows a logical consideration of project uncertainties. A large contingency is applied to the MTA Administration because the allocated budget is low for this project. Startup costs are relatively easy to estimate, resulting in a smaller contingency. Landscape design has a large contingency because it is most likely underestimated at $37,573. The open-end consultant has a lower contingency compared to other soft costs, and the reason for this was not clear. The cost of fare collection equipment is based upon previous purchases resulting in a low contingency. Utility relocation is subject to large cost variations due to latent conditions. Real estate acquisitions tend to run over budget, generally because current owners try to obtain a premium value for their property, under the stressed circumstances.

4.2.2 Schedule Data

Data regarding project schedule at the time of bidding was very limited. MTA did not prepare a detailed schedule at the bidding time, partly because they expected that the contractor would provide a detailed schedule and then abide by it. The only documents found regarding owner's schedule were incorporated in the PMOC Budget Review by Sverdrup Civil, Inc. (1994). Pages A41, A42, and A43 of the PMOC document provided a preliminary version of the summary schedule, a reviewer's comment on the credibility of the schedule, and a revised master schedule. These pages are included in Appendix C, Schedule Data Documents.

4.3 TECHNICAL APPROACH

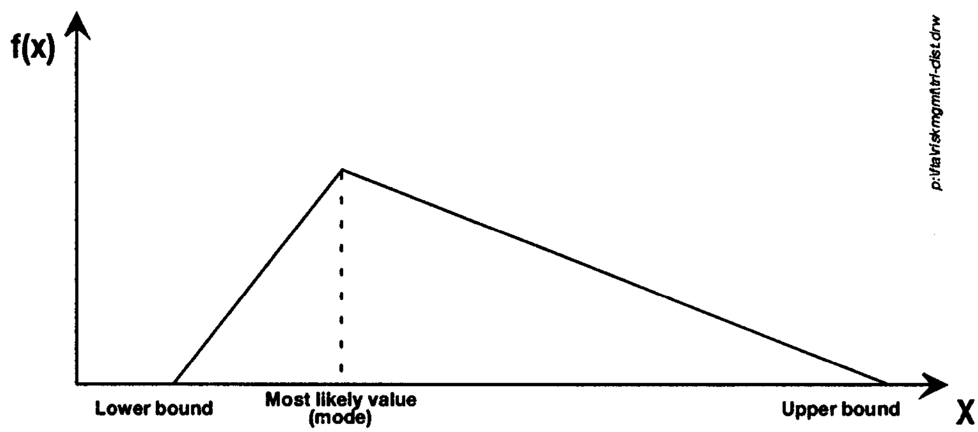
The technical approach used in the case study is organized for cost and schedule. The following sections describe the MTA case study technical approach.

4.3.1 Cost Analysis Technical Approach

Much research has been done on the nature of construction cost data and their historical distributions. Construction cost data are usually distributed unsymmetrically, have confined ends, take only positive values, and have one mode (i.e., most likely value). Several distributions -- such as lognormal, triangular, and beta -- can be reasonable candidates for construction data. A recent study found that the cost items (such as concrete, electrical, mechanical, etc.) in low-rise office buildings (two to four stories) are lognormally distributed (Wiser, 1991). Other researchers have used the triangular distribution for modeling cost (e.g., see Mlakar and Bryant, 1990).

For the technical approach in the MTA case study, major cost activities were identified for the design/build contract and for the total project. A distribution type was selected to model the construction costs, and corresponding ranges of values were suggested for each cost item. A triangular distribution, shown in Exhibit 4-13, was selected for modeling the project costs. Triangular distributions are simple distributions commonly used in similar projects and are easily understood. Triangular distributions use the most likely, minimum, and maximum values of a variable. In many cases, the triangular distribution works as well as more sophisticated distributions such as the beta distribution (McCrimmon and Ryavec, 1964).

EXHIBIT 4-13
Triangular Probability Distribution



The cost items were placed into three categories: those with a **high** level of uncertainty, those with a **moderate** level of uncertainty, and those with a **low** level of uncertainty. This classification was based on experience with transit projects, historical data published by the FTA, Phase II project characteristics, and MTA's assigned contingencies. For the total project, cost items considered in the risk analysis are mainly the line items listed on the owner's *Financial Summary* (see Appendix B). This section reviews the cost analysis technical approach: definition of the triangular data points, justification for the ranging, and an explanation of the logical sequence for performing the probability cost analysis.

4.3.1.1 Estimating the Triangular Data Points

The engineer's estimates, less the contingency and escalation factors, were assumed to be the most likely value of each cost item. These values were based on actual cost data from Central Light Rail Line Phase I of the transit project. The 10th and 90th percentile points were used because estimating the extreme values (0 and 100th percentile points) of these distributions is very difficult, based upon the available information. Exhibit 4-14 contains the parameters for design-build contract range estimating. Exhibit 4-15 contains the parameters for total project budget range estimating.

> ***High risk items.*** The 10th percentile point of the distribution was assumed to be either 0%, 5%, or 10% lower than the most likely value. The 90th percentile point of the distribution was assumed to be 50% or 100% higher than the most likely value of the distribution.
>
> ***Moderate risk items.*** The 10th percentile point of the distribution was assumed to be 5% lower than the most likely value. The 90th percentile point of the distribution was assumed to be 30% higher than the most likely value of the distribution.
>
> ***Low risk items:*** The 10th percentile point of the distribution was assumed to be 5% lower than the most likely value. The 90th percentile point of the distribution was assumed to be 10% or 20% higher than the most likely value of the distribution.

EXHIBIT 4-14
Cost Summary for the Design-Build Contract
Parameters of the Cost Risk Analysis
("Ranging")

	HUNT VALLEY			BWI			PENN STATION		
	10 Percentile	**Most likely**	**90 Percentile**	**10 Percentile**	**Most likely**	**90 Percentile**	**10 Percentile**	**Most likely**	**90 Percentile**
EXCAVATION AND BACKFILL	1,613,459	1,698,378	2,038,054	565,108	594,850	713,820	357,312	376,118	564,177
TRACKWORK	7,483,695	7,877,574	9,453,089	2,328,580	2,451,137	2,941,364	961,094	1,011,678	1,214,014
AERIAL STRUCTURES	285,855	300,900	391,170		0		2,166,865	2,280,910	3,421,365
RETAINING STRUCTURES	633,369	666,704	866,715	282,815	297,700	387,010	814,156	857,006	1,114,108
UTILITIES	897,800	997,556	1,496,334	26,010	28,900	43,350		0	
STATIONS & PARKING	1,063,050	1,119,000	1,342,800	195,700	206,000	247,200	523,450	551,000	661,200
STATION WORK/TRAFFIC/LANDSC	314,070	330,600	495,900	19,000	20,000	30,000	76,000	80,000	120,000
TRACTION PWR & SUBST.	3,304,422	3,478,339	4,521,841	1,950,007	2,052,639	2,668,431	94,768	99,756	129,683
TRACT.-OTHER RELATED COSTS		0			0			0	
OVERHEAD CONTACT SYSTEM	2,058,568	2,166,914	2,816,988	1,448,345	1,524,574	1,981,946	467,410	492,011	639,614
OCS-OTHER RELATED COSTS	778,039	818,988	1,064,684	417,232	439,192	570,950	21,432	22,560	29,328
SIGNALS	5,383,309	5,666,641	7,366,633	4,041,432	4,254,139	5,530,381	799,392	841,465	1,093,905
SIGNALS-OTHER RELATED COST	339,378	357,240	464,412	131,905	138,847	180,501	59,280	62,400	81,120
SUBTOTALS		25,478,834			12,007,978			6,674,904	

DESIGN FOR D/B CONTRACT   Use a Uniform Distribution with limits 1.03 and 1.05 to estimate the DESIGN COSTS.

ESCALATION FOR 3 YEARS   Use a Uniform Distribution with limits 1.035 to 1.055 to estimate annual ESCALATION COSTS.

EXHIBIT 4-15
Cost Summary for Phase II
Parameters of the Cost Risk Analysis
("Ranging")

PROJECT TASKS	10 Percentile	Most Likely	90 Percentile	Range
Project Administration				
MTA Administration	1,562,130	1,735,700	2,603,550	-10% +50%
Systems Start Up	1,102,000	1,160,000	1,392,000	-5% +20%
Design Engineering				
PB/MK (EIS/PE)**(MTA-0221)**	constant	3,259,896		
PDI (EIS/PE)**(MTA-0225)**	constant	91,773		
PB/MK (Ext. Dfn.)**(MTA-0221)**	constant	1,600,000		
PDI (Ext. Dfn.)**(MTA-0225)**	constant	800,000		
WBCM (Ext. Dfn.)	100,000	100,000	200,000	0% +100%
STV/Lyon (Ext. Dfn.)	75,000	75,000	150,000	0% +100%
Landscape Design	37,573	37,573	75,146	0% +100%
Open End Consultant	2,777,000	2,777,000	4,165,500	0% +50%
Communications	459,800	484,000	580,800	-5% +20%
Landscaping	481,612	481,612	722,418	0% +50%
Fare Collection Equipment	866,400	912,000	1,003,200	-5% +10%
Agencies and Utilities	3,943,800	4,382,000	6,573,000	-10% +50%
Vehicles **(MTA-0244)**	constant	14,311,513		
Real Estate				
Appraisal/Acquisition	5,700,665	6,000,700	9,001,050	-5% +50%
Warren Rd. Crossing	constant	65,227		
SUM		38,273,994		

Apply ESCALATION factor (Uniformly Distributed between 1.035 and 1.055 per year) for Landscaping and Fare Collection Equipment.

4.3.1.2 Justification for Probabilistic Ranging

This section explains the assumptions used to develop the ranges for each cost item input into the triangular distribution functions. These ranges were based on the estimated potential for variations in cost.

4.3.1.2.1 Cost Items Outside the Design-Build Contract

Exhibit 4-15 lists the Phase II cost items outside of the design-build contract. Several data items were finalized and are constant values. These items include four design contracts and vehicle prices. A constant value was also assigned to "Warren Road Crossing" because this was a small cost item with little impact on the outcome.

- *Project Administration*. Project administration has a low budget due to the assignment of project management and quality assurance responsibilities to the contractor. This low budget is very risky because any project delays will cause the cost to increase. System startup is less prone to variation and is a low risk item.

- *Design Contracts*. Both extended definition design contracts were assigned a large range of values because these items have frequently changed from their original estimates. The landscape design contract has a low budget, making it a high risk item. Open end consultant (design) is a risky item, due to the cost reimbursable type of contract involved. The lower limit and the most likely value were set as equal, because it is unlikely that there would be a cost underrun on this item.

- *Landscaping*. No information is available on this, but Abacus Technology believes that if the landscaping design budget is modified, then most likely the landscape construction cost will be affected.

- *Fare Collection Equipment*. Fare collection equipment is a low risk item because the same type of equipment is being used that was previously purchased.

- *Communications*. Communications is modeled low risk.

- *Utilities and Right-of-Way Acquisitions*. These items are generally the most risky items in the budget. Utility relocation has always been prone to cost escalation, due to unknown conditions existing at the site. For this project, however, there are no major concerns, especially for the Hunt Valley and BWI Extensions. Most of the track goes through rural areas, with a limited possibility of unknown conditions. Because of this, the range chosen for utility relocations is considered realistic. Right-of-way acquisition is another area where estimating costs accurately is difficult. The PMOC Budget Review team raised this concern, and MTA responded that no large cost deviations in right-of-way were expected[15]. Appraisal and Acquisition costs were combined and considered to be a high risk item.

[15] In the Sacramento LRT system completed in 1987, there was a 37% cost overrun in R.O.W., compared to the preliminary engineering estimate (Schumann, 1989).

4.3.1.2.2 Cost Items Within the Design-Build Contract

Exhibit 4-16 contains the specific range variations of the cost items which comprise the design-build contract. The engineer's estimate consists of relatively large contingencies and escalation factors. Furthermore, an additional $5.8 million contingency was later added to the design-build budget, resulting in a larger budget with lower risk of overrun.

- *Excavation and Backfill.* This is a low risk item for the Hunt Valley and BWI Extensions because the engineer's estimate were high and most of the work is done in open land. However, the Penn Station Extension is a high risk item due to the possibility of piling, structural excavation, and encountering hazardous material.

- *Trackwork.* This is a low risk item because typically there are no large cost variations, but there is some risk due to coordination with other agencies.

- *Aerial Structures.* Aerial structures includes the most complicated structure in the project, which is the transit bridge over Interstate 83. All costs were estimated using actual unit costs achieved in Phase I to estimate costs for Phase II. While this approach works well for items such as trackwork, it may not reflect all aspects of bridge construction. Because of this, there is more uncertainty regarding the estimate, and this item was therefore considered high risk.

- *Retaining Structures.* Retaining structures were considered to be of moderate risk because some of the structures included concrete work and there is always uncertainty associated with estimating labor productivity for formwork and rebar setting.

- *Stations and Parking.* These straight-forward cost items are low risk items.

- *Station Work, Traffic.* This item was considered high risk because it includes traffic maintenance, which has a low cost estimate.

- *Systems (Traction Power, Overhead Catenary System, Signals).* Systems is a moderate risk[16] item because the cost of power stations is uncertain.

- *Systems Related Costs.* System related costs, which include excavation and concrete work to install the systems, are moderate risk items because of the uncertainty associated with labor productivity for formwork and rebar setting.

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[16] In Sacramento LRT system, the traction power installation cost was underestimated significantly ($3.96M *vs* $840,000) (Schumann, 1989).

- *Final Design*. Another major area of concern is the Final Design effort for the design-build contract. This cost item is not included as a separate line-item in the MTA engineer's estimate, and so a uniform distribution of 3% to 5% total Phase II cost has been modeled for final design, in order to perform the probabilistic analysis.

EXHIBIT 4-16
Range Variations for Phase II Design-Build

	HUNT VALLEY	Range	BWI	Range	PENN STN	Range
EXCAVATION AND BACKFILL	1,698,378	-5% +20%	594,850	-5% +20%	376,118	-5% +50%
TRACKWORK	7,877,574	-5% +20%	2,451,137	-5% +20%	1,011,678	-5% +20%
AERIAL STRUCTURES	300,900	-5% +30%	0		2,280,910	-5% +50%
RETAINING STRUCTURES	666,704	-5% +30%	297,700	-5% +30%	857,006	-5% +30%
UTILITIES	997,556	10% +50%	28,900	10% +50%	0	10% +50%
STATIONS & PARKING	1,119,000	-5% +20%	206,000	-5% +20%	551,000	-5% +20%
STATION WORK/TRAFFIC/LANDSC	330,600	-5% +50%	20,000	-5% +50%	80,000	-5% +50%
TRACTION PWR & SUBST.	3,478,339	-5% +30%	2,052,639	-5% +30%	99,756	-5% +30%
TRACT.-OTHER RELATED COSTS	0		0		0	
OVERHEAD CONTACT SYSTEM	2,166,914	-5% +30%	1,524,574	-5% +30%	492,011	-5% +30%
OCS-OTHER RELATED COSTS	818,988	-5% +30%	439,192	-5% +30%	22,560	-5% +30%
SIGNALS	5,666,641	-5% +30%	4,254,139	-5% +30%	841,465	-5% +30%
SIGNALS-OTHER RELATED COSTS	357,240	-5% +30%	138,847	-5% +30%	62,400	-5% +30%
SUBTOTALS	25,478,834		12,007,978		6,674,904	

DESIGN FOR D/B CONTRACT	3% to 5% of total D/B Budget: Engineer's Estimate doesn't include an allowance for contractor's design effort!
Add Escalation for 3 years	Range = 3.5% to 5.5% per year

4.3.1.3 Probabilistic Cost Analysis

Two probabilistic models were developed to support a Monte Carlo simulation which assesses the risk of cost overruns for the Phase II Project. The first model forecasts cost for the design-build contract. The second model estimates the total project budget, which included results from the design-build cost model simulation. Both models are comprised of all major cost items, or cost components, C_i's. Total cost is calculated by summing the individual C_i's, then adding to that total a percent for the final design effort, and finally increasing the total budget by the annual escalation factor for three years. Some budget items, such as cost of vehicles and the four preliminary design contracts, were not escalated to derive total project cost, because the MTA had already committed funds for these items at the time of the engineer's estimate (4/94).

4.3.1.3.1 Cost Simulation

C_i's for this analysis come from Exhibits 4-14 and 4-15. Distribution of each C_i was entered into the @RISK spreadsheet using the triangular distribution function. The 10%, most likely, and 90% values from Exhibits 4-14 and 4-15 were entered into the distribution functions for each probability model. All fixed costs, which include vehicles already purchased at a cost of over $14.3 million and preliminary engineering, have no associated risk and are constant values in the models. The cost of Final Design, performed by the design-build contractor, was modeled with a uniform distribution. The probabilistic model for the total project included results of the design-build simulation. The values for each model were totaled and escalated by the cost escalation factor (distributed uniformly) and the simulation was run for 5,000 iterations.

4.3.1.3.2 Cost Item Correlations

Cost correlation between some of the cost items were accounted for to avoid underestimating the risk variance. The following are correlations between cost items that were considered in this study:

- The cost of aerial structures and retaining structures for the Penn Station Extension were positively correlated due to the proximity of the site and similarity of construction activities;

- The civil aspects of the systems work, categorized within "Overhead Catenary System Other Related Costs" and "Signals-Other Related Costs," were positively correlated to the "Excavation and Backfill" operation due to the proximity of the site and similarity of the operations;

- The station enhancement costs, categorized within "Station Work," could have been positively correlated with "Stations and Parking," but were not because the cost item and its influence on the total variance was so small;

- The total design-build contract cost was positively correlated to the costs for "MTA Administration" and "Open End Consultant" which are used for project inspection and other related items; and

- The "Appraisal" and "Acquisition" of real estate cost items were grouped together, because the study makes the assumption that these costs are positively correlated (i.e., these cost elements are expected to "move" together, and in the same direction).

4.3.2 <u>Schedule Analysis Technical Approach</u>

The approach taken to analyze the schedule was to develop a network of activities using all available data and then to conduct a probabilistic analysis by introducing ranges of variability for each networked activity. Reasonable ranges were assigned to activity durations which were thought to have potential for variation. Next, a histogram and a cumulative distribution function (CDF) were produced by the software, for the probability distribution associated with total project duration. Using the CDF for the total project duration, it is possible to assess the probabilities associated with the completion dates for the design-build contract, and the project.

4.3.2.1 The Project Network

A network of activities was developed, based on the barcharts provided on pp. A41 and A43 of the PMOC Budget Review report and the Project Master Schedule obtained from the MTA. This network, and the inter-activity relationships that define it, form the basis for conducting a schedule risk analysis.

The basis of the network used for this analysis is the original barchart (p. A43 of the PMOC Budget Review Report), prepared in 1992. Later, the project scope went through some changes, mainly in the BWI Extension. In the 1992 barchart, Phase II was aggregated into four segments: Hunt Valley Conrail, Hunt Valley north of Conrail, BWI airport, and Penn Station. In a commentary on the barchart, a member of the PMOC essentially agreed that the durations chosen were reasonable[17]. The reason for breaking down the Hunt Valley Extension into two segments was that the segment along the Conrail alignment could be designed and constructed faster, as much of the alignment was already available and ready. This barchart was developed at a point that the owner intended to use a traditional approach in procuring the project. Because of this, the PMOC reviewer recommended some modifications to make the schedule more representative of the turnkey mode.

4.3.2.2 Modifications to the Project Network

Under the turnkey approach, it is possible to save time and reduce cost by eliminating the time needed for awarding separate design and construction contracts. Based on the reviewer's comments, overlaps were modeled across traditionally consecutive activities, to capture turnkey schedule characteristics. The modified network consists of activities suggested in the owner's barchart. This network shows a total duration of 690 calendar days between NTP and the end of the design-build contract. Durations for each activity were taken from engineer's estimate (p. A42 - A43) with minor modifications.

In the only major modification, the duration of BWI Civil Construction was reduced from 420 days to 300 days. This reduction is justified because the scope of work for this extension was later reduced and because only part of the work was done by the design-build contractor. This modification is also consistent with Sverdrup reviewer's discussion on p. A42 of the PMOC Budget Review Report.

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[17] In an effort to ". . . [place] the durations on an even keel with the 25 months contained within the design-build contract," PMOC in its January 1994 review deleted three activities which had previously been included in the Phase II schedule, prior to MTA determination to proceed with the project on a design-build basis. Also, BWI's civil construction work was thought by PMOC to "be simpler" than that envisioned in developing the 1992 schedule. The durations resultant from the PMOC review were thus under 25 months for each segment, which was the target for the design-build contract. The only exception was BWI, with a schedule of 28 months, but PMOC said: ". . . the three months delta for BWI [is] perceived as a minimum schedule benefit resulting directly from the design-build concept."

An overall duration of 690 days allows for a schedule contingency of 10% (total design-build duration allowed = 760 calendar days, or 25 months).[18] The Hunt Valley (North of Conrail) segment lies on the critical path. The Pennsylvania Station Extension is very close to critical with a total float of 15 days. The BWI segment follows closely. This is in line with what was perceived by the owner at the time of bidding. According to MTA personnel, at the time of bidding, all three extensions were expected to take about the same amount of time.

Here is a brief summary of assumptions used in developing the network:

- Task durations have been taken from the engineer's estimate. They are based on actual durations experienced in similar segments in Phase I and have been verified by the Sverdrup group review (see p. A42 of the PMOC Budget Review).

- All durations are expressed in calendar days. To replicate this accurately in the scheduling software, a 7-day workweek was assumed for the network calendar.

- Landscape Design can be done after completion of Civil Design. In the master schedule, this activity is scheduled to start on June 1, 1996.

- Ticket Vending Machine (TVM) activity can start after system design is complete.

- TVM installation should be completed before Startup[19].

- System Installation(s) for three extensions have finish-to-finish (FF=0) links with Startup. This means that Startup will finish at the completion of design-build contract.

- An overlap of 30 days was assumed between System Design and Design/Fabricate/Deliver Systems Equipment for each segment. That is, Design/Fabricate/Deliver Systems Equipment was thought to start 30 days before the completion of System Design. Given the turnkey nature of the project, this assumption may be conservative.

- There is a finish-to-finish (FF) dependency of 67 days from System Installation to Landscape Construction. That is, Landscape Construction is scheduled to

[18] U.S. Department of Transportation, Summary of the Work, p. 26.

[19] System Startup occurs two months prior to Pre-revenue Service and Revenue Operation. The activities do not overlap. System Startup includes testing the system prior to beginning revenue service, or actual passenger operations; and Startup defines completion of the design-build contract.

finish 67 calendar days after the finish of all System Installation tasks. This dependency was introduced to replicate the owner's schedule (see Phase II master schedule obtained from the MTA, Appendix C). Note that Landscape Construction falls during the winter months in the project master schedule. Winter is not the best time for performing this activity, but landscape construction should not prevent the project from going into revenue service, and will have minimal impact on the study objective. It is possible for Revenue Service to begin while Landscape Construction is incomplete.

