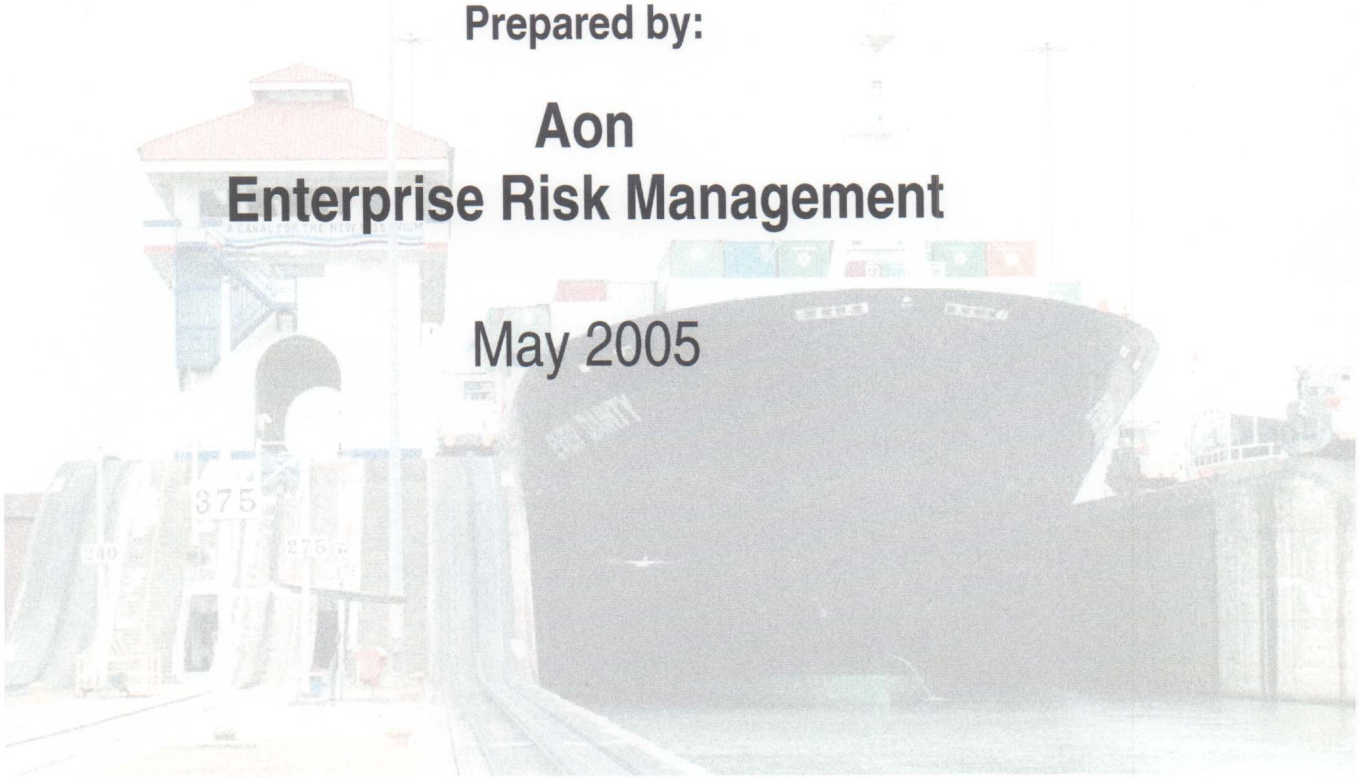
The Panama Canal Authority
Canal Expansion
Risk Assessment Report



Prepared by:

Aon
Enterprise Risk Management

May 2005

AON

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The Enterprise Risk Assessment project team is comprised of members from both ACP and Aon.

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Distribution, Reliances and Limitations

Distribution

This document represents a report of the data, findings, observations and suggested next steps associated with the Panama Canal Authority ("ACP") Canal Expansion Risk Assessment project. The central purpose of the project was to identify and evaluate material risks associated with the proposed canal expansion at the enterprise level.

This report and its supporting documentation, either attached or contained elsewhere, is considered to be "firm sensitive" and applicable to both the ACP and Aon. When distributed, this document should be provided in its entirety and the client should control its circulation.

Reliances and Limitations

This document should be viewed with the understanding that Aon relied extensively on information provided by the ACP and information obtainable within the public domain to develop the data, findings, observations and suggested next steps contained within this report. The information is assumed to be current, unless specified, and has not been audited for error or misrepresentation. Aon also recognizes that observations and attitudes may change over time.

Judgments about this document, its observations and methods should be made only after reviewing it in its entirety. Aon project team members are available to explain or amplify any matter presented herein, and it is assumed that the user of this document will seek explanation or amplification of any matter in question.

Sampling Error

The statistical results and information from interviews provided in this report is potentially subject to error as a result of sample size, non-randomness of the sample population and the biases associated with self-reported and third-party-collected data. Aon has attempted to avoid providing misleading information; however, in some cases, perfect information may not have been attainable.

Executive Summary

The Panama Canal Authority ("ACP") retained Aon to conduct an assessment of the risks associated with an expansion of the canal and to lay the foundation for an enterprise-wide risk management process that will allow the ACP to identify, quantify and prioritize material risks related to the expansion project. In our analysis, we have sought to evaluate future risks, and review the risks in light of the current environment. We also sought to identify areas of opportunity to enhance ACP's ability to succeed in the canal expansion project.

Our review indicated that the ACP has identified numerous risks that could "impair" or delay the canal construction project, although the impression of the possible risk impact varies across the organization. For purposes of this analysis, materiality at the enterprise level was defined as a project delay of over 1.5 years and/or cost overruns of over $200 million. Through the aggregation of the interviews and an internal and external data review, we identified twenty-two key risks.

Based on our analysis, ten risks were deemed to exceed the ACP's risk tolerance and materiality threshold. From a risk prioritization standpoint, these risks were selected for further review and analysis. The table below identifies the critical risks and type of analysis conducted.