- There are two general right-of-ways: one is at Notice to Proceed (NTP)+90 days, and the other is NTP+563 days. Right-of-way availability for specific alignment segments is designated in the Phase II graphical engineering specifications as follows:

<u>BWI</u>	
Station S/E 364+87.24 to Station B/W 36+00	NTP +90 days
Station B/W 36+00 to Station B/W 85+00	NTP +90 days
Station B/W 85+00 to Station 140+00	NTP +563 days
<u>Hunt Valley</u>	
Station N/E 658+11.41 to Station H/V 37+80	NTP +90 days
Station H/V 37+80 to Station H/V 62+27	NTP +563 days
Station H/V 62+27 to Station 100+00	NTP +90 days
Station H/V 100+00 to Station 163+40	NTP +90 days
Station H/V 163+40 to Station H/V 241+12	NTP +90 days
<u>Penn Station</u>	
Station P/N 69+83.5 to Station P/N 87+36.96	NTP +90 days.

For the BWI segment 85+00 to 140+00, the Civil/Trackwork will be done by the MAA. Also, for Hunt Valley segment 37+80 to 62+27, excavation, grading, catenary foundation, sub-ballast, ballast and trackwork will be done by Baltimore County. Systems work in both segments will be done by Whiting-Turner, the design-build contractor.

- There is a finish-to-start (FS) lead time of -60 days from Civil Design to Civil/Trackwork Construction. That is, construction begins 60 days before the finish of civil design. This overlap seems justified because of the turnkey nature of the work.

- For the BWI segment between 85+00 and 140+00 (5,500 ft), duration of System Installation has been prorated. Duration of this segment is calculated as (5,500/14,000)(180 days) = 71 days. The duration for the earlier part of System Installation is then 180-71 = 109 days.

- For the HV (Conrail) System Installation, the duration for the segment between 37+80 and 62+27 which has a later right-of-way availability, has been calculated by pro-rating the total duration relative to total track length as: (180)[(6227-3780)]/24,112 = 19 days. The duration for the balance of the activity was calculated as 180-19 = 161 days.

- The following overlaps have been considered:

  - Penn Station - Civil Design to System Design (start-to-start [SS] 120 days);

  - Hunt Valley (Conrail) - Civil Design to System Design (SS 90 days);

  - Hunt Valley (North of Conrail) - Civil Design to System Design (SS 90 days); and

  - BWI - Civil Design to System Design (SS 90 days).

A listing of all activities included in this network using their deterministic durations is given in Exhibit 4-17. A barchart depicting the network is provided in Exhibit 4-18.

EXHIBIT 4-17
Deterministic Activities for the MTA Schedule Analysis

ACTIVITY ID	ORIG DUR	ACTIVITY DESCRIPTION	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT
A1	0	Bid Opening	26SEP94		26SEP94		0
A2	0	NTP	24JAN95		24JAN95		0
HNC3	240	Civil Design	24JAN95	20SEP95	24JAN95	20SEP95	0
P3	240	Civil Design	24JAN95	20SEP95	8FEB95	5OCT95	15
BW3	240	Civil Design	24JAN95	20SEP95	23FEB95	20OCT95	30
HC3	180	Civil Design	24JAN95	22JUL95	23FEB95	21AUG95	30
ROWHV	90	HV Right-of-Way (ROW) Acquisition	24JAN95	23APR95	24APR95	22JUL95	90
ROWPENN	90	Penn Station ROW Acquisition	24JAN95	23APR95	9MAY95	6AUG95	105
ROWBWI	90	BWI ROW Acquisition	24JAN95	23APR95	24MAY95	21AUG95	120
BW5	150	System Design	24APR95	20SEP95	24MAY95	20OCT95	30
HC5	150	System Design	24APR95	20SEP95	24MAY95	20OCT95	30
HNC5	150	System Design	24APR95	20SEP95	24MAY95	20OCT95	30
P5	120	System Design	24MAY95	20SEP95	8JUL95	4NOV95	45
HC4	180	Civil/Trackwork Construction	24MAY95	19NOV95	20DEC95	16JUN96	210
HNC4	330	Civil/Track Construction	23JUL95	16JUN96	23JUL95	16JUN96	0
P4	360	Civil/Trackwork Construction	23JUL95	16JUL96	7AUG95	31JUL96	15
BW4	300	Civil/Track Construction	23JUL95	17MAY96	22AUG95	16JUN96	30
BW6	270	Design/Fab/Deliver Systems Equip.	22AUG95	17MAY96	21SEP95	16JUN96	30
HC6	270	Design/Fab/Deliver Systems Equip.	22AUG95	17MAY96	21SEP95	16JUN96	30
HNC6	270	Design/Fab/Deliver Systems Equip.	22AUG95	17MAY96	21SEP95	16JUN96	30
P6	270	Design/Fab/Deliver Systems Equip.	22AUG95	17MAY96	5NOV95	31JUL96	75
TVM	345	TVM Procurement	21SEP95	30AUG96	5NOV95	14OCT96	45
LANDESG	90	Landscaping Design	21SEP95	19DEC95	7AUG96	4NOV96	321
BW7	109	System Installation	18MAY96	3SEP96	17JUN96	3OCT96	30
HC7	161	System Installation	18MAY96	25OCT96	17JUN96	24NOV96	30
HNC7	180	System Equipment Installation	17JUN96	13DEC96	17JUN96	13DEC96	0
P7	135	System Equipment Installation	17JUL96	28NOV96	1AUG96	13DEC96	15
ROWBWI2	0	ROW Access for 85+00/140+00	9AUG96		4OCT96		56
ROWHV2	0	H.V. ROW Access for 37+80/62+27	9AUG96		25NOV96		108
BW7-2	71	System Installation for 85+00/140+00	4SEP96	13NOV96	4OCT96	13DEC96	30
STARTUP	60	System Start-up	15OCT96	13DEC96	15OCT96	13DEC96	0
LANDCONS	120	Landscaping Construction	22OCT96	18FEB97	5NOV96	4MAR97	14
HC7-1	19	System Installation for 37+80/62+27	26OCT96	13NOV96	25NOV96	13DEC96	30
D/B COMPLE	0	D/B Contract Complete	14DEC96		14DEC96		0
PREREV	81	Pre-revenue Service	14DEC96	4MAR97	14DEC96	4MAR97	0
REV	0	Revenue Operation	5MAR97		5MAR97		0

EXHIBIT 4-18
Central Light Rail Line - Extensions
CLRL Master Schedule (Page 1 of 2)

EARLY START	EARLY FINISH	Activity
26SEP94		A1 Bid Opening
24JAN95		A2 NTP
15OCT96	13DEC96	STARTUP System Start-up
14DEC96		D/B COMPLE D/B Contract Complete
14DEC96	4MAR97	PREREV Pre-revenue Service
5MAR97		REV Revenue Operation
22OCT96	18FEB97	LANDCONS Landscaping Construction
21SEP95	30AUG96	TVM TVM Procurement
21SEP95	19DEC95	LANDESG Landscaping Design
		BWI Extension
24JAN95	20SEP95	BW3 Civil Design
24APR95	20SEP95	BW5 System Design
23JUL95	17MAY96	BW4 Civil/Track Construction
22AUG95	17MAY96	BW6 Design/Fab/Deliver Systems Equipment
18MAY96	3SEP96	BW7 System Installation
4SEP96	13NOV96	BW7-2 System Installation for 85+00/140+00
9AUG96		ROWBWI2 R.O.W. Access for 85+00/140+00
24JAN95	23APR95	ROWBWI BWI R.O.W. Acquistion
		Hunt Valley Conrail Alignment
24JAN95	22JUL95	HC3 Civil Design
24APR95	20SEP95	HC5 System Design
22AUG95	17MAY96	HC6 Design/Fab/Deliver Systems Equipment
18MAY96	25OCT96	HC7 System Installation
26OCT96	13NOV96	HC7-1 System Installation for 37+80/62+27
24JAN95	23APR95	ROWHV HV R.O.W. Acquistion
9AUG96		ROWHV2 H.V. R.O.W. Access for 37+80/62+27
24MAY95	19NOV95	HC4 Civil/Trackwork Construction

Timescale: 1994 (S O N D), 1995 (J F M A M J J A S O N D), 1996 (J F M A M J J A S O N D), 1997 (J F M A M J)

Plot Date 12FEB96
Data Date 26SEP94
Project Start 1SEP94
Project Finish 4MAR97

Activity Bar/Early Dates
Critical Activity
Progress Bar
Activity Late Dates
Milestone/Flag Activity

CLR4

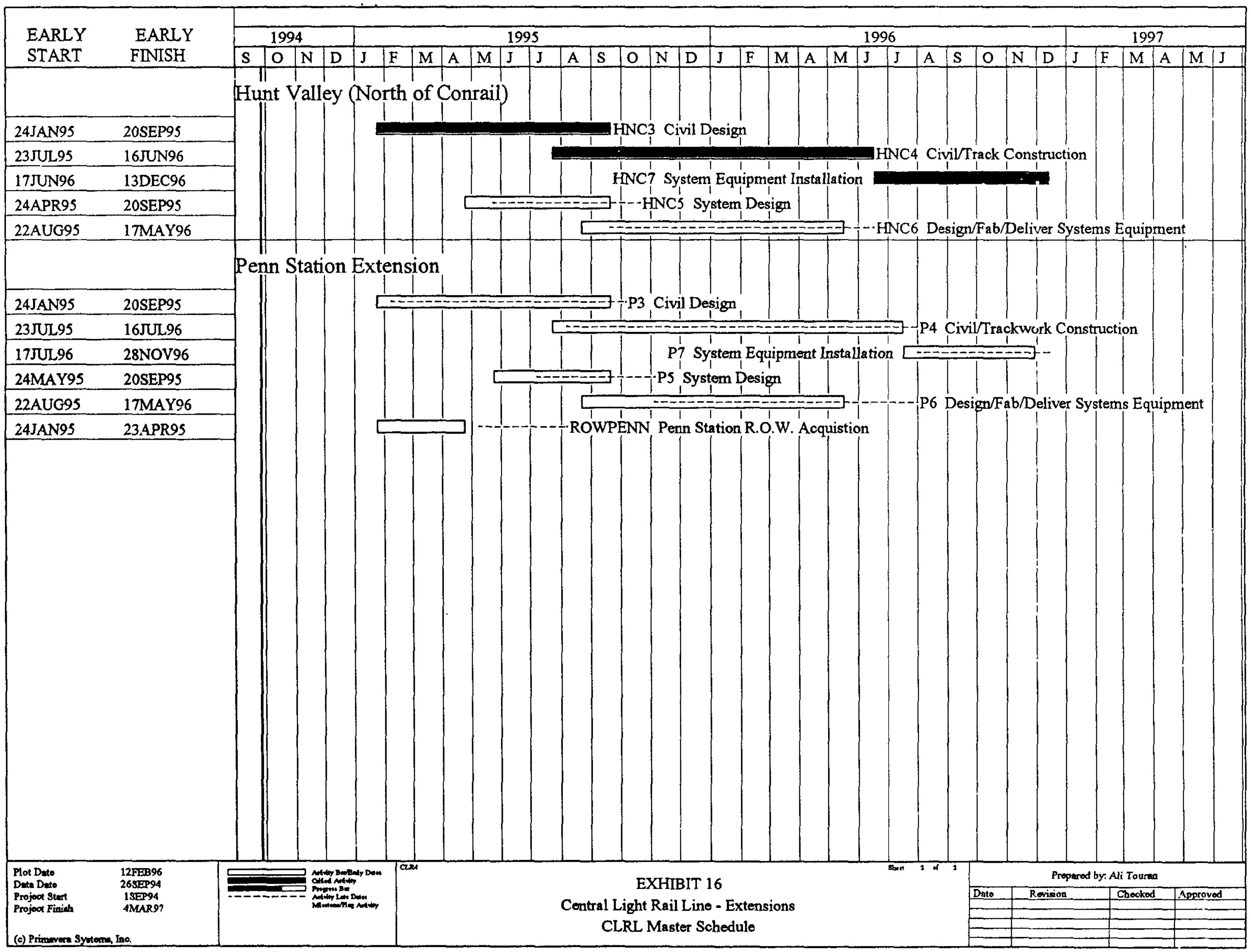
Sheet 1 of 2

EXHIBIT 16
Central Light Rail Line - Extensions
CLRL Master Schedule

Prepared by: Ali Touran

Date	Revision	Checked	Approved

EXHIBIT 4-18
Central Light Rail Line - Extensions
CLRL Master Schedule (Page 2 of 2)

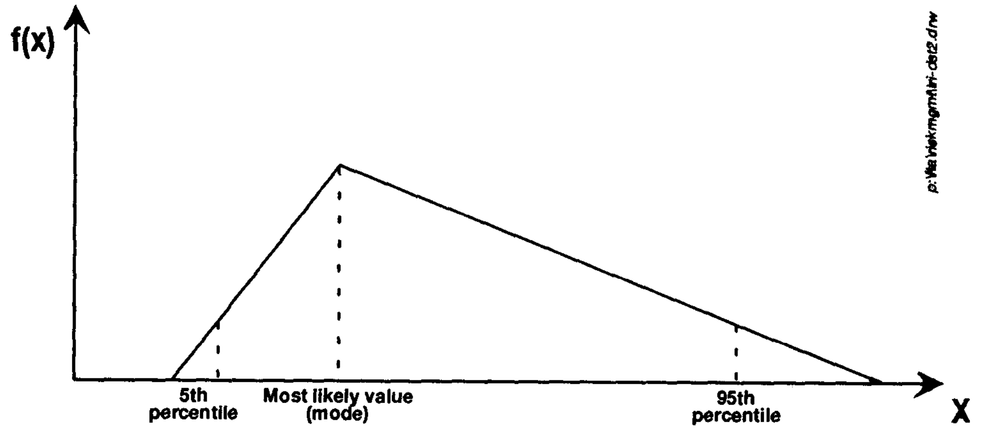


4.3.2.3 Probabilistic Analysis Methodology

The use of probabilistic durations for construction activities dates back to the late 1950s and the development of the PERT method[20]. In the PERT method, a beta distribution is used to model activity duration time. Reasons for this choice of distribution are mainly due to the characteristics of construction cost and schedule data, i.e., construction data is usually distributed unsymmetrically, has confined ends, and is unimodal (has only one most likely value). MacCrimmon and Ryavec (1964) have suggested that the use of triangular distribution for modeling activity duration times is no less accurate than using beta distribution. The benefit is, of course, the simplicity of the triangular distribution. Moder, *et al.* (1983) suggest that in probabilistic scheduling, it would be preferable to estimate the most likely value, the 5th percentile and the 95th percentile values of the distribution as it would be extremely difficult to estimate the extreme points (0 percentile and 100th percentile points) of the distribution.

This study follows the suggestion of Moder et al., and uses a triangular distribution to model activity duration times. The 5th percentile, most likely, and 95th percentile values are specified (Exhibit 4-19). For the study, the most likely value of each activity duration was the value given in the existing network. This is reasonable because these are the best estimates available, and also because these data were obtained from actual duration times incurred in similar segments of the MTA Phase I project.

EXHIBIT 4-19
Triangular Probability Distribution



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[20] *Program Evaluation and Review Technique (PERT)* is a probabilistic network-based scheduling technique where every activity is modeled as a random variable distributed according to a beta or unimodal distribution. The total project duration is computed along the network's critical path (the longest path) by summing the means of the activities on the critical path *(Touran et al., 1994).*

Ranges Used. The 5th and 95th percentile points of the distribution were estimated by working with a scheduling expert with extensive experience in transit scheduling. Additional information came from interviews with the MTA personnel in charge of the Central Light Rail Line Phase II project. They were very helpful, and provided background and justifications for the durations and the level of risk involved in various activities. Exhibit 4-20 lists the probabilistic durations and their parameters.

EXHIBIT 4-20
Central Light Rail Line Phase II
Parameters of the Schedule Risk Analysis*

Activities	5 percentile	most likely	95 percentile	Range used**
BWI Civil Design	180	240	360	-25% +50%
HV (Conrail align.) Civil Design	180	180	270	0% +50%
HV (North of Conrail) Civil Design	180	240	360	-25% +50%
Penn. Stat. Civil Design	180	240	360	-25% +50%
BWI System Design	120	150	225	-20% +50%
HV (Conrail align.) System Design	120	150	225	-20% +50%
HV (North of Conrail) System Design	120	150	225	-20% +50%
Penn. Stat. System Design	120	120	180	0% +50%
Design/Fab/Del.	210	270	405	-22% +50%
BWI Civil Construction	240	300	420	-20% +40%
HV (Conrail align.) Civil Construction	144	180	270	-20% +50%
HV (North of Conrail) Civil Construction	264	330	495	-20% +50%
Penn. Station Civil Construction	288	360	540	-20% +50%
BWI System Installation	87	109	164	-20% +50%
BWI System after ROW	57	71	107	-20% +50%
HV (Conrail align) System Installation	129	161	242	-20% +50%
HV (Conrail align) System after ROW	19	19	40	0% +100%
HV (North of Conrail) System Installation	144	180	270	-20% +50%
Penn. St. System Installation	108	135	203	-20% +50%
TVM Procurement	310	345	448	-10% +30%
Pre-revenue Service	60	81	120	-25% +50%
Startup	45	60	90	-25% +50%
ROW Availabilities (NTP+563 days)	0	0	60	

(*) All durations are in calendar days.
(**) The range is given in respect to the most likely value.

Only those activities that had the potential to impact the project duration were ranged. For this reason, activities dealing with landscaping design and landscaping construction were not ranged. No uncertainty was associated with the Notice to Proceed (NTP). Although NTP delay is a common cause of delay for projects, in this case NTP had already occurred.

In general, the study employed a skewed triangular distribution where the 5th percentile estimate is 0% to 25% shorter than the most likely estimate, and the 95th percentile estimate is 30% to 100% longer than the most likely estimate. This skewed distribution was chosen because the range of schedule overrun (open ended) is always much wider than the range of schedule underrun. Furthermore, the amount of the owner's backup information regarding schedule was very limited indeed. There is no documentation about productivity rates assumed, assumptions made, or contingencies used for the schedule. Because of these concerns, the choice was reluctantly made to model duration times relatively pessimistically.

Additional information regarding the duration and ranges used for particular tasks is given below:

Civil Design. Civil design for each segment is estimated to take about 8 months (see Appendix C, pages C2 and C3), with the exception of Hunt Valley (Conrail Alignment) which is estimated to take about 6 months. There is already so much information about this alignment that would almost certainly reduce the design period. An optimistic duration of 6 months and a pessimistic duration of 12 months was assigned to each of the first three segments. For Hunt Valley (Conrail), it was felt that the minimum time needed still would be 6 months with a maximum of 9 months. Usually, civil design duration is increased because of the communication process with the owner.

An important issue in project time management is preplanning needed for obtaining various types of permits and right-of-ways. In Central Light Rail Line Phase II the owner has assumed responsibility for right-of-way acquisitions and much of the permits. Many times in transit projects, the right-of-way acquisitions could be on the critical path rather than the civil design. The pessimistic durations specified will account for the problems encountered in obtaining necessary permits and delays of right-of-way acquisitions.

System Design. System design durations seem a little optimistic. One needs a minimum duration to be able to account for submittals, their processing, and possible revisions. System design submittals were ranged between -20% and +50% except for the Penn Station Extension. In that extension, the extent of system design seems limited. Because of this, a 4-month duration was assumed for the most likely value, and it was felt that this activity could not be completed sooner than 4 months either.

Civil/Trackwork Construction. Durations for these activities varied from 6 to 12 months. For all four segments the lower bound was assumed to be 20% lower than the most likely estimate. The upper bound of BWI segment was taken as 40% longer than its most likely estimate because it was felt that given the job scope, even under adverse conditions this activity should be accomplished within 14 months. The BWI segment is being constructed by the design-build contractor and the MAA. The volume of work for the design-build contractor is relatively small, so the main concern is the coordination needed between the MAA and the contractor. Also, permitting is difficult because of the proximity to the airport.

The Penn Station Extension construction was estimated to take 12 months mainly because of the major bridge construction activity over Interstate 83. Also, coordination with AMTRAK is needed in this activity that can potentially delay the work.

Design/Fabricate/Deliver. This activity was assumed to take about 9 months, ranging between 7 and 13.5 months. System procurement usually takes longer than the most likely value used here, but the comparison data available were for larger projects. Thus, we used the owner's estimate for the most likely value and used a relatively large range.

System Installation. The owner's estimate of 6 months was adopted, and ranged between -20% and +50%. For Penn Station however, because of the limited scope of work, that was reduced to 4.5 months for the most likely value.

Ticket Vending Machine Procurement. There was less uncertainty with this activity as the owner wanted to buy equipment similar to the one used in Phase I. Thus the duration was ranged between -10% and +30% of the most likely value.

Right-of-Way Availabilities. Right-of-ways that were expected to be available at NTP+30 days were far enough from critical path to have no impact on project duration. The range used for civil design would be sufficient to absorb impacts of extraordinary right-of-way delays. For right-of-ways that were expected to be available at NTP+563 days, it was assumed that these right-of-ways may be delayed from 0 to 60 days according to a triangular distribution.

Pre-revenue Service and Startup. According to interviews with MTA personnel, these activities are relatively low risk. Because the activity durations were small and any potential changes in actual durations would translate to large percentage point deviations, we used the standard range (-25% to +50%).

4.3.2.4 Software and Methodology

The Critical Path Method (CPM) network was developed using Microsoft Project, a scheduling tool. The probabilistic analysis was conducted using @RISK for Project (1994), an add-in software module working with Microsoft Project and the Microsoft Excel spreadsheet package. @RISK is designed for probabilistic analysis and simulation. The package allows the user to specify distribution type and ranges of variation for activities within the project, and then conducts a Monte Carlo simulation analysis on the CPM network. Because @RISK functions as an add-in module, and because it requires close coordination between Project and Excel, a number of trials were required to gain confidence with the software and master its idiosyncracies. @RISK for Project provides a useful tool, but does not include many convenience features that might enable easy modification of the model and the simulation parameters, or rapid re-running of a simulation.

The simulation was run using the distribution and ranges specified above for 1,000 iterations. For networks of this size, a simulation run with about 400 iterations should provide reliable results (Moder, *et al.*, 1983). Crandall (1977) suggests that a sample size of 1,000 iterations should provide an adequate level of confidence. Increasing the number of iterations beyond 500 did not significantly change the results.

4.4 STUDY FINDINGS

The case study findings are organized for cost and schedule analysis. Within each category, separate simulations were conducted for the design-build contract and for total project cost.

4.4.1 Cost Analysis

The study findings include results of the Phase II probabilistic cost analysis[21], as well as a cost sensitivity analysis which was performed for the design-build contract, for the three Phase II extensions.

4.4.1.1 Probabilistic Cost Analysis

The study results indicate that the Phase II funding is quite adequate. The probabilistic forecast yields an expected value[22] for total project cost of $99.27 million. This gives a confidence level of about 96% for finishing the project within the total budget of $106.34 million. If the unallocated contingency of $2.8 million is excluded from total project cost, then the probabilistic analysis indicates that there is an 88% chance that the project will not experience a cost overrun. These results indicate that the project contingencies (both allocated and unallocated) provide for a high degree of confidence in the total cost of the project.