Risk Category	Risk	Analysis Method
Administrative & Operational	• Inefficient organizational structure • Channel disruption	• Benchmarking • Quantitative model
Environmental, Political and Social	• Environmental concerns/planning • Inadequate communications strategy	• ACP effort underway • ACP effort underway
Execution	• Project completion delay • Changes in cost projections/overruns • Change in project scope, design or definition • Recruitment and retention of quality and quantity of skilled labor • Employee safety	• Quantitative model • Quantitative model • Quantitative model • Quantitative model • Benchmarking
Market	• Inaccurate revenue projections	• ACP effort underway

The interviewees perceived that the largest risk to the expansion project is project completion delay. A material delay can arise from multiple causes, including problems related to contractors, equipment, labor, logistics, and weather. Many of these delay risks can be at least partially mitigated.

Aon generally agrees that the identified risks are critical to the expansion, however our perspective differs in two areas. First, the most critical risk to the expansion project is the organizational structure of the ACP. The current organizational structure, while functional for current day to day operations, may prove dysfunctional in the long term and will likely create wasteful managerial processes in future Canal operations whether this may be a modernization or expansion project. Reorganizing the ACP's structure prior to the project initiation can mitigate the potential financial impact of this risk on the expansion project.

Second, the ACP identified employee safety as a critical risk. Based on construction project statistics and Panamanian financial obligations to injured or deceased employees, Aon's view is that this is not a critical risk because it will not reach the materiality threshold.

Of the ten critical risks identified, five risks were selected for detailed quantitative modeling. These risks included:

- Project completion delay,
- Recruitment and retention of quality and quantity of skilled labor,
- Changes in cost projects/overruns,
- Changes in project definition, scope or design, and
- Channel disruption.

An integrated risk model was developed incorporating these five risks to quantify the potential and probable monetary and/or operational impact of risks associated with a prolonged project completion delay or significant cost overruns. The risks to the expansion project are not static and Aon has delivered a stochastic modeling tool that allows the ACP to easily change cost estimates, timelines and distribution parameters as time passes and better information becomes available.

Recommendations to mitigate risk are provided and incorporate the guiding principles of risk management: risk administration, risk assessment, risk control and risk finance. Specific recommendations are provided, as appropriate, for key risks.

We commend the ACP's commitment to adopting and implementing an enterprise risk management process and use it in a forward-looking context. Our conclusions and recommendations are offered in support of this process and are intended to enhance the ACP's ability to effectively plan for and effectively execute on its goals of canal expansion.

1. Project Overview, Purpose and Objectives

1.1 Overview of Enterprise Risk Management

Enterprise Risk Management (ERM) is evolving as an integral part of the process to improve the success of business strategies. Assessing and controlling risk is not limited to mitigating unexpected losses, but also assists in attaining business goals and ensuring that opportunities are not overlooked. The likely reduction in losses and business setbacks, combined with an increased ability to meet business objectives, will strengthen stakeholder confidence. This approach to risk management is considered good corporate governance and is being adopted by organizations around the world as a best practice.

1.2 Project Purpose and Objectives

As part of the project planning phase for the expansion of the Panama Canal, the ACP retained Aon, a risk management and consulting services organization, to conduct an assessment of the risks associated with an expansion of the canal and to lay the foundation for an enterprise-wide risk management process that will allow the ACP to identify, quantify and prioritize material risks related to the expansion project.* The observations in this report are from the ACP personnel, and consolidated by Aon.

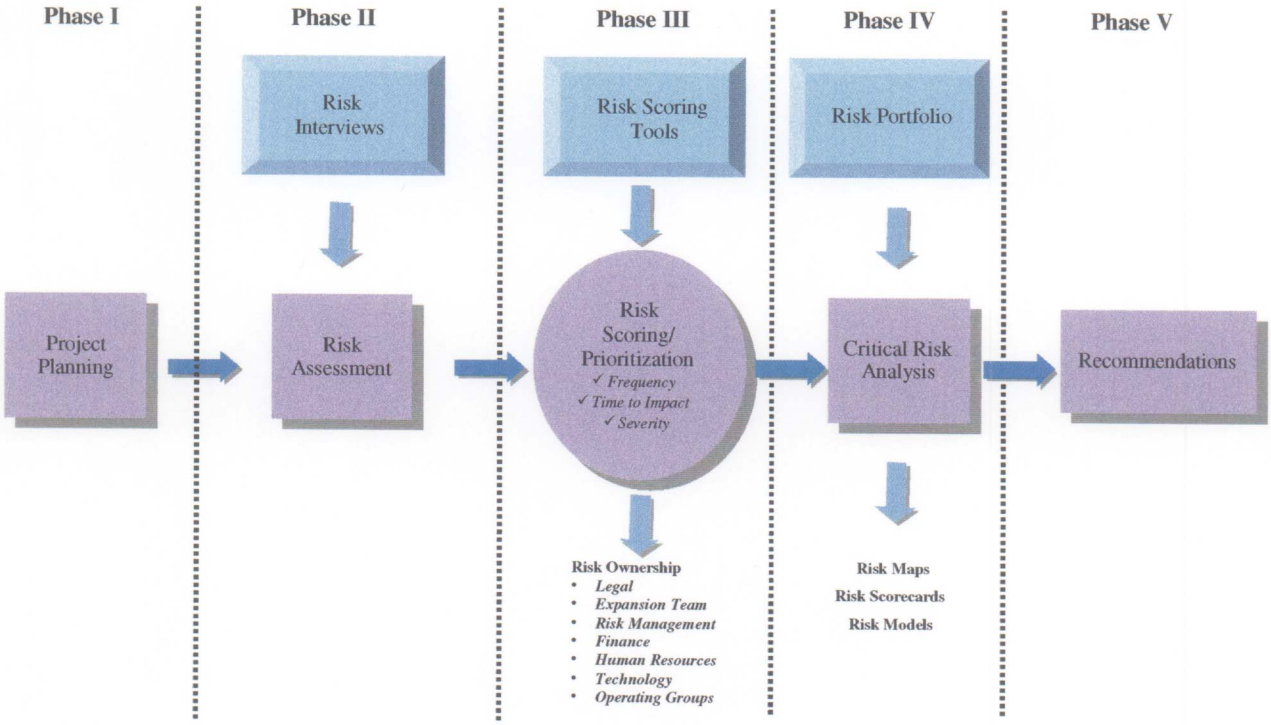
The project objectives were to:

- Integrate the key risk management concepts into the overall decision matrix being developed for the expansion project
- Develop an enterprise risk management framework/process
- Integrate expansion project risk information into a best practice model for major construction projects
- Identify and prioritize critical risks for the expansion project taking into account the inter-relationship of risk between current operations and the expansion project
- List potential solutions for critical risks.

* An assessment of the ACP's Risk Management department is provided in Aon's Risk Management Unit Analysis report.

2. Project Phases

Aon utilized a multi-step work plan to achieve the project objectives. Further detail of each project phase follows.



2.1 Phase I - Project Planning

Project team members from Aon and the ACP met on October 6, 2004 to conduct a project planning meeting. The purpose of this meeting was to lay the groundwork for the risk assessment project and to assess the "current state" of work already in progress. Since the risk assessment process involves a diverse group of ACP professionals, it was critical to make sure the project was properly focused to minimize the need for future scope of work revision and time commitment from firm personnel. In this session, the ACP's core ERM team worked with Aon's ERM specialists to address the following key issues:

- Review of the project goals and objectives
- Define the format for the project reports
- Identify key project milestones and deliverables
- Define the ACP's view of materiality and validate the risk ranking scoring parameters
- Identify the various risk owners within the ACP to be interviewed and surveyed
- Initiate data collection
- Develop the interview guide.

2.2 Phase II - Risk Assessment

In November 2004, Aon engaged in site tours of the ACP locations and facilitated on-site interview sessions with 43 senior management personnel of the ACP's business units and support functions. Aon conducted the interviews using a custom-designed interview guide, and the questionnaire was administered to a single interviewee or group of interviewees by Aon consultants. The ACP risk management unit coordinated the interview selection process, based on criteria provided by Aon, to bring together a group of senior management personnel that would have a broad view of the risks associated with the canal expansion project.

# Interviewed	42	
ACP Business Areas Represented	Administration Contracts Engineering Environmental Finance Human Resources Information Security Legal Marine Operations Marketing	Physical Security Planning Productivity Program Management Office Public Relations Risk Management Safety Treasury Tolls Management
ACP Interviewees	Alberto Aleman Manuel Alvarado Eugenia Alvarez Agustin Arias Oscar Bazan Alcaro Cabal Rodolfo de Carlo Mara Cevallos Ana Maria Chiquilani Juan Hector Diaz Alfredo Gonzalez Jorge de la Guardia Arcelio Hartley Jacinto Holnes Efrain Isaza Albert Joyce Roselinda Kam Ricardo Len Francisco Loaiza Walter Luschinger Valentine Lynch	Jose Maturel Stella Mendez Antonio Michel Francisco Miguez Lilia de Morales Cesar Murillo Stanley Muschett Amanda O'Meally Max de Pay Luz Pinzon Alfonso Regis Gladys Saarinen Rodlfo Sabonge Esteban Saenz Carlos Saldana Jose Salinas Enriqu Sanchez Ernst Schnack Karamjit Singh Reece Shaw Carlos Vargas
Aon Interviewers	Corey Gooch Danielle Jones Lisa Kremer	Paul Bitner Tito Ducruet Roger Ducruet

The interviews provided insight into the current and future risks of the canal expansion project, an understanding of risk mitigation techniques currently in use, and an overview of participants' recommendations for mitigation techniques. An outline of the interview guide is provided below.

Interview Section		Objective	Issues Evaluated
Section I:	Background and organization overview	Gain insight into interviewee perspective of the expansion project, new developments, strengths and weaknesses	Risk identification Emerging risk categories Risk remediation as a business process
Section II:	Risk definitions / Identification	Identify key risk categories and risk exposures	Risk identification Use of risk information Risk metrics
Section III:	Risk management / Mitigation	Identify key risk mitigation methods and evaluate their effectiveness	Risk ownership Risk metrics Risk remediation

Following the interviews, respondents validated and scored identified risks and mitigation strategies. Document and data analysis, including various current and historical organizational, operational and financial loss information, was also conducted during this phase. The information was evaluated and compared to the interview results.

2.3 Phase III - Risk Scoring/Prioritization

Upon completion of the Risk Assessment phase, the information obtained from the interviews and requested ACP documents were gathered. Identified risks were separated into four categories. The major enterprise risk categories used for this project are consistent with the ACP's categorization. The four categories and category descriptions follow.

Administrative & Operational:
Risks already inherent in the ACP's operations that could have an impact on the canal expansion project. Risks include limitations in decision-making within the organizational structure of the ACP, increase in operational costs with the expansion, and scarcity of human resources for administration and operation.

Execution:
Risks associated with realization/fulfillment of the expansion project including: delay of program, increase in investment costs (covering changes in materials and raw materials), lack of qualified labor for contractors, occupational safety for employees, problems in the hiring process, change in scope of project and changes in project design (covers design errors and geo-technical problems).

Environmental, Political and Social:
Risks which encompass social, political and environmental aspects include: handling water resources (water supply), pressure from environmental groups and other interest groups, delays in program approval and potential interference by political interests in the program.

Market:
Risks associated with market variables such as demand, pricing strategy, competition and global economic trends. Market risks include limitations in raising the tolls, global economic crisis, changes in naval market tendencies, (industry risk) and increases in competition (intermodal system of the United States and the Suez Canal).