For the probabilistic cost analysis, all contingencies were removed from the cost elements (cost variables) prior to the Monte Carlo simulation. Exhibit 4-21 shows the results of the probabilistic cost analysis for the total project budget. The Monte Carlo simulation ran for approximately 5,000 trials (4,969 iterations). The full range of output is from $88,687,911 minimum point, to $112,281,005 maximum point. The expected value or mean (average) of the distribution is $99,272,618. The frequency chart or "histogram" shows relative probability for each point over the simulation trials. For example, most of the points are clustered around $99 million, the expected value; some points fall near the minimum and maximum, but the probability of these "occurrences" in the simulation is much lower than the central points which are clustered around the mean. The histogram indicates an approximately normal or "bell-shaped" output distribution. The cumulative graph, or cumulative distribution function (CDF), shows ascending probabilities, 0% to 100%, over the entire range of simulation output. The CDF indicates the likelihood (probability) of overrun or underrun for any point in the output distribution.

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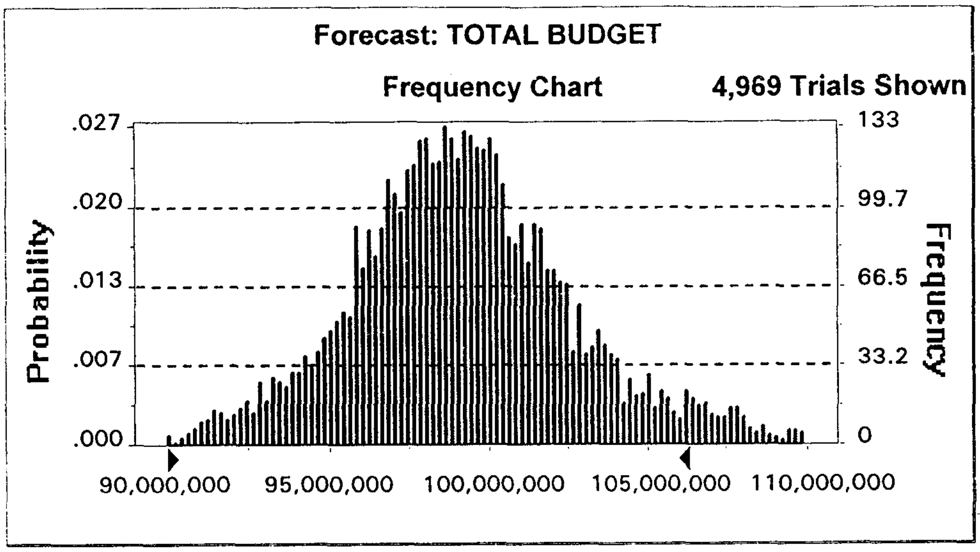
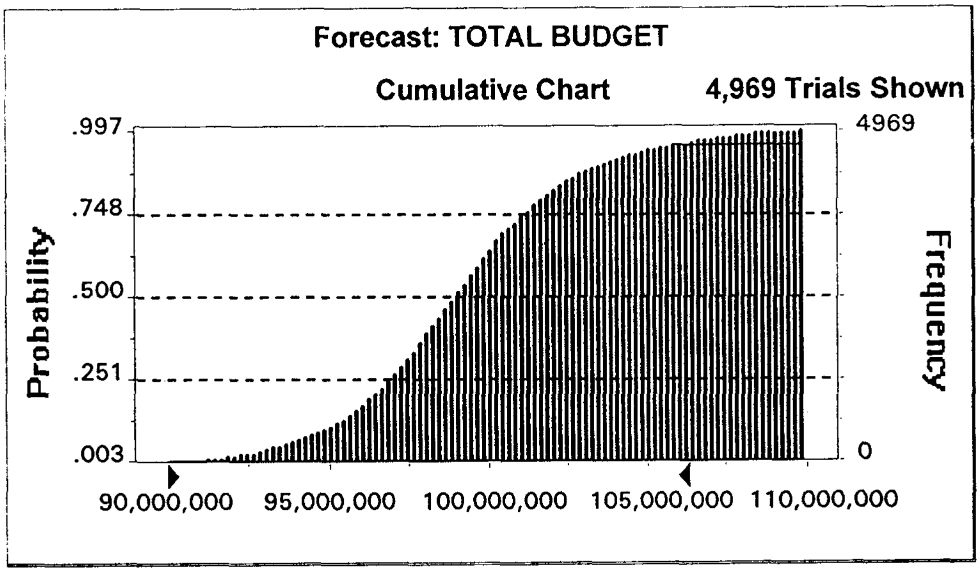
[21] *Risk variables* are cost elements.

[22] *Expected value* is the mean or average point of the probability distribution.

EXHIBIT 4-21
Statistical Results of Probabilistic Cost Analysis for Total Project Cost





Total Project Cost Statistic

Statistic	Value
Trials	5,000
Mean	$99,272,618
Median (approx.)	$99,094,444
Mode (approx.)	$98,700,000
Standard Deviation	$3,547,714
Coeff. of Variability	0.04
Range Minimum	$88,687,911
Range Maximum	$112,281,005

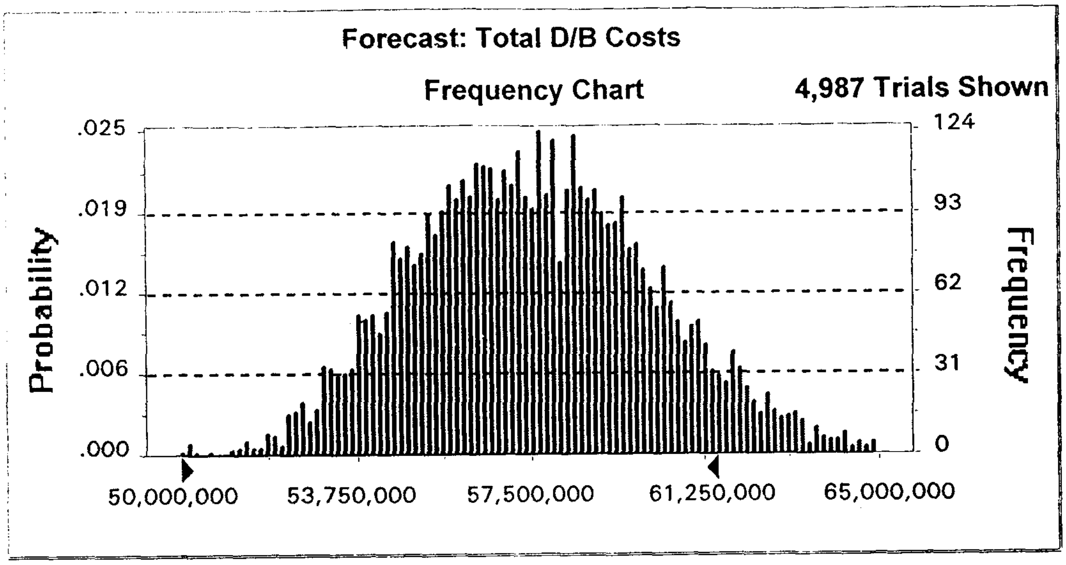
Cumulative Forecast for Total Project

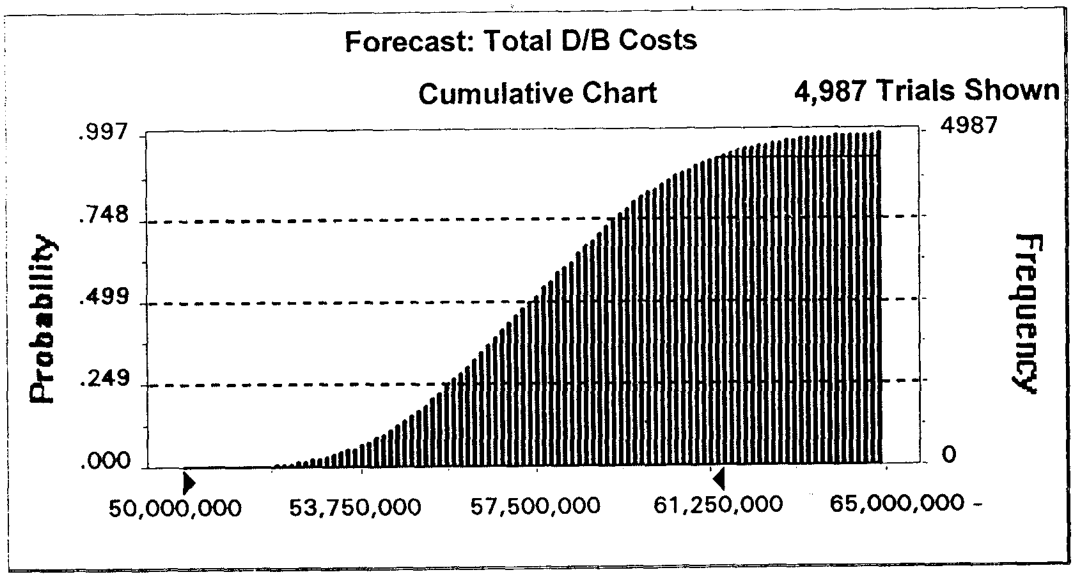
Percentile	Value
0%	$88,687,911
10%	$95,000,000
20%	$96,497,436
30%	$97,472,072
40%	$98,288,889
50%	$99,094,444
60%	$99,868,254
70%	$100,746,667
80%	$101,930,952
90%	$103,794,872
100%	$112,281,005

The simulation results for the design-build contract are somewhat less optimistic than the results for total project cost. The probabilistic simulation yields an expected value of $57.6 million. The total design-build budget of $61.6 million includes a designated contingency of $5.8 million: $55.8 million design-build bid plus $5.8 million contingency equals $61.6 million. Therefore the probabilistic study results show a 92% confidence level for the Whiting-Turner contract being completed within budget plus contingency; however, there is only a 25% chance that MTA *will not need* to use the design-build contingency of $5.8 million. These data suggest that the cost contingency for design-build is quite adequate.

Exhibit 4-22 shows the results of the probabilistic cost analysis for the design-build contract. The simulation used 5,000 iterations, and the output range for design-build cost is $50,101,327 minimum to $67,188,497 maximum. The expected value is $57,623,150. The histogram and CDF for the output distribution show relative and cumulative probabilities, respectively.

EXHIBIT 4-22
Statistical Results of Probabilistic Cost Analysis for Design-Build Contract





Design-Build Summary Cost Statistics

Statistic	Value
Trials	5,000
Mean	$57,623,150
Median (approx.)	$57,528,205
Mode (approx.)	$57,725,000
Standard Deviation	$2,595,785
Coeff. of Variability	0.05
Range Minimum	$50,101,327
Range Maximum	$67,188,497

Cumulative Forecast for Design-Build

Percentile	Value
0%	$50,101,327
10%	$54,356,667
20%	$55,335,000
30%	$56,120,588
40%	$56,819,355
50%	$57,528,205
60%	$57,261,765
70%	$58,966,667
80%	$59,802,273
90%	$61,056,250
100%	$67,188,497

In summary, the results of the risk analysis indicate a very small likelihood (100% - 96% = 4%) that Phase II will overrun the budget for total project cost. The analysis does show that there is high degree of certainty (100% - 25% = 75%) that the Whiting-Turner design-build contract *will not* be completed within the bid value of $55.8 million. However, the risk decreases considerably if the $5.8 million contingency for design-build is included, and the study finds that there is only an 8% (100% - 92% = 8%) chance that Whiting-Turner will overrun its total budget with contingency.

4.4.1.2 Cost Sensitivity Analysis

In order to study the effect of cost variation of every major portion of this project on the total cost for the design-build portion of the project, a sensitivity analysis was conducted to isolate the impact of each of the three Phase II extensions. Three scenarios are considered. In each scenario, only the cost items in one extension were ranged, while the other extensions' costs are fixed at their expected values. In this way, the effect is shown of one specific extension, on the total design-build contract. Exhibit 4-23 shows the results of this sensitivity analysis. The data in the row titled "Scenario I" gives the expected value, minimum, maximum, standard deviation and coefficient of variation of the total design-build cost, if cost items in the Hunt Valley Extension are ranged probabilistically, while all other cost items are fixed at their expected values[23]. The standard deviation of each extension is an indication of the contribution of that extension to the variation of the total cost.

EXHIBIT 4-23
Sensitivity Analysis for Design-Build Contract

Extension	Expected Value ($1000)	Minimum ($1000)	Maximum ($1000)	Standard Deviation ($1000)	COV[1]
Scenario I*	57,666	52,183	64,185	2,071	0.036
Scenario II**	57,651	54,756	61,402	1,237	0.021
Scenario III***	57,657	55,795	59,838	725	0.013

1 Coefficient of Variation (ratio of standard deviation to expected value).
* Hunt Valley modeled as random variable, everything else fixed.
** BWI modeled as random variable, everything else fixed.
*** Penn Station modeled as random variable, everything else fixed.

23 Note that these expected values are larger than the most likely values, because skewed triangular distributions were used to model the cost data.

The sensitivity analysis shows that the Hunt Valley Extension, because of its magnitude, has the largest contribution to project cost uncertainty. It should also be noted that the above results have been obtained by assuming that design costs (4%) and escalation costs (4.5% per year for three years = 14.1%) are fixed for the other two extensions.

When each of the three extensions is considered independently, the largest coefficient of variation belongs to Penn Station, at 8.1%, i.e., the ratio of standard deviation to mean for Penn Station cost is 0.081. This is to be expected, mainly because of the uncertainty in the cost of the bridge structure. This result shows that the Penn Station Extension is the riskiest of all extensions, for cost variables. However, Penn Station's overall contribution to the design-build contract uncertainty is *not* the largest, due to the relatively small size of this extension.

4.4.2 Schedule Analysis

The study findings include results of the Phase II probabilistic schedule analysis[24], as well as activity criticality indexes which were calculated for each identified schedule activity for the Phase II project.

4.4.2.1 Probabilistic Schedule Analysis

The study results indicate that the project schedule is relatively tight. There is an appreciable likelihood that the project will suffer a modest schedule delay. The network used for the analysis has a total duration of 690 calendar days, from the Notice to Proceed date to the end of the design-build contract. This duration allows for a schedule contingency of 10%, since the total duration allowed by contract is 760 calendar days. The probabilistic analysis performed in this case study indicates that this contingency is insufficient.

The Monte Carlo simulation was run for 1,000 trials (iterations), and output was directed for:

- Probable date for completion of the design-build contract; and
- Probable date for revenue service.

The Hunt Valley north of Conrail segment defines the critical or longest path as a result of the simulation. Exhibit 4-24 shows summary statistics[25], histogram and cumulative distribution function for the design-build contract. Exhibit 4-25 presents the same information for the expected Phase II opening date, or "revenue service."

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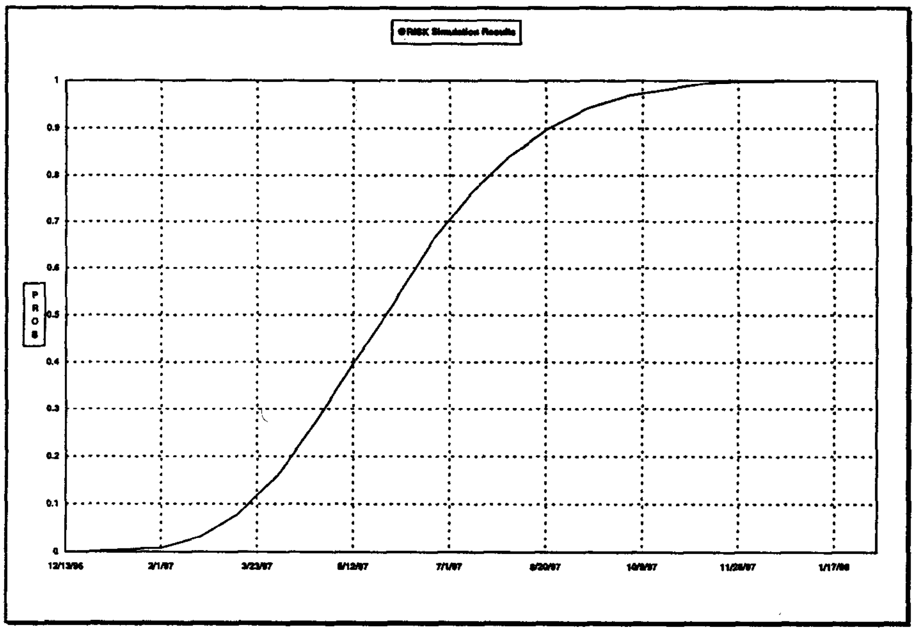
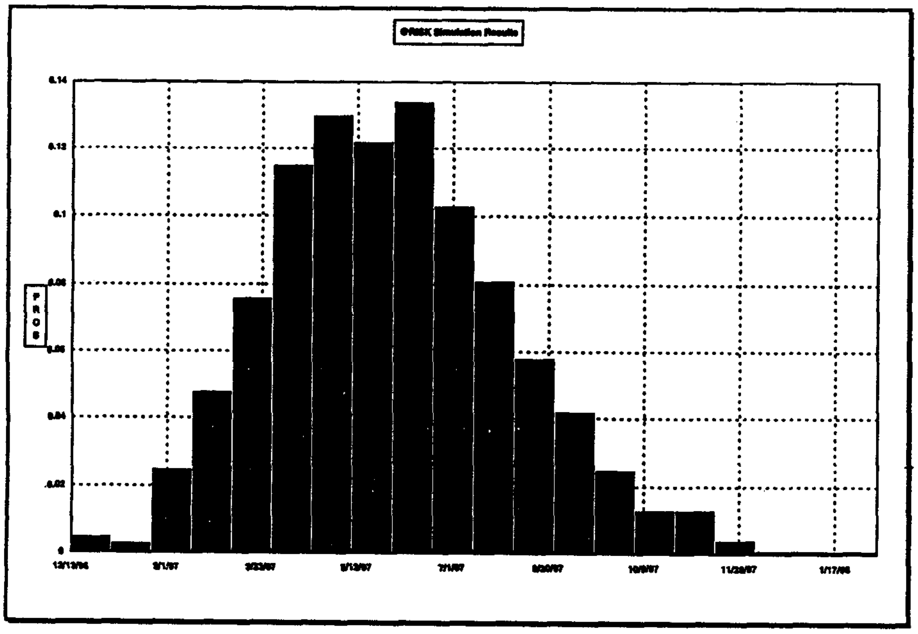
[24] *Risk variables* are activity durations.

[25] Summary statistics are reported by extension.

EXHIBIT 4-24
Statistical Results of Probabilistic Schedule Analysis for Design-Build Contract





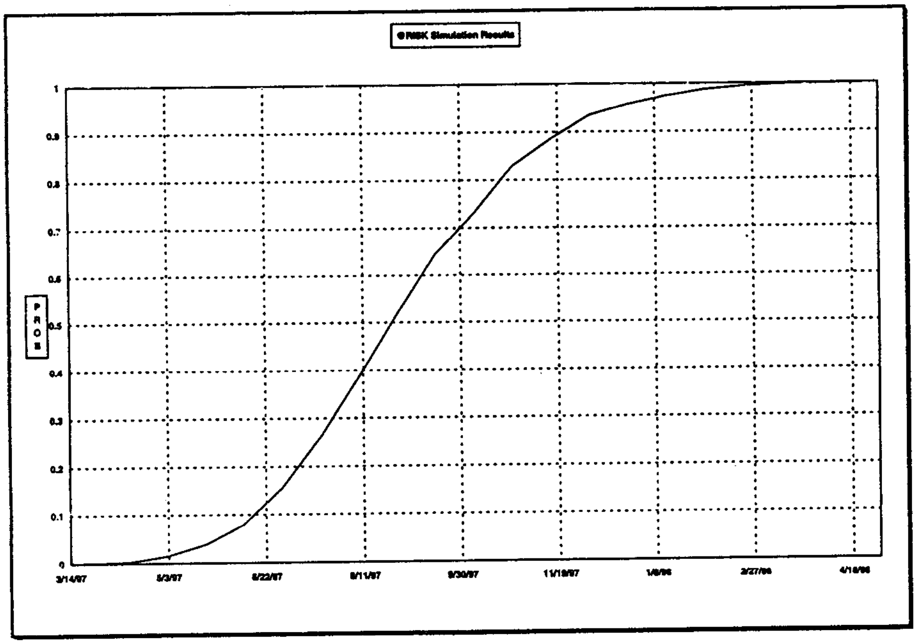
Design-Build Summary Schedule Statistics

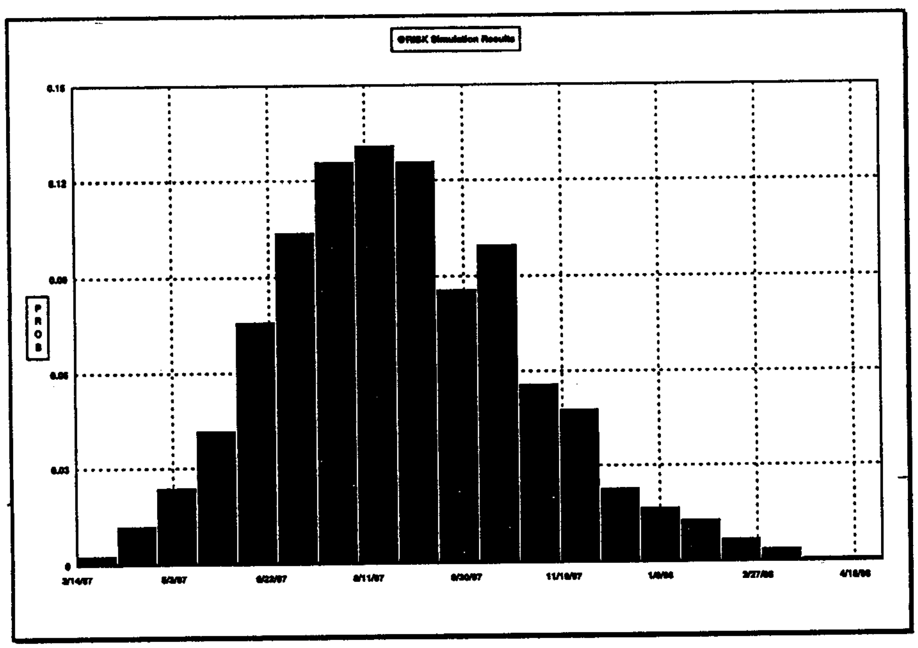
Statistic	Value
Trials	1,000
Mean	5-30-97
Standard Deviation	63.12 days
Range Minimum	12-14-96
Range Maximum	2-6-98

Cumulative Forecast for Design-Build

Percentile	Dates
0%	12-14-96
10%	3-14-97
20%	4-7-97
30%	4-24-97
40%	5-9-97
50%	5-26-97
60%	6-12-97
70%	6-30-97
80%	7-21-97
90%	8-20-97
100%	2-6-98

EXHIBIT 4-25
Statistical Results of Probabilistic Schedule Analysis for Total Project





Total Project Schedule Statistics

Statistic	Value
Trials	1,000
Mean	8-28-97
Standard Deviation	64.74 days
Range of Minimum	3-14-97
Range of Maximum	4-30-98

Cumulative Forecast for Total Project

Percentile	Dates
0%	3-14-97
10%	6-10-97
20%	7-4-97
30%	7-20-97
40%	8-8-97
50%	8-23-97
60%	9-8-97
70%	9-29-97
80%	10-19-97
90%	11-21-97
100%	4-30-98

Exhibit 4-24 shows May 30, 1997 as the expected completion date for the Whiting-Turner contract. This date is the expected value or mean of the distribution, and it represents a three-month project delay from the current MTA estimate of February 21, 1997 for completion of the design-build contract. The cumulative distribution function (CDF) in Exhibit 4-24 identifies a probability of approximately 53% (slightly better than even) for completing the design-build contract by May 30, 1997. The 75% confidence level for the design-build contract completion date is July 9, 1997. This date would result in almost a five-month delay.

Exhibit 4-25 gives the CDF for total project duration, and the date when the project is expected to be open for revenue service. The expected value for revenue service is August 28, 1997, again providing a 53% or better-than-even chance for project completion by that date. This date would represent a 3.5 month delay relative to the current MTA forecast for revenue service, May 17, 1997. A pessimistic estimate for revenue service would be the 90% level, or November 21, 1997.

It bears emphasis that ranges were chosen for this probabilistic analysis with minimal information regarding the method used by MTA in creating its activity durations. Also, a Level 01 network which shows predecessor and successor activity relationships was unavailable from MTA[26] for purposes of this case study; a CPM[27] was created for the purpose of this analysis by Dr. Touran, using PMOC information and summary barcharts which were provided by MTA. Due to these obstacles, the ranges used for the probabilistic analysis may be relatively conservative or pessimistic, and, therefore, more risk (duration) may have been introduced into the analysis. In order to capture turnkey approach characteristics, the constructed CPM uses overlaps for traditionally consecutive activities. Notably, 30 days overlap was used between Systems Design and System Design/Fabrication/ Delivery; 60 days overlap was used between Civil Design and Civil Trackwork Construction. In summary, the durations used to perform the probabilistic schedule estimate were conservative; however, it is believed that this is reasonable due to the lack of complete information.

4.4.2.2 Activity Criticality Indexes

Criticality indexes were calculated for all activities that had potential for variation. Criticality index is a ratio between 0 and 1.0 which gives the probability of a specific activity being on the critical path. Exhibit 4-26 shows the criticality indexes for many of the Phase II activities. For example, activity HNC4 (Civil/Trackwork Construction for the Hunt Valley north of Conrail alignment) has a criticality index of 0.299. This means that out of 1,000 iterations, this activity was on the critical path 299 times. The higher the criticality index of an activity, the larger the probability that it may affect the project duration.

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[26] MTA did provide such a Level 01 barchart report from the Whiting-Turner *Primavera* scheduling system, but, notwithstanding the combined efforts of the study consultants, the schedule relationships could not be readily determined from this report.

[27] CPM designates critical path method, or any time-phased network which may be used to status and interpret identified project activities.

EXHIBIT 4-26
Activity Criticality Indexes for Project Schedule

Activity	Criticality Index
BWI Civil Design	0.221
HV (N.C.)* Civil Design	0.405
Penn Civil Design	0.240
HV (C)** Civil Design	0.133
BWI System Design	0.109
HV (N.C.) Civil Design	0.106
Penn System Design	0.036
HV (C.) System Design	0.133
BWI Civil Construction	0.112
HV (N.C.) Civil Construction	0.299
Penn Civil Construction	0.204
HV (C.) Civil Construction	0
BWI Sys. Des/Fab/Del.	0.099
HV (N.C.) Des/Fab/Del.	0.097
Penn Des/Fab/Del.	0.024
HV (C.) Des/Fab/Del.	0.127
BWI System Installation	0.211
HV (N.C.) System Installation	0.396
Penn System Installation	0.228
HV (C.) System Installation	0.127

* Hunt Valley North of Conrail Alignment
** Hunt Valley Conrail Alignment

In the Critical Path Method used for this probabilistic analysis, because the length of the four paths are close, several activities from different paths have the potential to become critical and impact the project duration. Because of this, no one path is critical most of the time. This makes the schedule vulnerable to delays because the number of critical activities is relatively large. Exhibit 4-26 is a convenient tool to identify the more critical activities. These include:

- Civil design in all three extensions;
- Civil/trackwork construction in Penn Station and Hunt Valley (north of Conrail); and
- Equipment system installation in all three extensions.

The path showing the highest degree of criticality (risk) is the Hunt Valley north of Conrail alignment, due to its length and number of critical activities. Penn Station is also highly critical, mainly because of the uncertainty involved in the bridge design and construction.[28]

4.5 MTA CASE CONCLUSIONS

The results of the MTA probabilistic risk analysis are twofold:

- The design-build contract will *probably* overrun schedule; and
- The total project will *probably not* overrun cost.

The Phase II project has substantial cost contingencies[29], and the worse-case scenario appears to be a five-month delay for the Whiting-Turner work. If this delay occurs, then approximately $1.7 million in field and home office indirect cost burden[30] will be assessed the owner (MTA), in the probable event that the delay is owner-initiated; even so, the project's $5.8 million design-build contingency is more than adequate to cover this cost assessment. The study finds that there is a 92% level of confidence that Whiting-Turner will meet its total budget of $61.6 million.

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[28] This elevated structure had to be re-designed four times prior to construction.

[29] This reference is to both *allocated* and *unallocated* contingencies.

[30] Research has shown that for contracts which are on the same cost scale as Phase II, indirect cost assessment due to owner-initiated schedule overrun would approximate this level:

$3 thousand per day General & Administrative expense plus $8 thousand per day field overhead expense = $11 thousand per day x 150 days = $1.7 million.

The two case conclusions, however, must be considered independently. That is, the results for cost and schedule cannot be related. Conditional probabilities would be needed to demonstrate results of this nature, and such an effort is beyond the scope of this study. However, the point can legitimately be made that the cost profile (cost analysis) *does* take into consideration the risk of schedule overruns. That is, the variability which is modeled in the cost analysis includes the effect of schedule delays.

Overall, results of the probabilistic analysis show that the Phase II project may be characterized as having low risk. The risk associated with construction of the aerial structure at Penn Station, which is Phase II's most highly variable activity, is diluted by the longer critical path for the Hunt Valley segment. Moreover, the only construction modification which is foreseen at this time, $75,000 for tactile edges, is easily covered in the existing contingencies.

The case concludes that, although there is a good chance that the Whiting-Turner design-build contract will overrun its 760-day schedule, there is a 96% probability that the MTA Phase II project will be completed within its total budget of $106.34 million. This probabilistic risk analysis has employed data sources and techniques which are fully documented in this report.

5.0 OBSERVATIONS AND RECOMMENDATIONS

The two case studies provided an opportunity to observe turnkey procurement in practice. The Extend Alternate Runway project affords a close look at military design-build contracting. The Maryland Mass Transit Administration (MTA) Phase II project demonstrates public sector transit design-build. This section provides case observations and study recommendations which are based on the background material for the Tinker Air Force Base project, and the cost and schedule risk analysis which was performed for MTA Phase II.

5.1 OBSERVATIONS

Turnkey contracting affords an owner-agency some significant advantages in the contemporary market for large and complex construction procurement. By overlapping design and construction activities, which are traditionally done sequentially, the total project duration will be shortened. This is a major advantage of turnkey contracting. However, turnkey is still a novel approach for the public sector. As a result of conducting the probabilistic risk analysis described in this report, the following observations[1] apply:

Turnkey holds less potential for litigation for the owner-agency. By using a turnkey approach, the number of potential claims (lawsuits) is likely to be reduced, since the contractor has responsibility for the final design and therefore cannot claim a changed condition or design error due to design incompleteness. Design autonomy is normally present in the traditional design-bid-build approach; with design-build, final design activities are often performed simultaneously with construction activities by one contractor, and so turnkey affords less potential for litigation for the owner, with respect to claims related to design liability, professional ethics, and innovation in the project's design. Due to the apparent diminished likelihood of claims and litigation, participants in the two case studies noted that turnkey in fact holds promise for greater constructability, as well as increased creativity in the areas of design, methods, and materials.

For turnkey risk analysis, the focus is needed at the bid phase. Turnkey procurement is essentially *risk diversification* for the owner. That is, risk is transferred from the owner to the contractor; this risk is expressed in the bid and in the contract via "risk premium" rates, or contingencies. The onus is on the project owner (public agency) to ensure that the project is adequately defined, and that the project budget, including all design-build line items, is accurate and fair. With turnkey, the contractor will rigorously assess its own contingencies for the design-build portion of the project. The bid phase is the critical time when the owner and contractor will allocate and quantify all definable project risks. The final project budget is the result of this phase. Optimally, complete or advanced preliminary design is available at bid time to facilitate accurate risk diversification. The two case studies

[1] These observations are based on the two case studies described in this report, and are not intended to convey factual evidence or scientific (sample) findings.

show that guidance for project definition and risk allocation at bid time should include the following information:

- Alignment specifications through preliminary design;
- As-built information for existing work (cost and technical);
- Right-of-way limits and restrictions, including access;
- Public and private utility locations;
- Geotechnical information;
- Work to be performed by others (scope and schedule);
- Identification of known hazardous materials;
- Limitations of construction activities (hours, noise, and traffic impacts, etc.); and
- Third party agreement and permit requirements.

Once the turnkey project is defined and risks are allocated (i.e., contingencies are set by the owner, and the project budget is firm), the emphasis in bid-phase turnkey is the financial capability of the contractor to remain solvent and to perform the work. Normally, the owner is covered by a surety payment and performance bond for the contractor, and so this risk is therefore "assigned" or removed from the owner.

Quality Assurance/Quality Control (QA/QC) activities are critical for turnkey. The QA/QC function was critical to contractor evaluation and selection, for both case studies in this report. With turnkey, the owner sees the contractor as the most reasonable party to check the construction process, since the contractor has done the final design. Owner-audits and spot field inspections are relied on to oversee the contractor's work. In the case of MTA, the owner maintains a unilateral right to dismiss the contractor's QA/QC staff. QA/QC for design includes checking and review procedures used to ascertain that contract documents are error free and meet client and code requirements; for the construction phase, QA/QC includes documentation of all operations, activities, tests and inspections (preparatory, initial, and follow-up), including the work of any subcontractor. Owner spot-checks and field inspections are critical for projects where QA/QC tasks are mainly performed by the contractor.

Project control and project oversight decisions are critical for turnkey. In order for the owner-agency to realize the positive benefits of risk diversification in turnkey contracting, there needs to be in place a formalized project management control system for the project, which has the ability to (1) control the contractor, and (2) forecast scope and schedule changes. The project control system should yield real-time variance reports and impact analyses, as the project progresses, and should be linked to contractor pay authorization. The Tinker Air Force Base case study came closest to demonstrating such a system, with its formalized system of stepped Notices to Proceed (NTPs) prior to authorizing construction, and in its requirement for a cost-loaded network (includes the ability to quantify schedule variance) as the basis for contractor payment.

Schedule impacts are a key variable for turnkey risk. Contractor schedule efficiencies (effective overlap, and time and material economies-of-scale) and schedule problems (weather, geotechnical conditions, vendor difficulties, and right-of-way/permit/utilities/agency obstacles are all to be expected with turnkey) may impact the turnkey project budget in a major way. Risk diversification occurs rigorously and "up front" for turnkey procurement, and this process results in generally adequate line-item contingencies for both owner and contractor. Schedule risk, on the other hand, is a major and ongoing consideration for turnkey contracting. Construction lead times are frequently very difficult to anticipate. Both case studies demonstrate the importance of schedule risk for turnkey, by the inclusion of substantial liquidated damages clauses for schedule overruns.

5.2 STUDY RECOMMENDATIONS

Turnkey contracting exposes the public project owner to a measure of uncertainty or risk, primarily because the method is relatively new to the contemporary public sector. Although some significant older public works projects were built through turnkey contracting[2], the concept has re-emerged in current times because public funds for new starts and extensions are in great demand, and are therefore scarce. It is estimated that turnkey contracting can save as much as 50% of the cost of a conventional project: "A rule of thumb says that 30% time savings generate some 10% cost savings. In addition, based on the shorter execution time, idle working capital can be reduced."[3]

Due to the uncertainties *(risk)* present in turnkey contracting for the public sector, it is important to make sure that this method is adapted to fit the public project owner's unique conditions and specific project objectives. Over time, turnkey contracting for public transit will form a valuable repository or database of factual information pertinent to contemporary public sector turnkey contracting. The Federal Transit Administration (FTA) Turnkey Demonstration Program will greatly assist efforts to document risk and offer risk-avoidance and risk-analysis strategies for future turnkey contractors. Recommendations from this study are as follows:

Document "Lessons Learned" for the turnkey project, while work is in progress. With the turnkey approach, which is relatively new for the public sector, the owner needs to be especially aware of risk assessment as the project is unfolding. Although turnkey presents some important potential advantages for the agency-owner, it is a non-traditional contracting method which is being re-introduced and newly-integrated into the public works arena; and so the opportunity cannot be missed to observe and chronologue significant events and outcomes

[2] The Brooklyn Bridge and New York subway lines (IRT and BMT lines) are examples of older public works turnkey projects. More recently, the Federal Railroad Administration's electrification of the Boston-New Haven, CT segment of the Northeast Corridor was a turnkey contract.

[3] Metro Magazine, July/August, 1995, p. 60.

which will unfold with its current implementation. Several critical areas which would particularly benefit from such timely documentation are:

(1) ***The reconciliation of owner and contractor management systems.*** Project reviews (meetings and documentation) and inspections are normally performed by the owner, under traditional contracting. With turnkey, the owner has authority, but is farther removed from project operations than in traditional contracting. This configuration can either introduce risk, or reduce it. How the integration of owner/contractor management systems is being played out in practice, is extremely critical information in this early stage of turnkey's use in the public sector. Related to this is the need for reliable documentation of owner experience with project oversight staff level (number of staff and mix of owner/contractor responsibilities).

(2) ***The follow-through which takes place by owner and contractor, for each of the design disciplines.*** Two clear differences in turnkey contracting are the assignment of final design risk to the contractor, and the overlap of design and construction activities in project operations. Documentation needs to capture the experience of the owner, who is now the recipient of "packaged" design services. Under traditional contracting methods, the designer is an independent architectural and engineering firm, and has a service-oriented relationship with the owner; in turnkey, design is integrated into the construction activities, and the owner can assume roles ranging from observer to detailed approver.

(3) ***Experience with contractor incentives and penalties.*** Risk assessment and risk mitigation are new sciences in public sector turnkey contracting. Both cases employed in this study utilized liquidated damages to ensure contractor compliance in critical areas of project performance.[4] Only the Extend Alternate Runway project used contractor incentives, these being in the form of value engineering or cost reduction proposals, which the contractor had an option to submit during final design. Sverdrup Civil, the design-build contractor, will share in the estimated cost savings if the value engineering is approved by the Air Force (the owner). Documentation is needed to describe project experience with turnkey contractor incentives and penalties. Most contractor time is spent developing cost reduction proposals and in planning to avoid liquidated damage assessments. Owners will need to perform cost-benefit analysis for project efforts, including describing time spent by both the contractor and the owner in the development of cost-saving plans, and the actual estimated savings which are achieved.

[4] For the Tinker Air Force Base Extend Alternate Runway project, liquidated damages will be assessed upon late completion of the runway intersection segment, which is currently scheduled for August 1996; for MTA Phase II, liquidated damages occur only for late final completion of the total design-build project.

Direct more risk mitigation activities to the turnkey bid period. The owner should develop a bid breakdown for the design-build contractor, to include with the "two-step" or low-bidder proposal process. The bid breakdown would detail and summarize the owner's conceptual estimate (the engineer's estimate), and would enable direct comparison between the bid(s) and the owner's estimate. This document (bid breakdown) would also serve as the basis for contract negotiations leading to contract award, and then later would perform a project control function, measuring contractor performance and predicting trends. In the Extend Alternate Runway project, the U.S. Army Corps of Engineers requires the design-build contractor to prepare and submit a cost-loaded network prior to pay authorization, but this study finds that although this documentation is sufficient to monitor the ongoing operations of the project, its weakness lies in the fact that it (1) is prepared solely by the contractor, and (2) may bear little relationship to the project bid specifications (owner's estimate). For turnkey, as with traditional contracting methods, it is the owner's responsibility to ensure that the contractor's schedule conforms to the owner's estimate. The study recommends that owners have a "barometer" (bid breakdown, above) so that proactive management measures can be implemented in a timely manner, and that significant budget and schedule variances can be anticipated. The sooner a problem is identified or a negative trend realized, the greater is the likelihood that the issue can be dealt with *before* it becomes major, or gives rise to a claim. By breaking down the owner's estimate, and ultimately the design-build contractor's bid, into discrete areas of work responsibility; the owner will be able to predict and explain the potential delay in the schedule, and therefore the final cost and duration of the project.

Right-of-way acquisitions, utility relocations, and third-party requirements are still the largest risk factors to be dealt with by owners (absent complex geotechnical concerns regarding earthwork or tunneling), and attention should be given at bid time to an adequate definition of these specifications, and an equitable risk assignment in these volatile areas. Greater definition of risk in the bid document will yield a better estimate by the turnkey contractor, with subsequent negotiations more likely to bring the project within budget. Finally, allocated and unallocated contingencies can be understood and distributed with relative ease, the greater the degree of work and risk definition which is contained in the bid.

Turnkey should be tailored to the project, and to prevailing local or regional conditions. There appears to be no single "best" method for turnkey contracting. For complex projects, a hybrid approach may best suit the total situation. For the MTA Phase II project (a complex project), the turnkey contractor, though a single entity, shared much of the risk with the owner. This risk sharing occurred mainly in the area of "soft cost." Much uncertainty in the normally risk-prone areas of utility relocations, real estate acquisition, public agency commitments, and permits was removed from the turnkey contractor by MTA. This is an example of hybrid turnkey, where, due to the complexity of the project, the owner (or another contractor) assumes much of the project uncertainty, and the turnkey contractor comes in and completes the design and builds the guideway. For many linear projects, such as the Extend Alternate Runway project at Tinker Air Force Base, a classic turnkey approach can generally be used, where the turnkey contractor is the sole point of reference for virtually all activities which are required to final-design and build the project. Some projects may also be suited for a "superturnkey" process, where a single contractor builds the project and operates it for a period of time, then transfers the facility to the owner. With superturnkey, the contractor may also arrange for and even sponsor the project's capital funding.

The study recommends that government and owner consideration should also be given to small business participation in turnkey, and that the concept of re-competing large, multi-year sole-source awards be reviewed by FTA, to better realize economic price efficiencies for turnkey.

6.0 SUMMARY AND CONCLUSIONS

This chapter summarizes the case studies conducted of two large turnkey construction projects, and the probabilistic risk analysis study conducted on one of the projects. The major findings, observations, and conclusions of the study are also summarized.

6.1 SUMMARY

This study examined two large turnkey construction projects, in an effort to demonstrate the usefulness of probabilistic risk analysis for publicly funded transit infrastructure development. The two projects studied were the Tinker Air Force Base Extend Alternate Runway project, and the Baltimore Central Light Rail Extension, Phase II. An in-depth probabilistic risk analysis was carried out for the schedule and costs of the Baltimore Mass Transit Administration (MTA) project, while the Tinker Air Force Base project was studied generally.

6.2 CONCLUSIONS

The conclusions of the study fall into several areas, including findings regarding the two projects studied, findings regarding the turnkey approach, and findings regarding the utility of probabilistic risk analysis as a method of measuring the risk associated with large, complex transit construction projects. All three sets of findings are discussed below. Finally, future studies to confirm and extend the results of this study are recommended.

6.2.1 Findings Regarding the Two Projects Studied

Because the two projects in the case studies were very different in themselves, and because the study approaches were different, the findings regarding the projects are best reported separately.

Findings of the Tinker Air Force Base Case Study. The study of the Tinker Air Force Base project showed that the U.S. Army Corps of Engineers has taken a formalized and highly disciplined approach to risk analysis. The project was carefully defined before bidding, and contingencies were carefully studied prior to contract award. Nevertheless, design review is still an area of uncertainty for the Corps, as shown by the frequent adjustments made to the contractor Notice to Proceed (NTP) criteria.

Findings of the Baltimore Central Light Rail Line, Phase II Case Study. Because more data was available for the Baltimore MTA project, it was possible to conduct a formal probabilistic risk analysis as part of this study. The Phase II case study showed that the project incorporates low risk, with some contractor schedule overrun likely, but with a very low probability for total project cost overrun. Much effort was put into assessing the uncertainties associated with the individual task schedules and costs, and agreement was reached on an acceptable model to perform the probabilistic estimate.

6.2.2 Findings Regarding the Turnkey Approach

The use of the turnkey approach can lead to time savings, and therefore cost savings, over traditional design-bid-build contracting. Significant time savings come from eliminating one contract bidding cycle, because with turnkey a single contract is used for both design and build phases. Also, the turnkey contractor can optimize the work schedule by overlapping the design and construction phases. For example, the MTA project schedule conservatively assumes a 60-day overlap between civil design and construction, and a 30-day overlap between system design and system procurement.

The turnkey approach can also resolve some operational problems which have usually complicated traditional transit construction projects. For example, coordination between the systems contractor and the civil contractor has at times caused problems in traditional projects. In turnkey, since one contractor is responsible for all aspects of the project, these coordination problems can be prevented or resolved faster.

Procurement, installation, and testing of electrical systems (catenary and power supply, signals, and communication) will, normally, critically affect the schedule in transit projects, and have many times caused delays. In the turnkey approach, the contractor is usually responsible for systems final design, and therefore has more flexibility regarding planning for the required lead times, and for coordinating these activities. These characteristics of turnkey should all help to reduce the risk of purchasing, installing, and testing complex transit systems.

Because the turnkey approach is relatively new and untested in public projects, risk measurement and risk mitigation (risk analysis) is for this reason especially important for turnkey at this time. A distinguishing feature of turnkey is that risk assessment is mainly focused on the bid stage, with risk diversification accomplished during the critical initial period of the project, when budget and schedule are being established by the owner and the contractor. Some methods for mitigating risk in a turnkey project which is underway, and which hold application for probabilistic risk analysis, are:

- Implementing quality assurance and quality control;
- Maintaining good project oversight and control; and
- Investigating contractor incentives and penalties.

6.2.3 Findings Regarding the Use of Probabilistic Risk Analysis for Construction Project Risk Analysis

The application of probabilistic risk analysis to the MTA Phase II project demonstrated that probabilistic risk analysis produces useful results and insights at several stages of a turnkey project. Because the Monte Carlo simulation method of risk analysis simultaneously handles many variables and variable interdependencies, applying probabilistic risk analysis at project bid time yields important information regarding the estimated dimensions of project risk (relative and cumulative probabilities for cost and schedule overrun), and the relative criticality of tasks during the early stages of the project. A probabilistic forecast of the uncertainty (risk) associated with each project task enables project managers to better evaluate large turnkey bids, and, through the assignment and negotiation of risk premiums (project contingencies), to subsequently allocate total project risk between owner and contractor.

The results of probabilistic risk analysis are also a highly effective means of communicating risk between the partners involved in a collaborative turnkey project. The variables and the methodology underlying a model are clearly defined, and the graphic outputs of probabilistic analysis are clear and amenable to easy understanding. Models can easily be updated to incorporate actual results for the completed portions of a project, and re-run quickly. Therefore the collaborative interpretation and discussion of the subjective implications of the results can become the focus of meetings between project participants, leading to more effective risk communication and risk mitigation.