The identified risks were then scored using three key parameters: frequency, severity, and time to impact, using ACP-specific scoring criteria. The application of this risk scoring/risk ranking process added depth to the effort to assess the canal expansion risks, and identified those risks that need further analysis and control measures. Aon used the following rating scales for the risk scoring criteria.

Risk Factor Score	Frequency
1	Extremely Rare
2	Rare
3	Periodic
4	Recurrent
5	Occurs Frequently

It should be noted that the severity risk factor scores were derived from the ACP's materiality threshold defined in Section 3.2.2 as a project delay of over 1.5 years and/or cost overruns of over $200 million.

Risk Factor Score	Severity
1	Less than $10,000,000 (Less than 1 month delay)
2	$10,000,001 - $60,000,000 (1-3 month delay)
3	$60,000,001 - $100,000,000 (4-11 month delay)
4	$100,000,001 - $200,000,000 (1-1.5 year delay)
5	Over $200,000,000 (Delay over 1.5 years)

Risk Factor Score	Time to Impact
1	Warning – long term (months or years)
2	Warning – short term (days or weeks)
3	No warning

Aon analysts evaluated the data by validating the interview findings with respondents and averaging the risk scores. Once the risk factor scores were averaged, the following formula, derived specifically for the ACP, was used to determine the individual risk score:

Risk Score = (Frequency + Time to Impact + Severity) x Number of Respondents

Through the use of the scoring process, Aon developed a profile of the ACP's critical expansion risks and prioritized them based upon their individual risk score.

2.3.1 Risk Map

Based on the individual risk scores, a risk map was created that plots the score for each risk and graphically summarizes the potential frequency, severity and relative time to impact of each risk. This graphic illustration of the ACP's critical expansion project risks can be used as an effective communication tool for senior management, the Board and others throughout the organization. This map also serves as the foundation for the more extensive quantitative risk modeling phase of the project by providing a prioritization of additional risks in need of analysis.

The risk maps categorize risks into three distinct areas that are defined as follows:

Red risks are those that are critical to the ACP, either as a result of their highly likely occurrence (**Adjusted Frequency > 20**) or their potential to severely impact (**Adjusted Severity > 20**) the expansion project's financial viability.
Yellow risks are those that have a moderate likelihood of occurrence (**20 >Adjusted Frequency > 10**) and/or a moderate potential impact (**20 > Adjusted Severity > 10**) to the expansion project's financial viability.

Green risks are those that are either least likely to occur (**Adjusted Frequency < 10**) and/or their potential impact (**Adjusted Severity < 10**) would be of low relative consequence to the expansion project's financial viability.

Potential occurrence and impact were adjusted to minimize skewedness and were estimated as follows:

Adjusted Frequency placement was determined by using the following risk scoring formula:
(Frequency Score + Warning Score) x Number of Respondents

Adjusted Severity placement was determined by using the following risk scoring formula:
Severity x Number of Respondents

Identification of and prioritization of risk exposures was a composite of respondents' input and Aon consultants' industry information and judgment.

2.3.2 Risk Scorecard

For each of the key risks, Aon attempted to answer the following questions:

- How is the risk defined?
- What is the current state of the risk?
- Who owns the risk?
- What current action plans are in place to manage the risk?
- What additional actions are planned?
- What actions are recommended?

A risk scorecard for each risk was created to consolidate the information captured during the interview sessions that took place in November 2004. The information in the scorecards reflects the interviewees' perspectives and may not reflect Aon's viewpoint. The risk scorecards are included in the Presentation of Results section of this report.

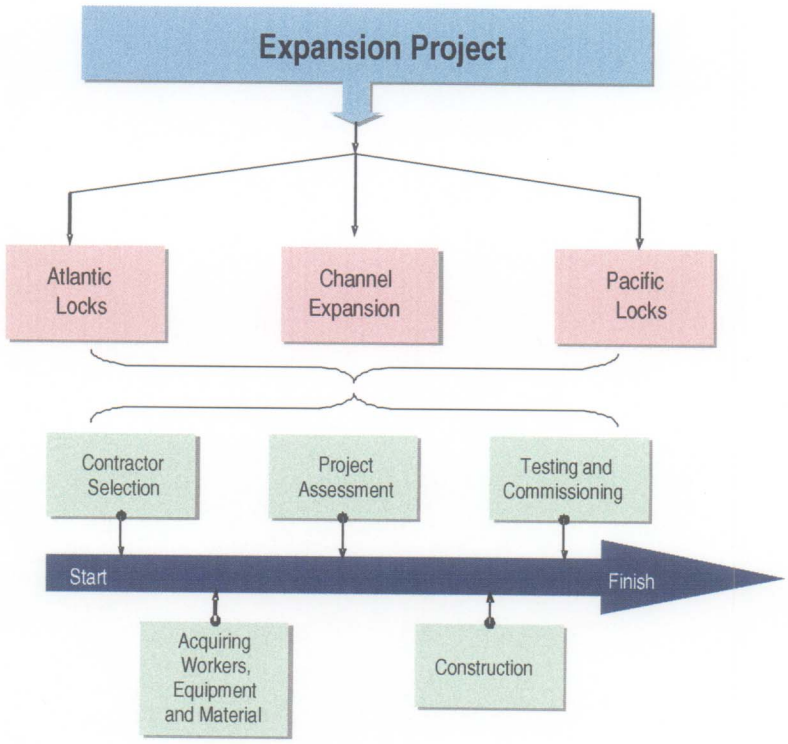
2.4 Phase IV – Critical Risk Analysis

2.4.1 Identification of Critical Risks

Ten risks were deemed to exceed the ACP's risk tolerance and materiality threshold based upon our risk scoring methodology. Of these ten risks, five were selected for quantitative analysis. Some risks were not modeled (see page 6) because they did not lend themselves to a quantitative exercise. These risks were either benchmarked by Aon or evaluated internally by the ACP. For instance, the ACP received an assessment of some of the key components of inaccurate revenue projections in the Mercer Market Demand Forecast study and these results have been incorporated into the model developed by Aon. The results of this model serve as input to the stochastic model Aon developed.

2.4.2 Risk Modeling

As part of this phase, financial modeling of five key risks using one or more of the Aon's proprietary loss simulation models, as well as custom-designed models for certain risks, was accomplished. Aon developed an analytical framework to produce simulated aggregate loss experience for 10,000 runs (each simulation includes 20 years or cash flows). The flow chart used in the quantitative model is provided below.



Modeling and benchmarking results are incorporated into the Quantitative Risk Modeling and Benchmarking Results 3.6.3.7

2.5 Phase V – Recommendations

Finally, Aon provided recommendations and/or proposed solutions for the critical risks. Recommendations may include suggestions for retaining, transferring, avoiding and/or mitigating risk and are included in Section 4. Recommendations of this report.

3. Presentation of Results

3.1 The Risk Management Process and Its Guiding Principles*

We have subdivided our findings and recommendations into the four basic elements of the risk management process: risk administration, risk assessment, risk control and risk financing. The key components for each basic element are provided below.

3.1.1 Risk Administration

- Create and sustain management commitment to risk management
- Adopt a clearly defined risk management structure
- Develop clearly targeted annual objectives
- Maintain sound communications with all affected levels of management

3.1.2 Risk Assessment

- Identify total assets and resources of organization
- Identify major exposures to loss
- Calculate values of assets and resources
- Measure current risk
- Project and communicate future losses and potential risk
- Calculate risk appetite

3.1.3 Risk Control

- Support proactive risk and loss control program
- Provide maximum incentive for participation in risk control program
- Monitor effectiveness of risk control activities

3.1.4 Risk Financing

- Finance risk, taking advantage of all available financial resources
- Maintain appropriate catastrophe protection
- Allocate risk financing costs among operating units on an equitable, understood and acceptable basis

* Tillinghast Towers Perrin

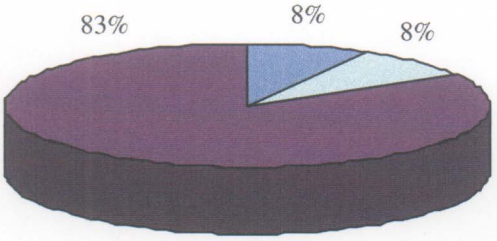
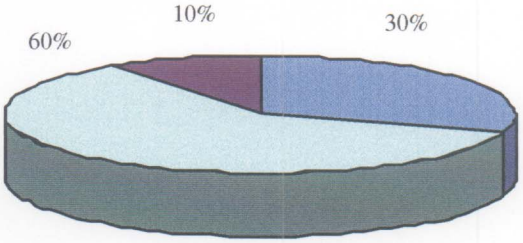
3.2 Summary of Project Observations

3.2.1 Risk Administration

- The ACP's organizational structure, based on a military model, is silo driven resulting in a lack of coordination and communication between units. The structure limits the ACP's ability to develop an enterprise-wide risk culture. While interviewees perceived this to be a major risk, Aon perceives this to be **the** critical risk as it increases the probability of cost overruns and/or time delays. Furthermore, as organizational structure issues are not quantifiable, the quantitative modeling results do not incorporate the impact of this risk.
- The organization's governance model is in need of a formal ERM oversight structure with Board of Director access and consistent reporting criteria.
- The ACP has a commitment to risk management but requires a clear ERM strategy that links to stakeholder values and provides guidance toward resource allocation. Similarly, the ACP needs to develop a common language for communicating risk. Metrics and indicators are not in place for the most significant exposures.
- Many business processes vary by department and/or division, contracts and procurement for example. With the ACP's future plans and projected growth, however, management supports the need for more standardized, replicable and automated processes.
- With all core functions, best-in-class people with the right skill sets are needed. These people need to be in a position to make strategic decisions and implement those decisions.
- Human capital elements are rarely incorporated in the company's key goals.
- Communications regarding risk management issues are provided, but may not reach all affected levels of management.

3.2.2 Risk Assessment

- During the interview process, respondents were asked to provide their opinion on materiality. While the results were captured, it became apparent that a substantial portion of the interviewees did not have a good understanding of the time value of money or the financial concept of materiality on an enterprise basis. Furthermore, most interviewees only seemed to grasp financial implications of risks that would directly impact their own business units.
- For purposes of this project, "materiality" at the enterprise level was defined as a time delay in project completion or project cost overruns. Senior management assigned the materiality thresholds as a project delay of over 1.5 years and/or cost overruns of over $200 million. The majority of interviewees agreed with these levels. In fact, 83% of respondents selected over $200 million as the materiality threshold for cost overruns. For project delay, respondents were slightly more conservative with 60% selecting between 1 to 1.5 years delay as the material level. Overall, 70% of respondents chose a project delay of more than 1 year as material (See Exhibit Below).

Cost Overruns	Project Delay
• Respondents overwhelmingly agreed that materiality for cost overruns is at least $100,000,000 • 91% of respondents replied that between $100,000,000 and $200,000,000 would be material to the project • Of the 91%, 83% of respondents replied that any amount exceeding $200,000,000 would be material for the project • 8% of respondents replied that less than $10,000,000 would be material to the project • No respondents selected values between $10,000,001 and $100,000,000	• Respondents were more divided in the definition of materiality for project completion delays • 70% of respondents replied that a delay greater than 1 year would be material for the project • Only 10% of respondents replied that a delay of over 1.5 years would be material for the project • Conversely, almost one-third of respondents (30%) replied that a delay of less than 1 month would be material for the project • No respondents selected a time delay of between 1 and 11 months
Materiality – Dollars  Less than $10,000,00 $10,000,001 – $60,000,000 $60,000,001 – $100,000,000 $100,000,001 – $200,000,000 Over $200,000,000	**Materiality – Time Delay**  Less than 1 month 1 – 3 months 4 – 11 months 1 – 1.5 years Over 1.5 years