The probabilistic method is extremely well suited to owner-based project control and oversight activities. This study recommends that project controls for turnkey be rigorous and owner-based, to ensure contractor delivery of a quality product, on time. Project financial summaries (spreadsheets) and cost-loaded networks (schedules) may be periodically modeled probabilistically[1], in order to accurately status the work and authorize payment for the contractor. The process for and results of such regular probabilistic estimating will ensure that the owner keeps abreast of project operations, as well as budget and schedule status.

6.2.4 Further Assessment of Probabilistic Risk Analysis in Turnkey Projects: Future Studies

There is much value in using probabilistic risk analysis for turnkey public sector construction applications. As a risk measurement and risk communication tool, probabilistic estimating is a powerful management resource. Collaborative decision-making is facilitated by simultaneous consideration of key decision variables, which are each modeled within an appropriate probability distribution, and then analyzed through simulation to yield the probabilistic results. The main obstacles to owner implementation appear to be: (1) understanding probabilistic concepts, at a practitioner's level; (2) acquiring the appropriate software to perform the analysis; and (3) training staff in the method.

The relatively small investments of training time and technology, needed to bring probabilistic capability "on-line," are quickly recouped through the long-term acquisition of superior risk analysis and, therefore, greater vision into and control over a capital project's

[1] This implies a process, described elsewhere in the study, of defining critical risk variables, and identifying ranges and probability distributions for them.

complex implementation. The Federal Transit Administration (FTA) Turnkey Demonstration Program will further evaluate turnkey projects for their suitability in developing this special expertise. Viable future studies include:

- Following the Baltimore Central Light Rail Line Phase II project by comparing the actual cost and schedule outcome, to the outcomes predicted in this study by the Abacus Technology probabilistic risk analysis. As part of this follow-up study, capture the actual schedule and costs at one or more milestone points in time, and re-run the probabilistic analysis on the remaining portion of the project.

- Conducting probabilistic risk analysis on the predicted costs and schedules of several comparable transit projects, some turnkey and some traditional. Compare the level of risk and the outcomes of the two sets of projects.

This study finds that risk measurement is simply the first step in turnkey risk mitigation. Review of project management techniques, and risk communication for turnkey projects are the logical follow-on to risk measurement and risk analysis.

Future study of risk analysis for turnkey construction should focus in particular on how *risk communication* is affected with use of the probabilistic method. In its ability to model events simultaneously and to graphically convey cumulative probabilistic results, probabilistic risk analysis is clearly "a natural" to foster collaborative and efficient decision-making. Project stakeholders need an early, clear grasp of a wide range of key variables in order to effectively proceed through all stages of the capital planning process, or Major Investment Study (MIS). Probabilistic risk analysis facilitates understanding of project complexities *over time*, and enables stakeholders to "model" their ideas and then see their combined outcomes, or probabilistic result. Confrontation over results is minimized or eliminated with use of the method, since the input process is collaborative by definition, and the output really represents the results of the probabilistic simulation, not someone's specific "what if" entry to gauge a new bottom line.

Probabilistic results are valuable for decision-makers: Will a project sustain a decline in the tax base? Are local funding sources able to meet debt coverage in the early years of project operation? These and many, many other questions are both fielded and generated through use of the probabilistic method in a public works planning forum.

In conclusion, this study establishes a base of credibility for probabilistic risk analysis, in the specific context of capital transit planning. The turnkey construction contracting method is also utilized in this study, because of its relative newness in the public sector, and therefore its greater potential for uncertainty or *risk* in successive phases of project development and implementation. Further study is now needed to assess the cost and schedule outcomes for the MTA Phase II central light rail extension project, relative to the forecast presented in the study; and study is needed to examine the impact of probabilistic risk analysis for project management techniques, and, especially, for risk communication practices in public transit capital development.

GLOSSARY

Absolute Value - The positive (non-negative) value of a mathematical term, e.g., the *absolute value* of -(10x+4) is 10x+4.

Allocated Contingency - A risk premium, or contingency amount, that is distributed to (included in) specific project cost line items.

Beta Distribution - A unimodal distribution with confined lower and upper bounds; shape can be asymmetrical, and depends on the particular distribution.

Coefficient of Variation - A measure of relative dispersion within a probability distribution. The *coefficient of variation* is the standard deviation of the probability distribution divided by its expected value (mean). This coefficient serves as a measure of relative risk.

Conceptual Cost - The owner's preliminary estimate of the total cost of design and construction. This estimate may serve as the basis for contract bid evaluation.

Confidence Interval - The probability (zero to 100 percent) that an observed value is the true or actual value. The *confidence interval*, expressed as a percent, is used to interpret the output or results of a probabilistic analysis.

Configuration Management - Design controls for quality assurance in a construction project; management of a project's initial design, through changes to completion.

Contingency - A risk premium factor or amount that is added to the project budget and/or the schedule, by any party to the contract, to allow/compensate for uncertainty or *risk* in project implementation.

Construction Risk - Risk associated with the physical construction phase of project development; for example, *construction risk* is differentiated from economic risk (loss of project income due to unpredictably low ridership or poor tax base) and political risk (project may be shelved due to new constituent representation).

Cost-Benefit Analysis - Economic analysis used to forecast the net value, usually over time, for a series of capital payments or revenue/cash flow related to project implementation.

Cost Escalation Factor - An inflation-adjustment factor applied to base year costs.

Cost Index - An inflation-adjustment factor applied to non-base year costs.

Critical Path - The longest path in a schedule of duration-defined activities.

Critical Variable - A cost or schedule element that is highly variable or is characterized by much uncertainty, and therefore carries greater risk than other, more predictable, project variables.

Criticality Index - A value between zero and 1.0 which describes the probability of a specific project activity being on the critical path. The *criticality index* is the ratio of the number of times an activity was on the critical path, to the total number of simulation runs.

Cumulative Distribution Function - The zero to 100 percent successive probability for each observed value in a probability distribution. Cumulative probability functions (CDFs) are normally used to express the total probability (zero to 100 percent) for a specified level of output variables (cost and schedule variables) following the probabilistic simulation analysis.

Design-Bid-Build - Traditional contracting method for a construction project, in which the design and (various) construction phases of the project are bid and performed by separate independent prime contractors, with close owner oversight.

Design-Build - Innovative contracting method, also known as *turnkey*, which allows for a single prime contractor to bid, design, and construct the project, with limited owner oversight.

Deterministic Method - Cost estimation method which allows for successive iteration of projected or estimated values, each yielding or "determining" a new bottom line.

Draft Environmental Impact Statement (DEIS) - National Environmental Protection Act documentation (NEPA, Title 23 Code of Federal Regulations, August 28, 1987) which evaluates (all) reasonable alternatives to transit infrastructure options which are specifically under consideration in the transit planning process for the region. *DEIS* is prepared when a determination is made that a transit construction project will cause significant impact to the human or natural environment. *DEIS* must be circulated for comment on behalf of the FTA or FHWA, to public officials, interest groups, and members of the public who are known to have an interest in the proposed actions.

Environmental Assessment (EA) - National Environmental Protection Act (NEPA, 1987) documentation which is required for proposed transit infrastructure options in cases where the significance of the environmental impact is not clearly established. When a determination is made in the transit infrastructure planning process that a proposed project is likely to cause significant impact to the human or natural environment, then DEIS and FEIS must be prepared by the agency applicant in lieu of *EA*.

Extended Payment Terms - Financing method which leverages existing project capital funds, by allowing a longer payback period and, usually, a cap on the interest rate.

Final Environmental Impact Statement (FEIS) - National Environmental Protection Act documentation (NEPA, Title 23 Code of Federal Regulations, August 28, 1987) which is prepared following circulation of DEIS. *FEIS* identifies the preferred transit alternative, and discusses substantive comments received on the DEIS. *FEIS* describes the mitigation measures that are to be incorporated into the proposed action; mitigation measures presented as commitments in the FEIS must be incorporated into the project as specified.

Fixed Guideway - Any permanent mode of capital transit infrastructure which requires facility construction prior to operation, such as rapid transit, commuter rail, trolley route/stations, and dedicated busway.

Histogram - A relative frequency polygon, or bar-chart, which shows discrete non-cumulative probabilities for all points in a probability distribution.

ISTEA - Intermodal Surface Transportation Efficiency Act, signed into law by President Bush in December 1991. The Act provides for the authorization of $155 billion in Federal monies from FY 1992 - FY 1997.

Iterate - To perform successive analyses, using the results of each test as the basis for the next round.

Joint Development - An agreement in which joint financing and development of a project or group of projects, is undertaken by both the owner and the developer.

Lognormal Distribution - A unimodal distribution that can take only positive values, and is skewed or "slanted" to the right.

Major Investment Study - *MIS*, the FTA/FHWA capital planning process for transportation infrastructure projects. *MIS* integrates the planning and environmental (NEPA) processes, and evaluates the overall effectiveness and cost-effectiveness of alternative investment strategies for U.S. transportation infrastructure. The purpose of *MIS* is to address substantial transportation problems, analyze solutions, and present this information to decision-makers who are "stakeholders" to the process, or vested parties. *MIS* considers factors such as direct and indirect costs of the alternatives; mobility and accessability improvements; and (any) foreseen impacts on social, economic, environmental, and safety aspects of the region, as well as project operating efficiencies, land use, financing, and energy consumption. Project scope, and conceptual and preliminary design are the end result of *MIS*, through a regionally-specific process of analysis and collaborative public involvement.

Monte Carlo Simulation - A computerized technique which is the basis for probabilistic risk analysis, and which replicates real life occurrences by mathematically modeling a projected event. Monte Carlo simulation uses pre-defined probability distributions of risk variables to perform random modeling over many "simulations" or computer trials. The results are probabilistic (they form a probability distribution) and therefore yield an expected value (mean) and a standard deviation, as well as cumulative probabilities (zero to 100 percent) which express total likelihood (probability) at any level of variable outcome.

Multivariate - An analytical technique that considers or solves for multiple (more than one) decision variables.

Non-Traditional Procurement - Construction contracting method such as turnkey or design-build, which avoids the traditional approach of awarding separate contracts for the design and construction phases, but instead awards responsibility for both phases to one contractor.

Notice-to-Proceed - Contractual authorization (usually proceeds from the project owner or funding agency) to start work, or to fulfill a specified contracting scope.

Ogive - A cumulative frequency polygon (distribution curve) which begins at zero and ends at 100 percent probability for the data points in the distribution.

PERT Method - Program Evaluation and Review Technique, a probabilistic network-based scheduling technique in which a beta distribution is used to model activity durations. 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.

Preliminary Design - A construction project's configuration drawings and methods specifications up to approximately the 30 percent level of completedness, or at a (similar) level which allows for final design and construction bidding to proceed.

Probability Density Function - A relative frequency curve which shows the total area (100 percent) of all data points contained in the distribution.

Probability Distribution - A distribution, input or output, of data point probabilities (can be discrete or continuous) which describe the probability of occurrence of all data points in the distribution. Probability distributions take many various shapes, and are each characterized by a mean (average) and a standard deviation (measure of internal variation). A normal probability distribution is characterized by a symmetrical bell-shaped curve.

Probabilistic Estimate - The result of a probabilistic risk analysis; a forecast for modeled cost or schedule events, which is the result of probabilistic or random simulation.

Probabilistic Risk Analysis - An analysis based on computer simulation, which uses pre-defined probability distributions to model input variables for project cost and schedule. The input variables are cost and schedule variables which possess a high degree of uncertainty. This uncertainty is expressed through "ranging" the variables, or defining their bounds according to the data points required by the input distributions. For example, triangular distribution requires *high, low*, and *most likely* values. Output variables for cost and schedule duration result from the computer simulation, and are also characterized by probability distributions having means (averages) and standard deviations (measures of internal dispersion). A cumulative distribution function describes the total probability or likelihood of occurrence at any level of output variable (cost or schedule). This technique -- *probabilistic risk analysis* -- requires effective user facilitation, but is a model for collaborative decision-making and risk mitigation.

Project Management Control System - Any method, process, or system which exists to manage project resources, document project activity, or authorize project events.

Quality Assurance/Quality Control - Design and construction review procedures used to validate and document the building of the project to specifications. QA/QC includes tests and inspections, and record keeping protocols to ensure accurate and timely owner authorization(s) of project activity and procurement events.

Random Variables - Computer-generated "y" axis values which, depending on a user-defined probability distribution, randomly generate new "x" values for each trial in a simulation.

Right-of-Way Acquisition - Contractual rights purchased for a project; purpose is to give an owner or contractor the right to use and construct on a specified location which is controlled by a third-party.

@RISK Software - Computer software designed to perform probabilistic risk analysis on a personal computer. @RISK is suitable for spreadsheet or schedule applications. The software allows the user to specify probability distribution type and ranges of variation for activities within the project (critical variables), and then conducts a Monte Carlo random simulation on the specified cost and schedule variables.

Risk - Uncertainty, or the potential for loss resulting from uncertainty.

Risk Allocation - See *Risk Diversification.*

Risk Checklist - A checklist of risk mitigation techniques that is used by project evaluators to manage and reduce the potential for loss in a project.

Risk Communication - The ability to produce and convey modeled outcomes -- deterministic and probabilistic -- to stakeholders in a capital decision-making process.

Risk Diversification - The process of distributing risk to all contractual parties in a construction project; *risk diversification* is normally accomplished through use of contingency amounts, or risk premiums.

Risk Management - The ongoing process of identifying risk, measuring and allocating risk, and mitigating risk. The purpose of *risk management* is to reduce the potential for loss on a project (monetary or other: for example, loss of suppliers; loss of revenue; loss of jobs; loss of lives).

Risk Measurement - The process of objectively and accurately assessing the amount of potential loss in a construction project. *Risk measurement* can be either deterministic (a number) or probabilistic (a percent associated with a number).

Risk Mitigation - The process of removing or reducing risk. *Risk mitigation* may include risk analysis, or other activities designed to assess the results of risk mitigation initiatives.

Risk Premium - Contingency amount(s) included in a construction contract to allocate or compensate for funding/cost and schedule uncertainties which are perceived by the contracting parties to be present in the project.

Risk Variable - A critical or highly variable cost or schedule (duration) element of a construction project.

Soft Costs - Professional service costs that are ancillary to the main construction project, such as design and engineering services, obtaining right-of-way permits, and project management and administration expense.

Stakeholders - Key or "vested" parties to the MIS project planning and decision-making process. *Stakeholders* include project "owners" or governmental representatives who influence and administer public project funding; local, state, and federal agencies who are impacted by the transit plan; elected officials, who represent the voting public and who enact laws to enable project development and project funding; the general public, including representatives of special interest and community groups; the business community, which may partner with government to fund capital transportation projects; and contractors and technical experts, with skills and knowledge unique to the construction process.

Superturnkey - A form of turnkey construction contracting where there is a single contract for design, construction, and initially operating the project in revenue service.

Tornado Graph - A graph which describes the calculated sensitivities of critical variables resulting from a Monte Carlo simulation.

Transit Capital Development - Transit capital infrastructure and fixed guideway construction (includes rail and bus/trolley guideways), and the related capital planning process.

Triangular Distribution - A statistical distribution which requires the identification of *high*, *low*, and *most likely* values for each selected variable. The resultant data points form the basis for the triangular, or three-point distribution.

Turnkey Construction - A public agency contracts with a private entity for delivery of a complete and operational project that will be publicly owned. The goal of turnkey contracting is to conserve public funds and lower project costs by overlapping design and construction activities (therefore saving time), and minimizing contract change orders.

Turnkey Demonstration Program - Ongoing Federal Transit Administration program to review risk management methods, and assess the cost and schedule outcomes for five U.S. transit infrastructure projects which are currently under construction. Impetus for the Turnkey Demonstration Program was provided by ISTEA, and the stated goal of that 1991 legislation to advance new technology and lower the cost of constructing new transit systems. The Turnkey Demonstration Program was announced in the August 13, 1992 *Federal Register*, with a call for Letters of Intent to participate. A national competition was held, and 17 responses were received. The selection criteria were: turnkey demonstration potential; local consensus; financial feasibility; understanding of project risk; management capability; and technical capability. The Baltimore MTA Phase II Central Light Rail Extension project is a participant in the Turnkey Demonstration Program.

Unallocated Contingency - A provisional fund which is formally set aside by the owner or contractor in the construction project budget, to allow for cost overrun and possible revenue shortfalls. The fund is typically set to a percentage of the contract bottom line, and invested in an interest bearing account until it is used.

Uniform Probability Distribution - A "flat curve" probability distribution which is characterized by only two points: a lower bound and an upper bound.

Value Engineering - Design proposal to lower the total project cost of construction.

Vendor Financing - Contractor provides or secures capital for project construction; reimbursement is generally made through progress payments made by the agency owner.

Vibrating the Assumptions - The technique of the Monte Carlo simulation in performing thousands of repetitions or trials of an event using random values. The precision of the approximation improves as the number of trials increases. Thus it is common for each analysis to include thousands of trials.

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APPENDIX A

TINKER AIR FORCE BASE
EXTEND ALTERNATE RUNWAY
DATA

CPM NETWORK MASTER SCHEDULE

The **Tinker Air Force Base Extend and Upgrade Alternate Runway CPM Network Design-Build** ***Master Schedule*** is available upon request at:

(1) U.S. Department of Transportation
Federal Transit Administration
Office of Planning
400 7th Street, S.W., Room 6432
Washington, DC 20590
Contact: Nancy S. Strine, (202) 366-8051

(2) Sverdrup Civil, Inc.
13723 Riverport Drive
Maryland Heights, MO 63043
Contact: Jim Fulk, (314) 770-5108

Extend Alternate Runway
Value-Loaded Schedule by Phase

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	BUDGET	EARNED
100	0	0	100		MILE NOTICE OF AWARD	.00	.00
1001	1	0	100		MILE KICKOFF MEETING	.00	.00
DMS01	0	0	0		MILE DESIGN MILESTONE 1	.00	.00
DMS02	0	0	0		MILE DESIGN MILESTONE 2	.00	.00
DMS03	0	0	0		MILE DESIGN MILESTONE 3	.00	.00
MS04	0	0	0		MILE MILESTONE 4; COMPLETE ALT RUNWAY TO STA 86+00	.00	.00
MS05	0	0	0		MILE MILESTONE 5; COMPLETE MAIN RUNWAY INTERFACE	.00	.00
MS06	0	0	0		MILE MILESTONE 6; COMPLETE CONTRACT	.00	.00
SUBTOTAL						.00	.00

PHASE 1 PART 1 PRELIM DESIGN

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	BUDGET	EARNED
2001	60	60	0	DGN1	COMPLETE 60% REVIEW DOCUMENTS	255480.00	.00
2002	21	21	0	DGN1	USAOE REVIEW 60% DOCUMENTS	.00	.00
2003	2	2	0	DGN1	60% DESIGN REVIEW MEETING	30000.00	.00
2004	10	10	0	DGN1	INCORPERATE 60% REVIEW CHANGES TO DWGS	68793.00	.00
10000	36	36	0	DGN1	COMPLETE 60% ELEC. DESIGN REVIEW	44520.00	.00
SUBTOTAL				001		398793.00	.00

PHASE 2 PART 2 FINAL DESIGN

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	BUDGET	EARNED
3001	1	1	0		DGN2 NTP DESIGN PHASE PART 2	.00	.00
3002	60	60	0		DGN2 COMPLETE 100% DESIGN DRAWINGS	270320.00	.00
3003	2	2	0		DGN2 100% DESIGN REVIEW MEETING	10000.00	.00
3004	21	21	0		DGN2 INCORPERATE CHANGES IN DOCUMENTS	39735.00	.00
10001	40	40	0		DGN2 COMPLETE 100% ELECTRICAL DESIGN DWGS.	29680.00	.00
10002	21	21	0		DGN2 INCORP. CHANGES INTO ELEC. DOCUMENTS	.00	.00
SUBTOTAL				002		349735.00	.00

PHASE 3A. SITE WORK SITE WORK

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	BUDGET	EARNED
3998	1	0	100		CNST FURNISH BID BOND	37163.00	37163.00
3999	1	1	0		MILE NTP CONSTRUCTION	.00	.00
4000	7	7	0		CNST SITE MOBILIZATION	127500.00	.00
4001	10	10	0		CNST CLEAR & GRUB SITE ● BOX CULVERT EXTENSION	19500.00	.00
4002	7	7	0		CNST REROUTE STREAM BED	21250.00	.00
4003	30	30	0		CNST PREPARE SUB BASE FOR BOX CULVERT	27500.00	.00
4004	60	60	0		CNST SET PRECAST BOX CULVERT SECTIONS	211500.00	.00
4005	10	10	0		CNST REVISE WATERWELL	4000.00	.00
4026	5	5	0		CNST RELOCATE WATERLINE	10000.00	.00
6000	3	3	0		CNST DELIVER PRECAST BOX CULVERT SECTIONS	25000.00	.00
6001	30	30	0		CNST FABRICATE PRECAST BOX CULVERT SECTIONS	189524.00	.00
SUBTOTAL				003		672937.00	37163.00

PHASE 3B. CONSTRUCTION DEMOLITION

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	BUDGET	EARNED
4009	43	43	0		CNST DEMO ALT RUNWAY LIGHTING & CONDUIT TO STA 86+00	35000.00	.00
4021	21	21	0		CNST DEMO EXISTING KEEL STA 66+58 /72+39	105000.00	.00
4023	15	15	0		CNST REMOVE CONCRETE STA 72+39 / 76+42	102000.00	.00
4025	12	12	0		CNST DEMO EXISTING OVERRUN STA 76+42 / 86+00	22500.00	.00
9000	3	3	0		MAIN SAW CUT MAIN RUNWAY TO SUB GRADE	12000.00	.00
9001	8	8	0		MAIN DEMO ASPHALT MAIN RUNWAY	22700.00	.00
SUBTOTAL				004		299200.00	.00