- Risk assessment is generally handled on a business unit or division basis. Methods vary from being highly structured and systematic to more ad hoc and subjective. Limited quantitative risk analyses are performed.
- The risk-based culture at the ACP is inconsistent with various business units operating at different levels of risk aversion/acceptance. Employee performance metrics are not typically adjusted for risk and most employees have received limited risk management training.
- As an organization planning for significant growth, the ACP continues to focus on methods to scale and structure itself to keep pace with the expansion. As the ACP expands and grows, so will its overall risk profile. Concerns exist with respect to availability of skilled laborers, qualifications of the current staff to manage such a massive undertaking, absenteeism, and succession planning.
- Numerous respondents indicated that the recruitment and retention of both the quantity and quality of skilled labor was a concern. This was true not only for the expansion project, but also for ongoing canal operations and was driven by the ACP's aging workforce and substantial vacation accruals. Lack of specific skill sets, such as project management, was also a concern.

3.2.3 Risk Control

- Mitigation efforts are in place for several of the identified risks, but many of the current efforts are tactical in nature and required a broader, strategic focus. These mitigation activities were not tested or audited during this project.
- Risk mitigation methods are often conducted on a business unit or division basis.

3.2.4 Risk Finance

- There is no formal structure or person responsible for making enterprise-wide risk finance decisions.
- The risk management unit's involvement in risk finance has been limited to insurance.
- In Aon's opinion, the historic stability of the ACP's operations, until this major expansion project, has not made evaluation of risk and subsequent risk finance decisions a priority.

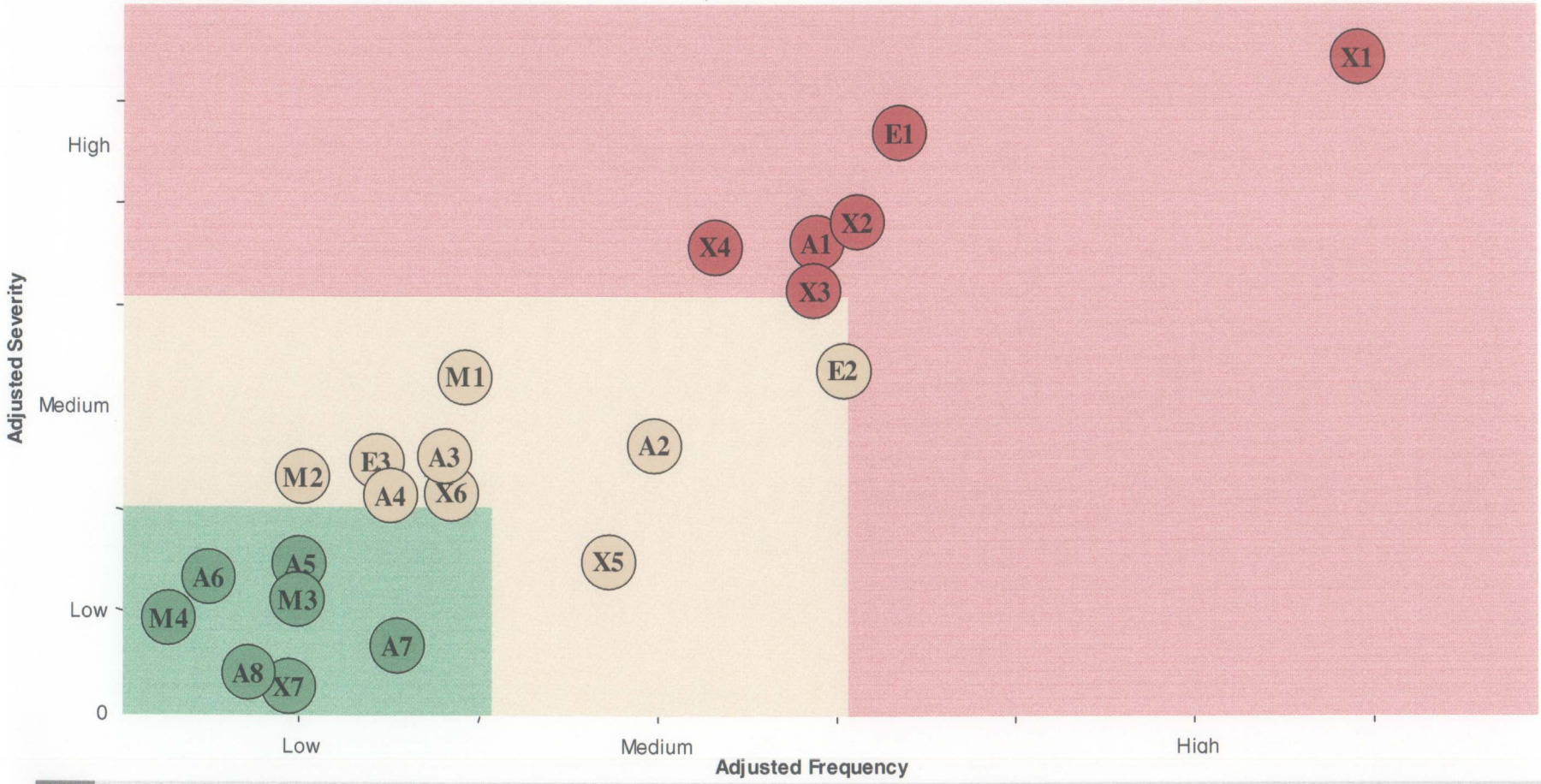
3.3 ACP Risk Map

The resulting risk map provides a graphical summary of the potential frequency, severity and relative time to impact of each risk. This map serves as the base information from which the ACP can evaluate the areas in need of mitigation, elimination, transfer and/or financing solutions.

During the project, numerous risks were identified which have been distilled down to twenty-two (22) key risks. These risks are coded into one of the following risk categories:

A = Administrative & Operational
E = Environmental, Political & Social
X = Execution
M = Market

ACP Risk Map



LEGEND

Administrative & Operational
- A1 – Inefficient organizational structure
- A2 – Channel disruption risks
- A3 – Limitations in quantity and quality of ACP project management resources
- A4 – Failure to obtain required Board approvals
- A5 – Radioactive/ hazardous materials spills
- A6 – Terrorism
- A7 – Succession planning of key employees
- A8 – Information Technology disruption

Environmental, Political & Social
- E1 – Environmental concerns/planning
- E2 – Inadequate communications strategy
- E3 – Government demands on Canal

Execution
- X1 – Project completion delay
- X2 – Recruitment and retention of quality and quantity of skilled labor
- X3 – Change in cost projections/overruns
- X4 – Change in project definition/scope/design
- X5 – Employee safety
- X6 – Procurement issues
- X7 – Security

Market
- M1 – Inaccurate revenue projections
- M2 – Competition
- M3 - Financial viability
- M4 – Maximum capacity reached prior to on –time completion

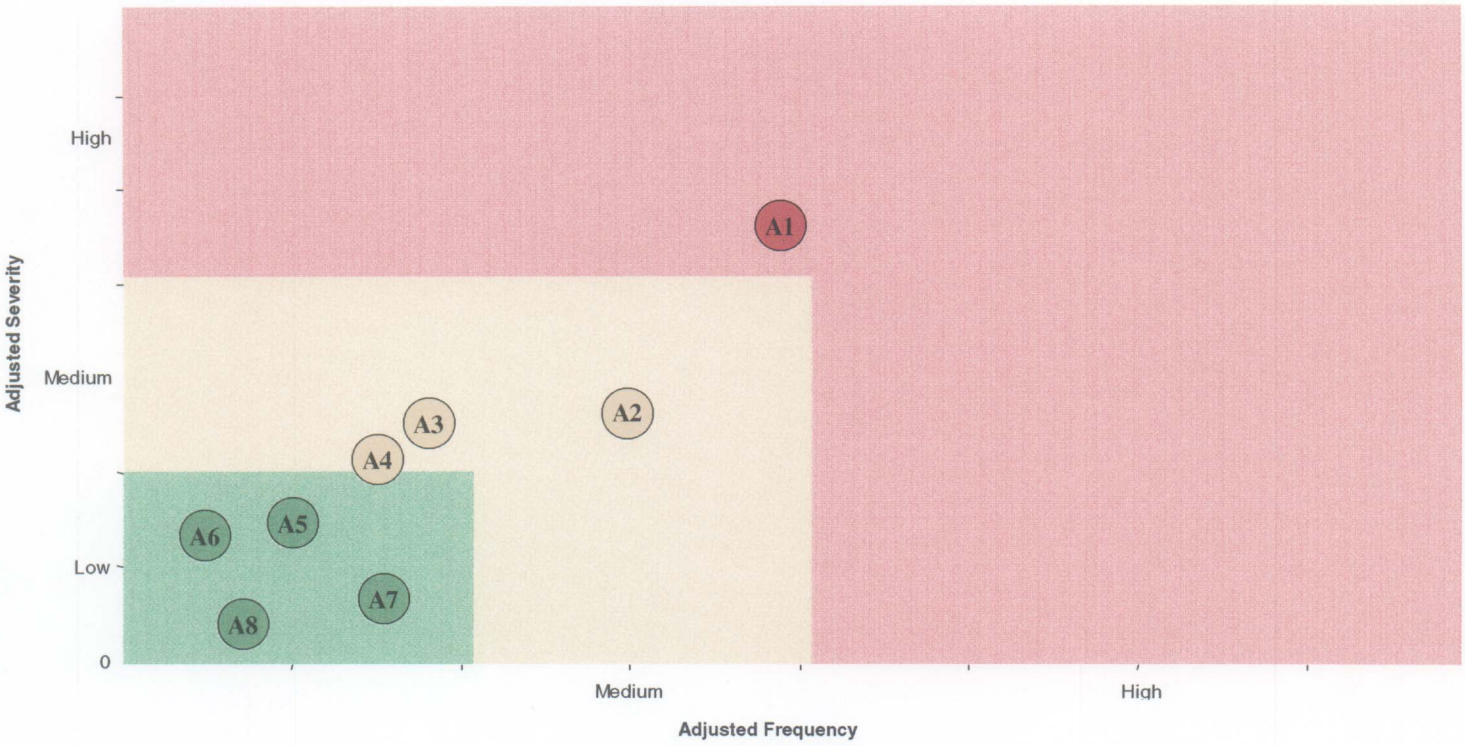
3.4 Evaluation of Risks by Category

In order to provide a more detailed analysis, further risk detail is provided separately for each of the four risk categories. Each section contains a risk map, risk scoring chart and detailed scorecards of each risk in the category. The information contained in this section is a compilation of the interviewees' responses and Aon's professional judgment.

3.4.1 Administrative and Operational Risks

Eight key risks were identified in the Administrative and Operational risk category. Risks in this category are inherent in the ACP's operations and may have an impact on canal operations.