PHASE 3C. REMAINING CONSTRICTION

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	BUDGET	EARNED
4006	15	15	0		CNST PREPARE SUBGRADE N.W. OVERRUN	191000.00	.00
4007	10	10	0		CNST PLACE SUBBASE N/W OVERRUN	294000.00	.00
4008	4	4	0		CNST PLACE ASPHALT N/W OVERRUN	30000.00	.00
4010	40	40	0		CNST MASS EXCAVATE 50' N/S ALT RUNWAY TO STA 86+00	285000.00	.00
4011	37	37	0		CNST MASS FILL BOX CULVERT AND 1000' RUNOFF AREA	315250.00	.00
4012	60	60	0		CNST PLACE S/G 50' SEC N/S ALT RUNWAY TO STA 86+00	262500.00	.00
4013	22	22	0		CNST PLACE ASPHALT 50'SEC N/S ALT RUNWAY TO STA 86+00	315000.00	.00
4015	5	5	0		CNST STRIPE ALT RUNWAY N/S TO STA 86+00	45000.00	.00
4016	5	5	0		CNST GRADE/ SEED/ MULCH DISTURBED AREAS TO STA 86+00	20000.00	.00
4017	15	15	0		CNST REMOVE ARRESTOR FACILITY STA 19+00	10000.00	.00
4018	20	20	0		CNST REINSTALL ARRESTOR FACITLY TO STA 8+00	15750.00	.00
4019	15	15	0		CNST REMOVE ARRESTOR FACILITY STA 65+00	10000.00	.00
4020	20	20	0		CNST REINSTALL ARRESTOR FACILITY TO STA 68+00	15750.00	.00
4022	9	9	0		CNST INSTALL CONCRETE KEEL STA 66+58 / 72+39	222500.00	.00
4024	7	7	0		CNST INSTALL CONCRETE STA 72+39 / 76+42	423836.00	.00
4030	10	10	0		CNST CLEAR AND GRUB N.W. OVERRUN AREA	10500.00	.00
4031	100	100	0		CNST LIME STABILIZE SUBBASE	235000.00	.00
4035	5	5	0		CNST CLEAR AND GRUB S.E. RUNWAY EXTENSION	10500.00	.00
4040	10	10	0		CNST CLEAR AND GRUB S.E. RUNWAY 87+00 / 98+00	11500.00	.00
4041	7	7	0		CNST REMOVE U.G. STORAGE TANK	21000.00	.00
4050	30	30	0		CNST DEMO ABDR PAD AND FACILITIES	75000.00	.00
4051	30	30	0		CNST DEMO MILLINGS RD.	15000.00	.00
4052	60	60	0		CNST REINSTALL EXISTING ABDR FACILITY TO NEW SITE	75000.00	.00
4054	21	21	0		CNST MASS EXCAVATE SE RUNWAY EXTENSION	197500.00	.00
4055	21	21	0		CNST PREPARE SUBGRADE SE RUNWAY EXTENSION	95000.00	.00
4056	21	21	0		CNST PLACE ASPHALT SE RUNWAY EXTENSION	35000.00	.00
4057	30	30	0		CNST MASS EXCAVATE SE RUNWAY EXT STA 87+00 / 98+00	112500.00	.00
4058	21	21	0		CNST PREPARE SUBGRADE SE RUNWAY STA 87+00 / 98+00	265000.00	.00
4059	30	30	0		CNST PRPARE SUBGRADE TAXIWAY	155000.00	.00
4060	21	21	0		CNST INSTALL TAXIWAY LIGHTING FIXTURES AND CONDUITS	.00	.00
4062	7	7	0		CNST PLACE TAXIWAY CONCETE KEEL	595063.00	.00
4063	10	10	0		CNST PLACE ASPHALT TAXIWAY SHOULDERS	104000.00	.00
4064	3	3	0		CNST STRIPE TAXIWAY	25000.00	.00
4065	7	7	0		CNST GRADE / SEED / MULCH TAXIWAY AREAS	15000.00	.00
4066	7	7	0		CNST FORM CONCRETE RUNWAY STA 87+00 / 98+00	55000.00	.00
4077	12	12	0		CNST POUR CONCRETE RUNWAY STA 87+00 / 98+00	315000.00	.00
4078	3	3	0		CNST STRIPE RUNWAY STA 87+00 / 98+00	15000.00	.00
4079	10	10	0		CNST GRADE/SEED/MULCH RUNWAY STA 87+00 / 98+00	10000.00	.00
4080	15	15	0		CNST PREPARE SUBGRADE INTERFACE W/ MAIN RUNWAY	150000.00	.00
4081	5	5	0		CNST POUR INTERFACE WITH MAIN RUNWAY	210000.00	.00
4082	2	2	0		CNST STRIPE INTERFACE WITH MAIN RUNWAY	15000.00	.00
4083	5	5	0		CNST GRADE/SEED/MULCH INTERFACE AREA W/ MAIN RUNWAY	10000.00	.00

PHASE 3C. REMAINING CONSTRICTION

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION -	BUDGET	EARNED
4084	5	5	0	CNST	REWORK PENDANT ARRESTOR CABLE & CHAIN	12500.00	.00
4100	7	7	0	CNST	REMOVE EXISTING PATROL ROAD	22500.00	.00
4101	30	30	0	CNST	INSTALL NEW FENCE N.W. SITE	45000.00	.00
5000	6	6	0	PRMT	PREP/ISSUE BID PKG - ERECT BOX CULVERT	5000.00	.00
5005	10	10	0	PRMT	EST/SUBMIT BID PROP. - ERECT BOX CULVERT	5000.00	.00
5010	5	5	0	PRMT	EVAL/AWARD BID PKG - ERECT BOX CULVERT	5000.00	.00
5015	10	10	0	CNST	MOBILIZE SUBCONTRACTOR - ERECT BOX CULVERT	35000.00	.00
5020	5	5	0	PRMT	PREP/ISSUE BID PKG - DEMOLITION	5000.00	.00
5025	10	10	0	PRMT	EST/SUBMIT BID PROP. - DEMOLITION	5000.00	.00
5030	5	5	0	PRMT	EVAL/AWARD BID PKG - DEMOLITION	5000.00	.00
5035	20	20	0	CNST	MOBILIZE SUBCONTRACTOR - DEMOLITION	35000.00	.00
5040	5	5	0	PRMT	PREP/ISSUE BID PKG - CLEAR & GRUB	5000.00	.00
5045	10	10	0	PRMT	EST/SUBMIT BID PROP. - CLEAR & GRUB	5000.00	.00
5050	5	5	0	PRMT	EVAL/AWARD BID PKG - CLEAR & GRUB	5000.00	.00
5055	20	20	0	CNST	MOBILIZE SUBCONTRACTOR - CLEAR & GRUB	35000.00	.00
5060	5	5	0	PRMT	PREP/ISSUE BID PKG - EARTHWORK	5000.00	.00
5065	10	10	0	PRMT	EVAL/SUBMIT BID PROP. - EARTHWORK	5000.00	.00
5070	5	5	0	PRMT	EVAL/AWARD BID PKG - EARTHWORK	5000.00	.00
5075	20	20	0	CNST	MOBILIZE SUBCONTRACTOR - EARTHWORK	75000.00	.00
5080	5	5	0	PRMT	PREP/ISSUE BID PKG - FURN/INSTALL AGG BASE	5000.00	.00
5085	10	10	0	PRMT	EST/SUBMIT BID PROP. - FURN/INSTALL AGG BASE	5000.00	.00
5090	5	5	0	PRMT	EVAL/AWARD BID PKG - FURN/INSTALL AGG BASE	5000.00	.00
5095	20	20	0	CNST	MOBILIZE SUBCONTRACTOR - FURN/INSTALL AGG BASE	35000.00	.00
5100	5	5	0	PRMT	PREP/ISSUE BID PKG - FURN/INSTALL CONC PAVING	5000.00	.00
5105	10	10	0	PRMT	EST/SUBMIT BID PROP. - FURN/INSTALL CONC PAVING	5000.00	.00
5110	5	5	0	PRMT	EVAL/AWARD BID PKG - FURN/INSTALL CONC PAVING	5000.00	.00
5115	20	20	0	CNST	MOBILIZE SUBCONTRACTOR - FURN/INSTALL CONC PAVIN	75000.00	.00
5120	5	5	0	PRMT	PREP/ISSUE BID PKG - FURN/INSTALL ASPH PAVING	5000.00	.00
5125	21	21	0	PRMT	EST/SUBMIT BID PROP. - FURN/INSTALL ASPH PAVING	5000.00	.00
5130	21	21	0	PRMT	EVAL/AWARD BID PKG - FURN/INSTALL ASPH PAVING	5000.00	.00
5135	20	20	0	CNST	MOBILIZE SUBCONTRACTOR - FURN/INSTALL ASPH PAVIN	50000.00	.00
5140	5	5	0	PRMT	PREP/ISSUE BID PKG - FURN/INSTALL FENCING	2500.00	.00
5145	10	10	0	PRMT	EST/SUBMIT BID PROP. - FURN/INSTALL FENCING	2500.00	.00
5150	5	5	0	PRMT	EVAL/AWARD BID PKG - FURN/INSTALL FENCING	2500.00	.00
5155	20	20	0	CNST	MOBILIZE SUBCONTRACTOR - FURN/INSTALL FENCING	5000.00	.00
5160	5	5	0	PRMT	PREP/ISSUE BID PKG - REMOVE/REINST ARRESTOR FAC	2500.00	.00
5165	10	10	0	PRMT	EST/SUBMIT BID PROP. - REMOVE/REINST ARREST FAC	2500.00	.00
5170	5	5	0	PRMT	EVAL/AWARD BID PKG - REMOVE/REINST ARREST FAC	2500.00	.00
5175	15	15	0	CNST	MOBILIZE SUBCONTRACTOR - REMOVE/REINST ARREST FA	5000.00	.00
5180	5	5	0	PRMT	PREP/ISSUE BID PKG - DESIGN/BUILD ELEC	5000.00	.00
5190	5	5	0	PRMT	REVIEW/AWARD BID PKG - DESIGN/BUILD ELEC	23366.00	.00
5205	56	56	0	PRMT	PURCHASE/DELIVER ELECTRICAL EQUIPMENT	.00	.00

PHASE 3C. REMAINING CONSTRICTION

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	BUDGET	EARNED
9002	3	3	0	MAIN	PREPARE SUBGRADE TO COMPACTION MAIN RUNWAY	50000.00	.00
9003	4	4	0	MAIN	CONSTRUCT CONCRETE KEEL MAIN RUNWAY	245750.00	.00
9004	7	7	0	MAIN	CURE CONCRETE MAIN RUNWAY KEEL	5000.00	.00
9006	8	8	0	MAIN	PLACE ASPHALT MAIN RUNWAY	22500.00	.00
9007	2	2	0	MAIN	STRIPE MAIN RUNWAY INTERSECTION/TAXIWAY	5000.00	.00
9008	2	2	0	MAIN	GRADE/ SEED/ MULCH DISTURBED AREAS	5000.00	.00
10003	10	10	0	PRMT	EST/SUBMIT BID PROP. - DESIGN/BUILD ELEC	5000.00	.00
10004	20	20	0	CNST	MOBILIZE SUBCONTRACTOR - DESIGN/BUILD ELEC	55650.00	.00
10006	42	42	0	CNST	Purchase/deliver L-862 HIRL B/M Fix.	33000.00	.00
10008	58	58	0	CNST	Purchase/Deliver L-850C HIRL B/M Fix.	8100.00	.00
10010	49	49	0	CNST	Purchase/Deliver L-861T B/M Fix.	10935.00	.00
10015	110	110	0	CNST	Purchase/Deliver L-858 D-T-G Marker	35640.00	.00
10020	110	110	0	CNST	Purchase/Deliver L-858 TGS Marker	36300.00	.00
10025	140	140	0	CNST	Purchase/Deliver L-858 Barrier Marker	7920.00	.00
10030	126	126	0	CNST	Purchase/Deliver Lighting Regulators	27000.00	.00
10035	28	28	0	CNST	Purchase/Deliver Vault Power Panel	10000.00	.00
10040	84	84	0	CNST	Purchase/Deliver L-850E B/M Threshold Fix.	127490.00	.00
10045	84	84	0	CNST	Purchase/Deliver L-850B B/M Threshold Fix.	111020.00	.00
10050	84	84	0	CNST	Purchase/Deliver MB-2 B/M Approach Fix.	25300.00	.00
10055	84	84	0	CNST	Purchase/Deliver L-840 REIL System	13660.00	.00
10060	166	166	0	CNST	Purchase/Deliver 35kW Gen Set ATS	50000.00	.00
10065	14	14	0	CNST	Purchase/Deliver 4 inch Conduit	16632.00	.00
10070	14	14	0	CNST	Purchase/Deliver 2 inch Conduit	12620.00	.00
10075	56	56	0	CNST	Purchase/Deliver L-824 Type C Lighting Cable	32400.00	.00
10080	84	84	0	CNST	Purchase/Deliver 500 MCM 15kV Power Cable	58320.00	.00
10085	34	34	0	CNST	Install Southwestern Bell DB between MH T2 & T4	54809.00	.00
10090	34	34	0	CNST	Remove/Replace 500MCM Duct Bank	119453.00	.00
10095	100	100	0	CNST	Remove/Replace Telephone & Fiber Optic Cables	109621.00	.00
10100	7	7	0	CNST	New 500MCM 15kV Power Cable	32535.00	.00
10105	3	3	0	CNST	NW End Install 2" Conduit (Approach System)	5481.00	.00
10110	15	15	0	CNST	NW End Install L-850 E & B Fixture Bases	69184.00	.00
10115	2	2	0	CNST	NW End Install L-824 Type C Lighting Cable	2138.00	.00
10120	30	30	0	CNST	NW End Install L-850 E & B Fixture Trim	23061.00	.00
10125	30	30	0	CNST	NW End Install MB-2 Approach Base & Fixture	20927.00	.00
10130	8	8	0	CNST	NW End Install Power & Comm. Manholes	21486.00	.00
10135	7	7	0	CNST	NW End Install L-849 REIL System	2023.00	.00
10140	7	7	0	CNST	NW End Install ILS Equipment Shed SOG	2740.00	.00
10145	15	15	0	CNST	NW End Install ILS Antenna Supports	4681.00	.00
10150	10	10	0	CNST	NW End Install ILS Ground Check Points	2039.00	.00
10155	5	5	0	CNST	NW End Install ILS Ground Well	444.00	.00
10160	2	2	0	CNST	NW End Install ILS Power Pedestal	630.00	.00
10165	15	15	0	CNST	NW End Install ILS Power Supply	7016.00	.00

PHASE 3C. REMAINING CONSTRICTION

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	BUDGET	EARNED
10170	5	5	0		CNST NW End Install ILS Gen. Set & ATS	17978.00	.00
10175	40	40	0		CNST Install 2" Conduit Sta -2+00 to 86+00	165034.00	.00
10180	20	20	0		CNST Install L-862 Base Sta -2+00 to 86+00	33434.00	.00
10185	5	5	0		CNST Install L-850C Base Sta -2+00 to 86+00	4604.00	.00
10190	20	20	0		CNST Install L-861T Base Sta -2+00 to 86+00	7340.00	.00
10195	30	30	0		CNST Install D-T-G Base & SOG Sta -2+00 to 86+00	19052.00	.00
10200	30	30	0		CNST Install TGS Base & SOG Sta -2+00 to 86+00	15007.00	.00
10205	5	5	0		CNST Inst Barrier MKR Base & SOG Sta -2+00 to 86+00	4595.00	.00
10210	25	25	0		CNST Install Circuits 1, 2, 3 & 4 Sta -2+00 to 86+00	58318.00	.00
10215	20	20	0		CNST Install L-862 HIRL Fixture Sta -2+00 to 86+00	8364.00	.00
10220	10	10	0		CNST Install L-850C Fixture Sta -2+00 to 86+00	1096.00	.00
10225	20	20	0		CNST Install L-861T Fixture Sta -2+00 to 86+00	1835.00	.00
10230	20	20	0		CNST Install D-T-G Sign Fixture Sta -2+00 to 86+00	1973.00	.00
10235	20	20	0		CNST Install TGS Fixture Sta -2+00 to 86+00	2083.00	.00
10240	5	5	0		CNST Install Barrier Fixture Sta -2+00 to 86+00	491.00	.00
10245	10	10	0		CNST Install ABDR Power Pedestal	1315.00	.00
10250	5	5	0		CNST Arrestor Facility @ Sta 8+00	1864.00	.00
10255	5	5	0		CNST Arrestor Facility @ Sta 88+00	1864.00	.00
10260	10	10	0		CNST Saw cut & demo Concrete for AF Circuits	16443.00	.00
10265	10	10	0		CNST Install Vault Power Panel	10424.00	.00
10270	30	30	0		CNST Install Airfield Lighting Regulators	15895.00	.00
10275	5	5	0		CNST System Testing to Sta 86+00	19184.00	.00
10280	7	7	0		CNST Install R/W & T/W Lighting	10962.00	.00
10285	3	3	0		CNST SE End Install 2" Conduit (Approach System)	5481.00	.00
10290	15	15	0		CNST SE End Install L-850 E & B Fixture Bases	69184.00	.00
10295	2	2	0		CNST SE End Install L-824 Type C Lighting Cable	2138.00	.00
10300	30	30	0		CNST SE End Install L-850 E & B Fixture Trim	23061.00	.00
10305	30	30	0		CNST SE End Install MB-2 Approach Base & Fixture	20927.00	.00
10310	7	7	0		CNST SE End Install ILS Equipment Shed SOG	2740.00	.00
10315	15	15	0		CNST SE End Install Antenna Supports	4681.00	.00
10320	10	1	0		CNST SE End Install ILS Ground Check Points	2039.00	.00
10325	5	5	0		CNST SE End Install ILS Ground Well	444.00	.00
10330	2	2	0		CNST SE End Install ILS Power Pedestal	630.00	.00
10335	15	15	0		CNST SE End Install ILS Power Supply	7016.00	.00
10340	5	5	0		CNST SE End Install ILS Gen. Set & ATS	17978.00	.00
10345	7	7	0		CNST SE End Install L-849 REIL System	2021.00	.00
10350	5	5	0		CNST Install 2" Conduit from 86+00	5481.00	.00
10355	10	10	0		CNST Install L-862 Base from Sta 86+00	4187.00	.00
10360	2	2	0		CNST Install L-850C Base from Sta 86+00	658.00	.00
10365	20	20	0		CNST Install L-861T Base from Sta 86+00	7340.00	.00
10370	2	2	0		CNST Install D-T-G Base & SOG from Sta 86+00	1627.00	.00
10375	6	6	0		CNST Install TGS Base & SOG from Sta 86+00	3015.00	.00

PHASE 3C. REMAINING CONSTRICTION

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	BUDGET	EARNED
10380	5	5	0	CNST	Install Circuits 2, 3 & 4 from Sta 86+00	2127.00	.00
10385	3	3	0	CNST	Install L-862 HIRL Fixture from Sta 86+00	1041.00	.00
10390	1	1	0	CNST	Install L-850C Fixtures from Sta 86+00	219.00	.00
10395	10	10	0	CNST	Install L-861T Fixtures from Sta 86+00	1835.00	.00
10400	1	1	0	CNST	Install D-T-G Sign Fixtures from Sta 86+00	237.00	.00
10405	5	5	0	CNST	Install TGS Fixtures from Sta 86+00	285.00	.00
10410	5	5	0	CNST	System Testing from Sta 86+00	6632.00	.00
99999	307*	307*	0	MILE	CONSTRUCTION PERIOD	.00	.00
D-1001	3	3	0		RAISE ELECTRICAL MANHOLE	.00	.00
D-1002	2	2	0		REGRADE AREA AROUND WATERWELL	.00	.00
D-1003	14	14	0		UPGRADE DUCT BANK TO WELL	.00	.00
D-1004	7	7	0		UPGRADE 15" STS	.00	.00
SUBTOTAL				005		7967199.00	.00
REPORT TOTAL						9687864.00	37163.00

Extend Alternate Runway
Schedule/Total Float

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT
100	0	0	100		MILE NOTICE OF AWARD	6SEP95A				
1001	1	0	100		MILE KICKOFF MEETING		12SEP95A			
3998	1	0	100		CNST FURNISH BID BOND	8JAN96A	8JAN96A			
2001	60	60	0		DGN1 COMPLETE 60% REVIEW DOCUMENTS	6SEP95	4NOV95	6SEP95	4NOV95	0
2002	21	21	0		DGN1 USAOE REVIEW 60% DOCUMENTS	5NOV95	25NOV95	5NOV95	25NOV95	0
2003	2	2	0		DGN1 60% DESIGN REVIEW MEETING	26NOV95	27NOV95	26NOV95	27NOV95	0
2004	10	10	0		DGN1 INCORPERATE 60% REVIEW CHANGES TO DWGS	28NOV95	7DEC95	28NOV95	7DEC95	0
3001	1	1	0		DGN2 NTP DESIGN PHASE PART 2	8DEC95	8DEC95	8DEC95	8DEC95	0
3002	60	60	0		DGN2 COMPLETE 100% DESIGN DRAWINGS	9DEC95	6FEB96	9DEC95	6FEB96	0
3003	2	2	0		DGN2 100% DESIGN REVIEW MEETING	7FEB96	8FEB96	7FEB96	8FEB96	0
3004	21	21	0		DGN2 INCORPERATE CHANGES IN DOCUMENTS	9FEB96	29FEB96	9FEB96	29FEB96	0
3999	1	1	0		MILE NTP CONSTRUCTION	18JAN96*	18JAN96	18JAN96*	18JAN96	0
4001	10	10	0		CNST CLEAR & GRUB SITE @ BOX CULVERT EXTENSION	28MAR96	6APR96	28MAR96	6APR96	0
4002	7	7	0		CNST REROUTE STREAM BED	7APR96	13APR96	7APR96	13APR96	0
4003	30	30	0		CNST PREPARE SUB BASE FOR BOX CULVERT	14APR96	13MAY96	14APR96	13MAY96	0
4004	60	60	0		CNST SET PRECAST BOX CULVERT SECTIONS	17APR96	15JUN96	17APR96	15JUN96	0
4009	43	43	0		CNST DEMO ALT RUNWAY LIGHTING & CONDUIT TO STA 86+00	17APR96	29MAY96	17APR96	29MAY96	0
4010	40	40	0		CNST MASS EXCAVATE 50' N/S ALT RUNWAY TO STA 86+00	20APR96	29MAY96	20APR96	29MAY96	0
4012	60	60	0		CNST PLACE S/G 50' SEC N/S ALT RUNWAY TO STA 86+00	24APR96	22JUN96	24APR96	22JUN96	0
4013	22	22	0		CNST PLACE ASPHALT 50'SEC N/S ALT RUNWAY TO STA 86+00	23JUN96	14JUL96	23JUN96	14JUL96	0
4015	5	5	0		CNST STRIPE ALT RUNWAY N/S TO STA 86+00	15JUL96	19JUL96	15JUL96	19JUL96	0
4016	5	5	0		CNST GRADE/ SEED/ MULCH DISTURBED AREAS TO STA 86+00	20JUL96	24JUL96	20JUL96	24JUL96	0
4021	21	21	0		CNST DEMO EXISTING KEEL STA 66+58 /72+39	20APR96	10MAY96	20APR96	10MAY96	0
4022	9	9	0		CNST INSTALL CONCRETE KEEL STA 66+58 / 72+39	11MAY96	19MAY96	11MAY96	19MAY96	0
4023	15	15	0		CNST REMOVE CONCRETE STA 72+39 / 76+42	20MAY96	3JUN96	20MAY96	3JUN96	0
4024	7	7	0		CNST INSTALL CONCRETE STA 72+39 / 76+42	4JUN96	10JUN96	4JUN96	10JUN96	0
4025	12	12	0		CNST DEMO EXISTING OVERRUN STA 76+42 / 86+00	11JUN96	22JUN96	11JUN96	22JUN96	0
4050	30	30	0		CNST DEMO ABDR PAD AND FACILITIES	24MAY96	22JUN96	24MAY96	22JUN96	0

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT
4054	21	21	0	CNST	MASS EXCAVATE SE RUNWAY EXTENSION	27JUN96	17JUL96	27JUN96	17JUL96	0
4055	21	21	0	CNST	PREPARE SUBGRADE SE RUNWAY EXTENSION	30JUN96	20JUL96	30JUN96	20JUL96	0
4056	21	21	0	CNST	PLACE ASPHALT SE RUNWAY EXTENSION	21JUL96	10AUG96	21JUL96	10AUG96	0
4057	30	30	0	CNST	MASS EXCAVATE SE RUNWAY EXT STA 87+00 / 98+00	11AUG96	9SEP96	11AUG96	9SEP96	0
4058	21	21	0	CNST	PREPARE SUBGRADE SE RUNWAY STA 87+00 / 98+00	14AUG96	3SEP96	14AUG96	3SEP96	0
4066	7	7	0	CNST	FORM CONCRETE RUNWAY STA 87+00 / 98+00	6SEP96	12SEP96	6SEP96	12SEP96	0
4077	12	12	0	CNST	POUR CONCRETE RUNWAY STA 87+00 / 98+00	13SEP96	24SEP96	13SEP96	24SEP96	0
4078	3	3	0	CNST	STRIPE RUNWAY STA 87+00 / 98+00	2OCT96	4OCT96	2OCT96	4OCT96	0
4079	10	10	0	CNST	GRADE/SEED/MULCH RUNWAY STA 87+00 / 98+00	5OCT96	14OCT96	5OCT96	14OCT96	0
4080	15	15	0	CNST	PREPARE SUBGRADE INTERFACE W/ MAIN RUNWAY	15OCT96	29OCT96	15OCT96	29OCT96	0
4081	5	5	0	CNST	POUR INTERFACE WITH MAIN RUNWAY	30OCT96	3NOV96	30OCT96	3NOV96	0
4082	2	2	0	CNST	STRIPE INTERFACE WITH MAIN RUNWAY	8NOV96	9NOV96	8NOV96	9NOV96	0
4083	5	5	0	CNST	GRADE/SEED/MULCH INTERFACE AREA W/ MAIN RUNWAY	10NOV96	14NOV96	10NOV96	14NOV96	0
4084	5	5	0	CNST	REWORK PENDANT ARRESTOR CABLE & CHAIN	15NOV96	19NOV96	15NOV96	19NOV96	0
4100	7	7	0	CNST	REMOVE EXISTING PATROL ROAD	21MAR96	27MAR96	21MAR96	27MAR96	0
5035	20	20	0	CNST	MOBILIZE SUBCONTRACTOR - DEMOLITION	1MAR96	20MAR96	1MAR96	20MAR96	0
5075	20	20	0	CNST	MOBILIZE SUBCONTRACTOR - EARTHWORK	1MAR96	20MAR96	1MAR96	20MAR96	0
5180	5	5	0	PRMT	PREP/ISSUE BID PKG - DESIGN/BUILD ELEC	6SEP95	10SEP95	6SEP95	10SEP95	0
5190	5	5	0	PRMT	REVIEW/AWARD BID PKG - DESIGN/BUILD ELEC	21SEP95	25SEP95	21SEP95	25SEP95	0
9000	3	3	0	MAIN	SAW CUT MAIN RUNWAY TO SUB GRADE	25JUL96	27JUL96	25JUL96	27JUL96	0
9001	8	8	0	MAIN	DEMO ASPHALT MAIN RUNWAY	28JUL96	4AUG96	28JUL96	4AUG96	0
9002	3	3	0	MAIN	PREPARE SUBGRADE TO COMPACTION MAIN RUNWAY	5AUG96	7AUG96	5AUG96	7AUG96	0
9003	4	4	0	MAIN	CONSTRUCT CONCRETE KEEL MAIN RUNWAY	8AUG96	11AUG96	8AUG96	11AUG96	0
9004	7	7	0	MAIN	CURE CONCRETE MAIN RUNWAY KEEL	12AUG96	18AUG96	12AUG96	18AUG96	0
9006	8	8	0	MAIN	PLACE ASPHALT MAIN RUNWAY	19AUG96	26AUG96	19AUG96	26AUG96	0
9007	2	2	0	MAIN	STRIPE MAIN RUNWAY INTERSECTION/TAXIWAY	27AUG96	28AUG96	27AUG96	28AUG96	0
9008	2	2	0	MAIN	GRADE/ SEED/ MULCH DISTURBED AREAS	29AUG96	30AUG96	29AUG96	30AUG96	0
10000	36	36	0	DGN1	COMPLETE 60% ELEC. DESIGN REVIEW	26SEP95	31OCT95	26SEP95	31OCT95	0

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT
10003	10	10	0		PRMT EST/SUBMIT BID PROP. - DESIGN/BUILD ELEC	11SEP95	20SEP95	11SEP95	20SEP95	0
10360	2	2	0		CNST Install L-850C Base from Sta 86+00	4SEP96	5SEP96	4SEP96	5SEP96	0
99999	307*	307*	0		MILE CONSTRUCTION PERIOD	18JAN96	19NOV96	18JAN96	19NOV96	0
DMS01	0	0	0		MILE DESIGN MILESTONE 1		4NOV95		4NOV95	0
DMS02	0	0	0		MILE DESIGN MILESTONE 2	8DEC95	7DEC95	8DEC95	7DEC95	0
MS04	0	0	0		MILE MILESTONE 4; COMPLETE ALT RUNWAY TO STA 86+00		24JUL96		24JUL96*	0
MS05	0	0	0		MILE MILESTONE 5; COMPLETE MAIN RUNWAY INTERFACE		30AUG96		30AUG96*	0
MS06	0	0	0		MILE MILESTONE 6; COMPLETE CONTRACT		19NOV96		19NOV96*	0
DMS03	0	0	0		MILE DESIGN MILESTONE 3		29FEB96		1MAR96*	1
5015	10	10	0		CNST MOBILIZE SUBCONTRACTOR - ERECT BOX CULVERT	1MAR96	10MAR96	5MAR96	14MAR96	4
6000	3	3	0		CNST DELIVER PRECAST BOX CULVERT SECTIONS	10APR96	12APR96	14APR96	16APR96	4
6001	30	30	0		CNST FABRICATE PRECAST BOX CULVERT SECTIONS	11MAR96	9APR96	15MAR96	13APR96	4
10280	7	7	0		CNST Install R/W & T/W Lighting	8AUG96	14AUG96	12AUG96	18AUG96	4
4017	15	15	0		CNST REMOVE ARRESTOR FACILITY STA 19+00	30APR96	14MAY96	6MAY96	20MAY96	6
4018	20	20	0		CNST REINSTALL ARRESTOR FACITLY TO STA 8+00	15MAY96	3JUN96	21MAY96	9JUN96	6
4019	15	15	0		CNST REMOVE ARRESTOR FACILITY STA 65+00	4JUN96	18JUN96	10JUN96	24JUN96	6
4020	20	20	0		CNST REINSTALL ARRESTOR FACILITY TO STA 68+00	19JUN96	8JUL96	25JUN96	14JUL96	6
10290	15	15	0		CNST SE End Install L-850 E & B Fixture Bases	11JUL96	25JUL96	17JUL96	31JUL96	6
10390	1	1	0		CNST Install L-850C Fixtures from Sta 86+00	25SEP96	25SEP96	1OCT96	1OCT96	6
4005	10	10	0		CNST REVISE WATERWELL	28MAR96	6APR96	4APR96	13APR96	7
4006	15	15	0		CNST PREPARE SUBGRADE N.W. OVERRUN	30APR96	14MAY96	7MAY96	21MAY96	7
4007	10	10	0		CNST PLACE SUBBASE N/W OVERRUN	5MAY96	14MAY96	12MAY96	21MAY96	7
4008	4	4	0		CNST PLACE ASPHALT N/W OVERRUN	20MAY96	23MAY96	27MAY96	30MAY96	7
4031	100	100	0		CNST LIME STABILIZE SUBBASE	20APR96	28JUL96	27APR96	4AUG96	7
5055	20	20	0		CNST MOBILIZE SUBCONTRACTOR - CLEAR & GRUB	1MAR96	20MAR96	8MAR96	27MAR96	7
10110	15	15	0		CNST NW End Install L-850 E & B Fixture Bases	7MAY96	21MAY96	14MAY96	28MAY96	7
10200	30	30	0		CNST Install TGS Base & SOG Sta -2+00 to 86+00	24MAY96	22JUN96	31MAY96	29JUN96	7
10235	20	20	0		CNST Install TGS Fixture Sta -2+00 to 86+00	23JUN96	12JUL96	30JUN96	19JUL96	7

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT
10275	5	5	0	CNST	System Testing to Sta 86+00	13JUL96	17JUL96	20JUL96	24JUL96	7
D-1001	3	3	0		RAISE ELECTRICAL MANHOLE	7APR96	9APR96	14APR96	16APR96	7
D-1002	2	2	0		REGRADE AREA AROUND WATERWELL	28APR96	29APR96	5MAY96	6MAY96	7
D-1003	14	14	0		UPGRADE DUCT BANK TO WELL	7APR96	20APR96	14APR96	27APR96	7
D-1004	7	7	0		UPGRADE 15" STS	21APR96	27APR96	28APR96	4MAY96	7
10030	126	126	0	CNST	Purchase/Deliver Lighting Regulators	7FEB96	11JUN96	15FEB96	19JUN96	8
10270	30	30	0	CNST	Install Airfield Lighting Regulators	12JUN96	11JUL96	20JUN96	19JUL96	8
10105	3	3	0	CNST	NW End Install 2" Conduit (Approach System)	15MAY96	17MAY96	24MAY96	26MAY96	9
4030	10	10	0	CNST	CLEAR AND GRUB N.W. OVERRUN AREA	17APR96	26APR96	27APR96	6MAY96	10
10285	3	3	0	CNST	SE End Install 2" Conduit (Approach System)	18JUL96	20JUL96	29JUL96	31JUL96	11
10175	40	40	0	CNST	Install 2" Conduit Sta -2+00 to 86+00	24MAY96	2JUL96	5JUN96	14JUL96	12
10185	5	5	0	CNST	Install L-850C Base Sta -2+00 to 86+00	23JUN96	27JUN96	5JUL96	9JUL96	12
10210	25	25	0	CNST	Install Circuits 1, 2, 3 & 4 Sta -2+00 to 86+00	13JUN96	7JUL96	25JUN96	19JUL96	12
10215	20	20	0	CNST	Install L-862 HIRL Fixture Sta -2+00 to 86+00	18JUN96	7JUL96	30JUN96	19JUL96	12
10220	10	10	0	CNST	Install L-850C Fixture Sta -2+00 to 86+00	28JUN96	7JUL96	10JUL96	19JUL96	12
10225	20	20	0	CNST	Install L-861T Fixture Sta -2+00 to 86+00	18JUN96	7JUL96	30JUN96	19JUL96	12
10230	20	20	0	CNST	Install D-T-G Sign Fixture Sta -2+00 to 86+00	18JUN96	7JUL96	30JUN96	19JUL96	12
10240	5	5	0	CNST	Install Barrier Fixture Sta -2+00 to 86+00	3JUL96	7JUL96	15JUL96	19JUL96	12
10040	84	84	0	CNST	Purchase/Deliver L-850E B/M Threshold Fix.	7FEB96	30APR96	20FEB96	13MAY96	13
10045	84	84	0	CNST	Purchase/Deliver L-850B B/M Threshold Fix.	7FEB96	30APR96	20FEB96	13MAY96	13
10025	140	140	0	CNST	Purchase/Deliver L-858 Barrier Marker	7FEB96	25JUN96	21FEB96	9JUL96	14
10205	5	5	0	CNST	Inst Barrier MKR Base & SOG Sta -2+00 to 86+00	26JUN96	30JUN96	10JUL96	14JUL96	14
10295	2	2	0	CNST	SE End Install L-824 Type C Lighting Cable	21JUL96	22JUL96	4AUG96	5AUG96	14
4026	5	5	0	CNST	RELOCATE WATERLINE	28MAR96	1APR96	12APR96	16APR96	15
10350	5	5	0	CNST	Install 2" Conduit from 86+00	10SEP96	14SEP96	25SEP96	29SEP96	15
10380	5	5	0	CNST	Install Circuits 2, 3 & 4 from Sta 86+00	12SEP96	16SEP96	27SEP96	1OCT96	15
10180	20	20	0	CNST	Install L-862 Base Sta -2+00 to 86+00	8JUN96	27JUN96	25JUN96	14JUL96	17
10375	6	6	0	CNST	Install TGS Base & SOG from Sta 86+00	10SEP96	15SEP96	29SEP96	4OCT96	19

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT
4059	30	30	0		CNST PRPARE SUBGRADE TAXIWAY	14AUG96	12SEP96	3SEP96	2OCT96	20
4060	21	21	0		CNST INSTALL TAXIWAY LIGHTING FIXTURES AND CONDUITS	13SEP96	3OCT96	3OCT96	23OCT96	20
4062	7	7	0		CNST PLACE TAXIWAY CONCETE KEEL	4OCT96	10OCT96	24OCT96	30OCT96	20
4063	10	10	0		CNST PLACE ASPHALT TAXIWAY SHOULDERS	11OCT96	20OCT96	31OCT96	9NOV96	20
4064	3	3	0		CNST STRIPE TAXIWAY	21OCT96	23OCT96	10NOV96	12NOV96	20
4065	7	7	0		CNST GRADE / SEED / MULCH TAXIWAY AREAS	24OCT96	30OCT96	13NOV96	19NOV96	20
10250	5	5	0		CNST Arrestor Facility @ Sta 8+00	15MAY96	19MAY96	5JUN96	9JUN96	21
10255	5	5	0		CNST Arrestor Facility @ Sta 88+00	19JUN96	23JUN96	10JUL96	14JUL96	21
10365	20	20	0		CNST Install L-861T Base from Sta 86+00	13SEP96	2OCT96	4OCT96	23OCT96	21
10190	20	20	0		CNST Install L-861T Base Sta -2+00 to 86+00	3JUN96	22JUN96	25JUN96	14JUL96	22
10195	30	30	0		CNST Install D-T-G Base & SOG Sta -2+00 to 86+00	24MAY96	22JUN96	15JUN96	14JUL96	22
10370	2	2	0		CNST Install D-T-G Base & SOG from Sta 86+00	10SEP96	11SEP96	3OCT96	4OCT96	23
4011	37	37	0		CNST MASS FILL BOX CULVERT AND 1000' RUNOFF AREA	20APR96	26MAY96	17MAY96	22JUN96	27
4101	30	30	0		CNST INSTALL NEW FENCE N.W. SITE	27MAY96	25JUN96	25JUN96	24JUL96	29
10002	21	21	0		DGN2 INCORP. CHANGES INTO ELEC. DOCUMENTS	9FEB96	29FEB96	9MAR96	29MAR96	29
10065	14	14	0		CNST Purchase/Deliver 4 inch Conduit	1MAR96	14MAR96	30MAR96	12APR96	29
10085	34	34	0		CNST Install Southwestern Bell DB between MH T2 & T4	15MAR96	17APR96	13APR96	16MAY96	29
10090	34	34	0		CNST Remove/Replace 500MCM Duct Bank	15MAR96	17APR96	13APR96	16MAY96	29
4051	30	30	0		CNST DEMO MILLINGS RD.	24MAY96	22JUN96	24JUN96	23JUL96	31
4052	60	60	0		CNST REINSTALL EXISTING ABDR FACILITY TO NEW SITE	23JUN96	21AUG96	24JUL96	21SEP96*	31
10305	30	30	0		CNST SE End Install MB-2 Approach Base & Fixture	10SEP96	9OCT96	11OCT96	9NOV96	31
10020	110	110	0		CNST Purchase/Deliver L-858 TGS Marker	8JAN96	26APR96	11FEB96	30MAY96	34
10015	110	110	0		CNST Purchase/Deliver L-858 D-T-G Marker	18JAN96	6MAY96	26FEB96	14JUN96	39
10395	10	10	0		CNST Install L-861T Fixtures from Sta 86+00	25SEP96	4OCT96	5NOV96	14NOV96	41
10410	5	5	0		CNST System Testing from Sta 86+00	5OCT96	9OCT96	15NOV96	19NOV96	41
4041	7	7	0		CNST REMOVE U.G. STORAGE TANK	23JUN96	29JUN96	4AUG96	10AUG96	42
10315	15	15	0		CNST SE End Install Antenna Supports	10SEP96	24SEP96	26OCT96	9NOV96	46
10335	15	15	0		CNST SE End Install ILS Power Supply	10SEP96	24SEP96	26OCT96	9NOV96	46

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT
10001	40	40	0	DGN2	COMPLETE 100% ELECTRICAL DESIGN DWGS.	5NOV95	14DEC95	22DEC95	30JAN96	47
10385	3	3	0	CNST	Install L-862 HIRL Fixture from Sta 86+00	25SEP96	27SEP96	12NOV96	14NOV96	48
5160	5	5	0	PRMT	PREP/ISSUE BID PKG - REMOVE/REINST ARRESTOR FAC	12FEB96*	16FEB96	1APR96	5APR96	49
5165	10	10	0	PRMT	EST/SUBMIT BID PROP. - REMOVE/REINST ARREST FAC	17FEB96	26FEB96	6APR96	15APR96	49
5170	5	5	0	PRMT	EVAL/AWARD BID PKG - REMOVE/REINST ARREST FAC	27FEB96	2MAR96	16APR96	20APR96	49
5175	15	15	0	CNST	MOBILIZE SUBCONTRACTOR - REMOVE/REINST ARREST FA	3MAR96	17MAR96	21APR96	5MAY96	49
10080	84	84	0	CNST	Purchase/Deliver 500 MCM 15kV Power Cable	1MAR96	23MAY96	20APR96	12JUL96	50
10100	7	7	0	CNST	New 500MCM 15kV Power Cable	24MAY96	30MAY96	13JUL96	19JUL96	50
5095	20	20	0	CNST	MOBILIZE SUBCONTRACTOR - FURN/INSTALL AGG BASE	1MAR96	20MAR96	22APR96	11MAY96	52
5070	5	5	0	PRMT	EVAL/AWARD BID PKG - EARTHWORK	3JAN96	7JAN96	25FEB96	29FEB96	53
10310	7	7	0	CNST	SE End Install ILS Equipment Shed SOG	10SEP96	16SEP96	3NOV96	9NOV96	54
4000	7	7	0	CNST	SITE MOBILIZATION	19JAN96	25JAN96	14MAR96	20MAR96	55
10405	5	5	0	CNST	Install TGS Fixtures from Sta 86+00	16SEP96	20SEP96	10NOV96	14NOV96	55
4035	5	5	0	CNST	CLEAR AND GRUB S.E. RUNWAY EXTENSION	27APR96	1MAY96	22JUN96	26JUN96	56
10325	5	5	0	CNST	SE End Install ILS Ground Well	10SEP96	14SEP96	5NOV96	9NOV96	56
10340	5	5	0	CNST	SE End Install ILS Gen. Set & ATS	10SEP96	14SEP96	5NOV96	9NOV96	56
10330	2	2	0	CNST	SE End Install ILS Power Pedestal	10SEP96	11SEP96	6NOV96	7NOV96	57
10355	10	10	0	CNST	Install L-862 Base from Sta 86+00	4SEP96	13SEP96	2NOV96	11NOV96	59
10400	1	1	0	CNST	Install D-T-G Sign Fixtures from Sta 86+00	16SEP96	16SEP96	14NOV96	14NOV96	59
5050	5	5	0	PRMT	EVAL/AWARD BID PKG - CLEAR & GRUB	3JAN96	7JAN96	3MAR96	7MAR96	60
10075	56	56	0	CNST	Purchase/Deliver L-824 Type C Lighting Cable	1MAR96	25APR96	30APR96	24JUN96	60
10320	10	1	0	CNST	SE End Install ILS Ground Check Points	10SEP96	10SEP96	9NOV96	9NOV96	60
5020	5	5	0	PRMT	PREP/ISSUE BID PKG - DEMOLITION	8DEC95	12DEC95	10FEB96	14FEB96	64
5025	10	10	0	PRMT	EST/SUBMIT BID PROP. - DEMOLITION	13DEC95	22DEC95	15FEB96	24FEB96	64
5030	5	5	0	PRMT	EVAL/AWARD BID PKG - DEMOLITION	23DEC95	27DEC95	25FEB96	29FEB96	64
5060	5	5	0	PRMT	PREP/ISSUE BID PKG - EARTHWORK	8DEC95	12DEC95	10FEB96	14FEB96	64
5065	10	10	0	PRMT	EVAL/SUBMIT BID PROP. - EARTHWORK	13DEC95	22DEC95	15FEB96	24FEB96	64
10345	7	7	0	CNST	SE End Install L-849 REIL System	4SEP96	10SEP96	8NOV96	14NOV96	65

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT
5000	6	6	0		PRMT PREP/ISSUE BID PKG - ERECT BOX CULVERT	8DEC95	13DEC95	13FEB96	18FEB96	67
5005	10	10	0		PRMT EST/SUBMIT BID PROP. - ERECT BOX CULVERT	14DEC95	23DEC95	19FEB96	28FEB96	67
5010	5	5	0		PRMT EVAL/AWARD BID PKG - ERECT BOX CULVERT	24DEC95	28DEC95	29FEB96	4MAR96	67
5115	20	20	0		CNST MOBILIZE SUBCONTRACTOR - FURN/INSTALL CONC PAVIN	1MAR96	20MAR96	7MAY96	26MAY96	67
5135	20	20	0		CNST MOBILIZE SUBCONTRACTOR - FURN/INSTALL ASPH PAVIN	1MAR96	20MAR96	7MAY96	26MAY96	67
10010	49	49	0		CNST Purchase/Deliver L-861T B/M Fix.	1MAR96	18APR96	7MAY96	24JUN96	67
10008	58	58	0		CNST Purchase/Deliver L-850C HIRL B/M Fix.	1MAR96	27APR96	8MAY96	4JUL96	68
10070	14	14	0		CNST Purchase/Deliver 2 inch Conduit	1MAR96	14MAR96	10MAY96	23MAY96	70
5040	5	5	0		PRMT PREP/ISSUE BID PKG - CLEAR & GRUB	8DEC95	12DEC95	17FEB96	21FEB96	71
5045	10	10	0		PRMT EST/SUBMIT BID PROP. - CLEAR & GRUB	13DEC95	22DEC95	22FEB96	2MAR96	71
10006	42	42	0		CNST Purchase/deliver L-862 HIRL B/M Fix.	1MAR96	11APR96	14MAY96	24JUN96	74
10060	166	166	0		CNST Purchase/Deliver 35kW Gen Set ATS	1MAR96	13AUG96	23MAY96	4NOV96	83
10095	100	100	0		CNST Remove/Replace Telephone & Fiber Optic Cables	19JAN96	27APR96	11APR96	19JUL96	83
10170	5	5	0		CNST NW End Install ILS Gen. Set & ATS	14AUG96	18AUG96	5NOV96	9NOV96	83
10130	8	8	0		CNST NW End Install Power & Comm. Manholes	19JAN96	26JAN96	13APR96	20APR96	85
10300	30	30	0		CNST SE End Install L-850 E & B Fixture Trim	23JUL96	21AUG96	16OCT96	14NOV96	85
4040	10	10	0		CNST CLEAR AND GRUB S.E. RUNWAY 87+00 / 98+00	2MAY96	11MAY96	1AUG96	10AUG96	91
5155	20	20	0		CNST MOBILIZE SUBCONTRACTOR - FURN/INSTALL FENCING	1MAR96	20MAR96	5JUN96	24JUN96	96
5140	5	5	0		PRMT PREP/ISSUE BID PKG - FURN/INSTALL FENCING	5FEB96*	9FEB96	16MAY96	20MAY96	101
5145	10	10	0		PRMT EST/SUBMIT BID PROP. - FURN/INSTALL FENCING	10FEB96	19FEB96	21MAY96	30MAY96	101
5150	5	5	0		PRMT EVAL/AWARD BID PKG - FURN/INSTALL FENCING	20FEB96	24FEB96	31MAY96	4JUN96	101
10035	28	28	0		CNST Purchase/Deliver Vault Power Panel	1MAR96	28MAR96	12JUN96	9JUL96	103
10265	10	10	0		CNST Install Vault Power Panel	29MAR96	7APR96	10JUL96	19JUL96	103
5120	5	5	0		PRMT PREP/ISSUE BID PKG - FURN/INSTALL ASPH PAVING	8DEC95	12DEC95	21MAR96	25MAR96	104
5125	21	21	0		PRMT EST/SUBMIT BID PROP. - FURN/INSTALL ASPH PAVING	13DEC95	2JAN96	26MAR96	15APR96	104
5130	21	21	0		PRMT EVAL/AWARD BID PKG - FURN/INSTALL ASPH PAVING	3JAN96	23JAN96	16APR96	6MAY96	104
5090	5	5	0		PRMT EVAL/AWARD BID PKG - FURN/INSTALL AGG BASE	3JAN96	7JAN96	17APR96	21APR96	105
10004	20	20	0		CNST MOBILIZE SUBCONTRACTOR - DESIGN/BUILD ELEC	8DEC95	27DEC95	28MAR96	16APR96	111

ACTIVITY ID	ORIG DUR	REM DUR	%	CODE	ACTIVITY DESCRIPTION	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT
5080	5	5	0		PRMT PREP/ISSUE BID PKG - FURN/INSTALL AGG BASE	8DEC95	12DEC95	2APR96	6APR96	116
5085	10	10	0		PRMT EST/SUBMIT BID PROP. - FURN/INSTALL AGG BASE	13DEC95	22DEC95	7APR96	16APR96	116
5110	5	5	0		PRMT EVAL/AWARD BID PKG - FURN/INSTALL CONC PAVING	3JAN96	7JAN96	2MAY96	6MAY96	120
10245	10	10	0		CNST Install ABDR Power Pedestal	23JUN96	2JUL96	31OCT96	9NOV96	130
5100	5	5	0		PRMT PREP/ISSUE BID PKG - FURN/INSTALL CONC PAVING	8DEC95	12DEC95	17APR96	21APR96	131
5105	10	10	0		PRMT EST/SUBMIT BID PROP. - FURN/INSTALL CONC PAVING	13DEC95	22DEC95	22APR96	1MAY96	131
10050	84	84	0		CNST Purchase/Deliver MB-2 B/M Approach Fix.	1MAR96	23MAY96	19JUL96	10OCT96	140
10125	30	30	0		CNST NW End Install MB-2 Approach Base & Fixture	27MAY96	25JUN96	16OCT96	14NOV96	142
10115	2	2	0		CNST NW End Install L-824 Type C Lighting Cable	22MAY96	23MAY96	14OCT96	15OCT96	145
10120	30	30	0		CNST NW End Install L-850 E & B Fixture Trim	24MAY96	22JUN96	16OCT96	14NOV96	145
10145	15	15	0		CNST NW End Install ILS Antenna Supports	27MAY96	10JUN96	26OCT96	9NOV96	152
10165	15	15	0		CNST NW End Install ILS Power Supply	27MAY96	10JUN96	26OCT96	9NOV96	152
10150	10	10	0		CNST NW End Install ILS Ground Check Points	27MAY96	5JUN96	31OCT96	9NOV96	157
10140	7	7	0		CNST NW End Install ILS Equipment Shed SOG	27MAY96	2JUN96	3NOV96	9NOV96	160
10155	5	5	0		CNST NW End Install ILS Ground Well	27MAY96	31MAY96	5NOV96	9NOV96	162
10160	2	2	0		CNST NW End Install ILS Power Pedestal	27MAY96	28MAY96	6NOV96	7NOV96	163
10055	84	84	0		CNST Purchase/Deliver L-840 REIL System	1MAR96	23MAY96	16AUG96	7NOV96	168
10135	7	7	0		CNST NW End Install L-849 REIL System	24MAY96	30MAY96	8NOV96	14NOV96	168
10260	10	10	0		CNST Saw cut & demo Concrete for AF Circuits	24MAY96	2JUN96	10NOV96	19NOV96	170
5265	56	56	0		PRMT PURCHASE/DELIVER ELECTRICAL EQUIPMENT	1MAR96	25APR96	25SEP96	19NOV96	208

APPENDIX B

SUPPLEMENTAL COST DATA FOR BALTIMORE CLRL PHASE II

CENTRAL LIGHT RAIL LINE - PHASE II
FINANCIAL SUMMARY BASED ON CURRENT WORKING ESTIMATE

PROJECT TASKS	CONTRACT NUMBER	ORIGINAL CONTRACT VALUE	APPROVED CHANGES	CURRENT CONTRACT VALUE	EARNINGS	PENDING CHANGES	LATEST ESTIMATE	POTENTIAL CHANGES	POTENTIAL ESTIMATE	FUTURE CHANGES & CLAIMS	CURRENT WORKING ESTIMATE
Project Administration											
MTA Administration					$1,575,684		$1,735,700		$1,735,700	$379,460	$2,115,160
Systems Start Up							$1,160,000		$1,160,000	$140,000	$1,300,000
SUBTOTAL					$1,575,684	$0	$2,895,700	$0	$2,895,700	$519,460	$3,415,160
Design Engineering											
PB/MK (EIS/PE)	MTA-0221	$3,259,896		$3,259,896	$2,655,929		$3,259,896		$3,259,896		$3,259,896
PDI (EIS/PE)	MTA-0223	$91,773		$91,773	$98,960		$91,773		$91,773		$91,773
PB/MK (Ext. Dfn.)	MTA-0221	$1,600,000		$1,600,000	$1,363,589		$1,600,000		$1,600,000		$1,600,000
PDI (Ext. Dfn.)	MTA-0225	$800,000		$800,000	$800,000		$800,000		$800,000		$800,000
WBCM (Ext. Dfn.)	MTA-0464	$200,000	$4,477	$204,477	$149,623		$204,477		$204,477		$204,477
STV/Lyon (Ext. Dfn.)		$75,000	$20,964	$95,964	$94,249		$95,964		$95,964		$95,964
Landscape Design							$37,573		$37,573	$9,393	$46,967
Open End Consultant		$2,758,980		$2,758,980	$427,082		$2,777,000		$2,777,000	$416,550	$3,193,550
SUBTOTAL		$8,785,649	$25,441	$8,811,090	$5,589,432	$0	$8,866,683	$0	$8,866,683	$425,943	$9,292,627
Construction of Facilities											
Design/Build Contract	MTA-3-48-1	$55,750,000		$55,750,000	$15,392,710		$55,750,000		$55,750,000	$5,810,000	$61,560,000
Landscaping							$587,085		$587,085	$70,450	$657,535
Fare Collection Equipment							$1,025,088		$1,025,088	$51,254	$1,076,342
Communications							$484,000		$484,000	$48,400	$532,400
Warren Road Crossing		$65,227		$65,227	$65,227		$65,227		$65,227		$65,227
Agencies & Utilities		$4,382,000		$3,524,457	$2,345,705		$4,382,000		$4,382,000	$959,658	$5,341,658
Vehicles	MTA-0244	$14,311,513		$14,311,513	$7,379,096		$14,311,513		$14,311,513		$14,311,513
SUBTOTAL		$74,508,740	$0	$73,651,197	$25,182,738	$0	$76,604,913	$0	$76,604,913	$6,939,762	$83,544,675
Real Estate											
Appraisals		$200,000		$200,000	$146,726		$200,000		$200,000	$43,800	$243,800
Acquisitions		$760,848		$760,848	$760,848		$5,317,404	$1,020,000	$6,337,404	$733,649	$7,071,053
SUBTOTALS		$960,848	$0	$960,848	$907,574	$0	$5,517,404	$1,020,000	$6,537,404	$777,449	$7,314,853
Unallocated Contingencies											$2,770,864
PROJECT TOTAL		**$84,255,237**	**$25,441**	**$83,423,135**	**$33,255,428**	**$0**	**$93,884,700**	**$1,020,000**	**$94,904,700**	**$8,662,614**	**$106,338,179**

CENTRAL LIGHT RAIL LINE - PHASE II
FINANCIAL SUMMARY BASED ON CURRENT WORKING ESTIMATE

PROJECT TASKS	CONTRACT NUMBER	ORIGINAL CONTRACT VALUE	APPROVED CHANGES	CURRENT CONTRACT VALUE	EARNINGS	PENDING CHANGES	LATEST ESTIMATE	POTENTIAL CHANGES	POTENTIAL ESTIMATE	FUTURE CHANGES & CLAIMS	CURRENT WORKING ESTIMATE
Project Adminstation											
MTA Administration							$1,735,700		$1,735,700	$379,460	$2,115,160
Systems Start Up							$1,160,000		$1,160,000	$140,000	$1,300,000
SUBTOTAL							$2,895,700	$0	$2,895,700	$519,460	$3,415,160
Design Engineering											
PB/MK (EIS/PE)	MTA-0221	$3,259,896		$3,259,896			$3,259,896		$3,259,896		$3,259,896
PDI (EIS/PE)	MTA-0225	$91,773		$91,773			$91,773		$91,773		$91,773
PB/MK (Ext. Dfn.)	MTA-0221	$1,600,000		$1,600,000			$1,600,000		$1,600,000		$1,600,000
PDI (Ext. Dfn.)	MTA-0225	$800,000		$800,000			$800,000		$800,000		$800,000
WBCM (Ext. Dfn.)		$100,000		$100,000			$100,000		$100,000		$100,000
STV/Lynn (Ext. Dfn)		$75,000		$75,000			$75,000		$75,000		$75,000
Landscape Design							$37,573		$37,573	$9,393	$46,967
Open End Consultant							$2,777,000		$2,777,000	$416,550	$3,193,550
SUBTOTAL		$5,926,669	$0	$5,926,669	$0	$0	$8,741,242	$0	$8,741,242	$425,943	$9,167,186
Construction of Facilities											
Design/Build Contract							$56,219,489		$56,219,489	$5,872,971	$62,092,460
Landscaping							$587,085		$587,085	$70,450	$657,535
Fare Collection Equipment							$739,070		$739,070	$88,688	$827,758
Agencies & Utilities							$4,382,000		$4,382,000	$959,658	$5,341,658
Vehicles	MTA-0244	$14,311,513		$14,311,513			$14,311,513		$14,311,513		$14,311,513
SUBTOTAL		$14,311,513		$14,311,513			$76,239,157	$0	$76,239,157	$6,991,768	$83,230,924
Real Estate											
Appraisals							$200,000		$200,000	$43,800	$243,800
Acquisition							$5,800,700		$5,800,700	$1,270,353	$7,071,053
SUBTOTAL							$6,000,700	$0	$6,000,700	$1,314,153	$7,314,853
Unallocated Contigencies											$3,210,056
PROJECT TOTAL											$106,338,179

APPENDIX C

SUPPLEMENTAL SCHEDULE DATA FOR BALTIMORE CLRL PHASE II

LATE START	LATE FINISH	ACTIVITY
7DEC92A		FTA APPROVE LETTER OF NO PREJUDICE (LONP)
11DEC92A	28OCT93A	PBMK PERFORM ADDITIONAL PRELIMINARY ENGINEERING
1JAN93A	16APR94	CERTIFICATE OF NEEDS, TITLE WORK & ROW APPRASIAL
1FEB93A	1MAY94	PDI PERFORM SYS. ENG.-DESIGN/BUILD PROPSAL & BID
1AUG93A	1APR94	GRANT APPROVAL-LONP, UTILITIES & ROW ACQUISITION
15OCT93A		DESIGN/BUILD PROPOSAL READY FOR INDUSTRY REVIEW
22OCT93A	12DEC93A	FEIS APPROVAL PROCESS (RECORD OF DECISION)
1JAN94A	18APR95	PENN STATION RIGHT OF ENTRY/ROW ACQUISITION
1JAN94A	18APR95	HUNT VALLEY RIGHT OF WAY ACQUISITION
1JAN94A	18APR95	BWI RIGHT OF WAY ACQUISITION
1JAN94A	16AUG94	FTA FULL FUNDING AGREEMENT
16MAR94		INVITATION FOR BIDS (IFB) - STEP 1
15MAY94	31JUL94	RECEIPT/REVIEW STEP 1 PROPOSALS
1AUG94		INVITATION FOR BIDS (IFB) - STEP 2
	17OCT94	BIDS OPENING
17JAN95		DESIGN/BUILD CONTRACT NTP
17JAN95	15FEB97	DESIGN & CONSTRUCTION
19APR95		START PENN STATION CONSTRUCTION
19APR95		START HUNT VALLEY CONSTRUCTION
19APR95		START BWI CONSTRUCTION
16FEB97	16APR97	SYSTEM START UP
17APR97	16MAY97	PRE-REVENUE SERVICE
17MAY97	17MAY97	REVENUE OPERATION

Timescale: 1993 – 1997 (N D J F M A M J J A S O N D ... J F M A M)

Plot Date 31JAN94
Data Date 1FEB94
Project Start 7DEC92
Project Finish 17MAY97

(c) Primavera Systems, Inc.

Activity Bar/Late Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

Sheet 1 of 1

MASS TRANSIT ADMINISTRATION
LIGHT RAIL - PHASE II DESIGN/BUILD
PROPOSED PROJECT SCHEDULE

PROGRAM CONTROL DEPARTMENT

Date	Revision	Checked	Approved

LRT PHASE II D/B SCHEDULE CREDITIBILITY (LRTIISCH) 1/28/94R

1. Attachment A was the Summary Schedule (as of 4/1/92) that was in use for the LRT extensions, prior to the determination to proceed on a Design/Build basis.

2. In developing the 4/1/92 schedule:
   a. the Civil Construction duration for Hunt Valley was derived from the actual civil durations of contract CL-05 one each for Conrail and non-Conrail Right-of-Way.
   b. the Civil Construction duration for Penn Station was derived from the actual civil duration of contract CL-02.
   c. the Civil Construction duration for BWI was derived from the actual civil duration of contracts CL-01 & CL-11.
   d. the Systems installation and testing durations for each segment were derived from actual Phase I durations.
   e. the Civil design durations were derived from actual Phase I durations.

The critical durations, in months, from start of civil design to Revenue Operations for each segment are as follows:

	HV Conrail	HV non-Conrail	Penn	BWI
Civil design	7.5	8	8	8
Advertise to NTP	4	4	4	4
Civil/trackwork construction	6	10	11	14*
Systems Equip install/test	6	6	5	6
Intergrate and Pre-Rev tests	2	2	1	2
delays-awaiting ROW	0	3	0	3
Totals	25.5	33	29	37

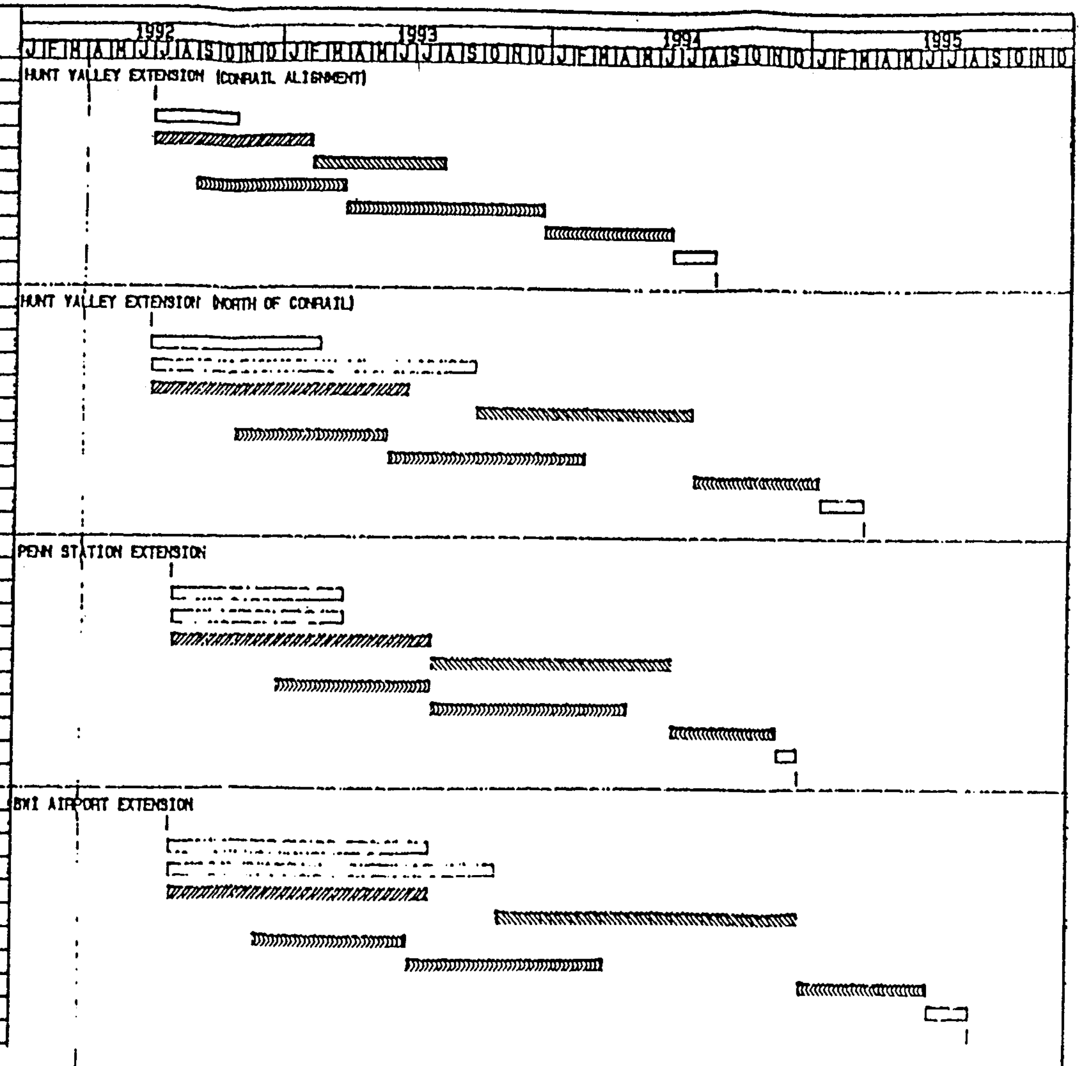
To put the above durations on an even keel with the 25 months contained within the D/B contract, we need to delete from the above table: "advertise to NTP"; "Intergrated and Pre-Rev tests" and "delays-awaiting ROW."

Compareable durations now====19.5======24========24========28

Except for BWI all the resultant durations are less than 25 months and the 3 months delta for BWI was precieved as a minimum schedule benefit resulting directly from the D/B concept. THIS ASSUMES THAT THE CONTRACTOR IS CAPEABLE OF AQUIRING ANY REQUIRED PERMITS, ETC.AND KEEPING THAT AQUISITION OFF HIS CONTRACT CRITICAL PATHS.

* = BWI'S CIVIL CONSTRUCTION WORK, AS NOW PLANNED, IS SIMPLER THAN THE CIVIL CONSTRUCTION WORK THAT WAS PLANNED AS OF 4/1/92

ACTIVITY DESCRIPTION	ORIG DUR	EARLY START	EARLY FINISH
FTA FUNDING APPROVAL	1	1JUL92	1JUL92
OBTAIN PERMITS	120	2JUL92	29OCT92
CIVIL DESIGN/AWARD	225	2JUL92	11FEB93
CIVIL/TRACKWORK CONSTRUCTION	180	13FEB93	11AUG93
SYSTEM DESIGN/AWARD	210	31AUG92	29MAR93
DESIGN/FAB/DELIVER SYSTEMS EQUIPMENT	270	30MAR93	24DEC93
SYSTEM EQUIPMENT INSTALLATION	180	25DEC93	22JUN94
INTEGRATED/PRE-REVENUE TESTING	60	23JUN94	21AUG94
REVENUE OPERATION - HUNT VALLEY EXT	1	22AUG94	22AUG94
FTA FUNDING APPROVAL	1	1JUL92	1JUL92
OBTAIN PERMITS	240	2JUL92	26FEB93
ACQUIRE PROPERTY (GILROY)	450	2JUL92	24SEP93
CIVIL DESIGN/AWARD	360	2JUL92	26JUN93
CIVIL/TRACKWORK CONSTRUCTION	300	26SEP93	22JUL94
SYSTEM DESIGN/AWARD	210	30OCT92	27MAY93
DESIGN/FAB/DELIVER SYSTEMS EQUIPMENT	270	29MAY93	22FEB94
SYSTEM EQUIPMENT INSTALLATION	180	23JUL94	18JAN95
INTEGRATED/PRE-REVENUE TESTING	60	19JAN95	19MAR95
REVENUE OPERATION - HUNT VALLEY EXT	1	20MAR95	20MAR95
FTA FUNDING APPROVAL	1	1AUG92	1AUG92
OBTAIN PERMITS	240	2AUG92	29MAR93
ACQUIRE PROPERTY	240	2AUG92	29MAR93
CIVIL DESIGN/AWARD	360	2AUG92	27JUL93
CIVIL/TRACKWORK CONSTRUCTION	330	29JUL93	23JUN94
SYSTEM DESIGN/AWARD	210	30DEC92	27JUL93
DESIGN/FAB/DELIVER SYSTEMS EQUIPMENT	270	29JUL93	24APR94
SYSTEM EQUIPMENT INSTALLATION	180	24JUN94	20NOV94
INTEGRATED/PRE-REVENUE TESTING	30	21NOV94	20DEC94
REVENUE OPERATION - PENN STATION EXT	1	21DEC94	21DEC94
FTA FUNDING APPROVAL	1	1AUG92	1AUG92
OBTAIN PERMITS	360	2AUG92	27JUL93
ACQUIRE PROPERTY (DIRECT CONNECTION SOUTH)	450	2AUG92	25OCT93
CIVIL DESIGN/AWARD	360	2AUG92	27JUL93
CIVIL/TRACKWORK CONSTRUCTION	420	27OCT93	20DEC94
SYSTEM DESIGN/AWARD	210	30NOV92	27JUN93
DESIGN/FAB/DELIVER SYSTEMS EQUIPMENT	270	29JUN93	25MAR94
SYSTEM EQUIPMENT INSTALLATION	180	21DEC94	18JUN95
INTEGRATED/PRE-REVENUE TESTING	60	19JUN95	17AUG95
REVENUE OPERATION - BWI EXT	1	18AUG95	18AUG95



Activity Bar/Early Dates
Critical Activity

PROJECT PHASE

Primavera Systems, Inc. 1984-1990

MASS TRANSIT ADMINISTRATION
CENTRAL LIGHT RAIL LINE - EXTENSIONS
PHASE 2 CONCEPTUAL PLAN - OVERVIEW

Project Start : 1JUL92
Data Date
Sheet 1 of 1

PHASE 2 - CONCEPTUAL PLANNING SCHEDULE
Date | Revision | Checked | Approved

C-3

NOTICE

DOT-T-96-19

DOT-T-96-19

Technology Sharing

A Program of the U.S. Department of Transportation