3.4.1.1 Administrative and Operational Risk Map

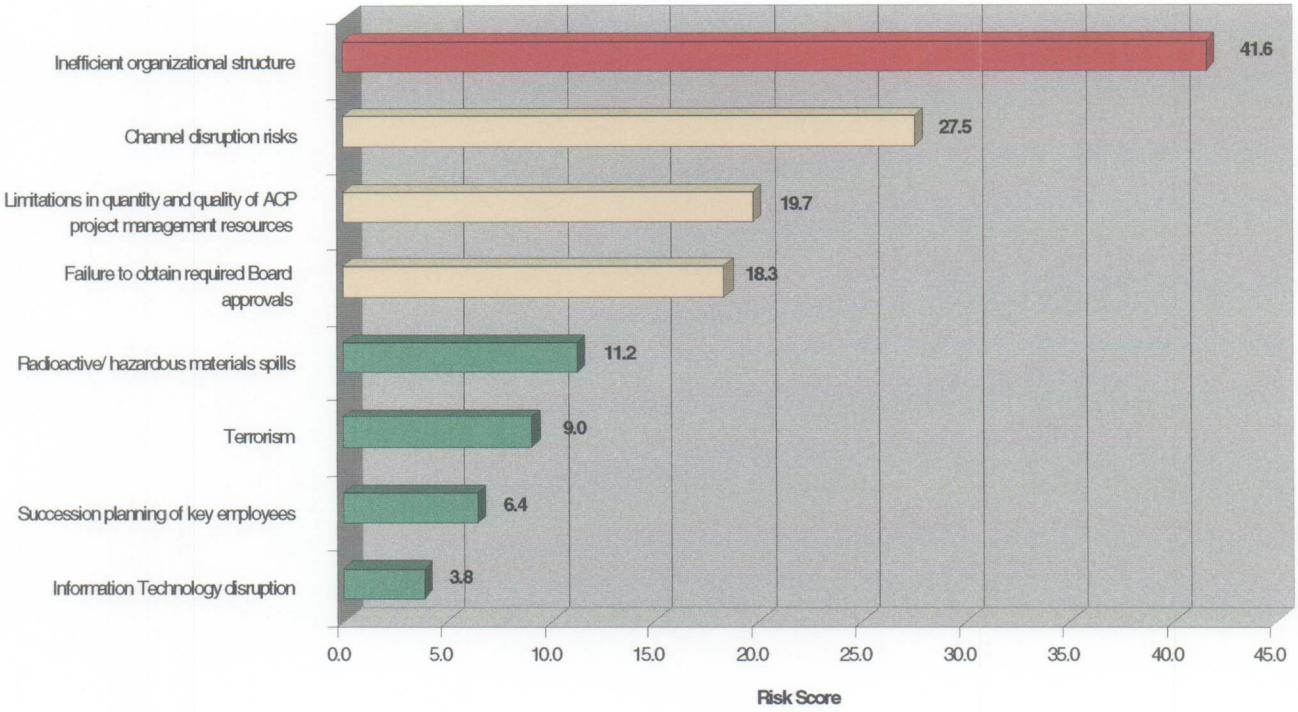


LEGEND

Administrative & Operational

A1 – Inefficient organizational structure
A2 – Channel disruption risks
A3 – Limitations in quantity and quality of ACP project management resources
A4 – Failure to obtain required Board approvals
A5 – Radioactive/ hazardous materials spills
A6 – Terrorism
A7 – Succession planning of key employees
A8 – Information Technology disruption

3.4.1.2 Administrative and Operational Risks Ranked by Risk Score



3.4.1.3 Administrative and Operational Risks Scorecard

Risk ID	Risk	Risk Owner	Mitigation Strategies
A1 Score: 41.6	Inefficient organizational structure - The inability to effectively coordinate and work with the business units of the organization Subcomponents: • Unclear lines of authority • Lack of formalized decision making process • Limitations in the decision making process • Silo structure (turf issues) • Oracle reporting • Separation of current and expansion project roles and responsibilities	• Expansion Team • Human Resources • Senior Management • Board of Directors	Current: • Possible project controls being evaluated ACP Recommendations: • Must make timely changes to the organizational structure. The awareness for change is there and action is needed. • Organization needs to revise the adequacy of the expansion project leadership. • Consolidate time keeping and update information system. Currently time has to be entered twice (one for payroll and one for the project management) and this decreases morale. The process is manually intensive and not currently integrated. The information systems needs to be user friendly (especially with reporting) and the information is only partially available for decision-making. • The ACP needs clear roles and responsibilities set and communicated for regular operations vs. the expansion project. Priorities and resources may compete. • Functions for expansion and operations need to be adequately staffed. Aon Recommendations: • See Section 4 for Recommendations

Risk ID	Risk	Risk Owner	Mitigation Strategies
A2 Score: 27.5	Channel disruption risks - The inability to maintain expansion productivity in the event of a negative waterway-related occurrence Subcomponents: • Vessel collision/ sinking • Landslides • Spills/ leaks • Site flooding • Water supply • Increased traffic	• Marine Operations	Current: • Multiple strategies in place for vessel passage, channel maintenance and water management Aon Recommendations: • See Section 4 for Recommendations

Risk ID	Risk	Risk Owner	Mitigation Strategies
A3 Score: 19.7	Limitations in quantity and quality of ACP project management resources - The inability to employ enough qualified project management resources to sustain the expansion project	• Human Resources • Expansion Team	Current • Project management training ACP Recommendations: • The ACP needs a defined recruitment strategy as it has limited experience in recruiting, hiring or training staff for this type of project • Evaluate possible outsourcing/elements of project management • Training of current personnel to fill gap in required skill sets Aon Recommendations: • No additional

Risk ID	Risk	Risk Owner	Mitigation Strategies
A4 Score: 18.3	Failure to obtain required Board approvals – Current procedures for obtaining Board approvals may impact Canal expansion productivity Subcomponents: • Difficulties in changing regulatory framework	• Administrator • Board of Directors	Current: • Interaction with key decision-makers • Lobbying efforts ACP Recommendations: • Strengthen decision making at the Board level • Board should develop mechanism for communicating internally prior to communicating externally Aon Recommendation: • Review corporate governance protocols to ensure that decisions related to the expansion project can be made in a timely manner

Risk ID	Risk	Risk Owner	Mitigation Strategies
A5 Score: 11.2	Radioactive/ hazardous materials spills - The inability to maintain expansion productivity in the event of a radioactive/hazardous material spill	• Marine Operations • Environmental • Risk Management • Security	Current: • Panama Canal Authority Contingency Plan • Mock drills and training • Enhanced security • Insurance Aon Recommendation: • Review external expertise capabilities and potentially contract for disaster recovery crisis management (including public relations) services • Enhance capabilities by partnering with other internal resources

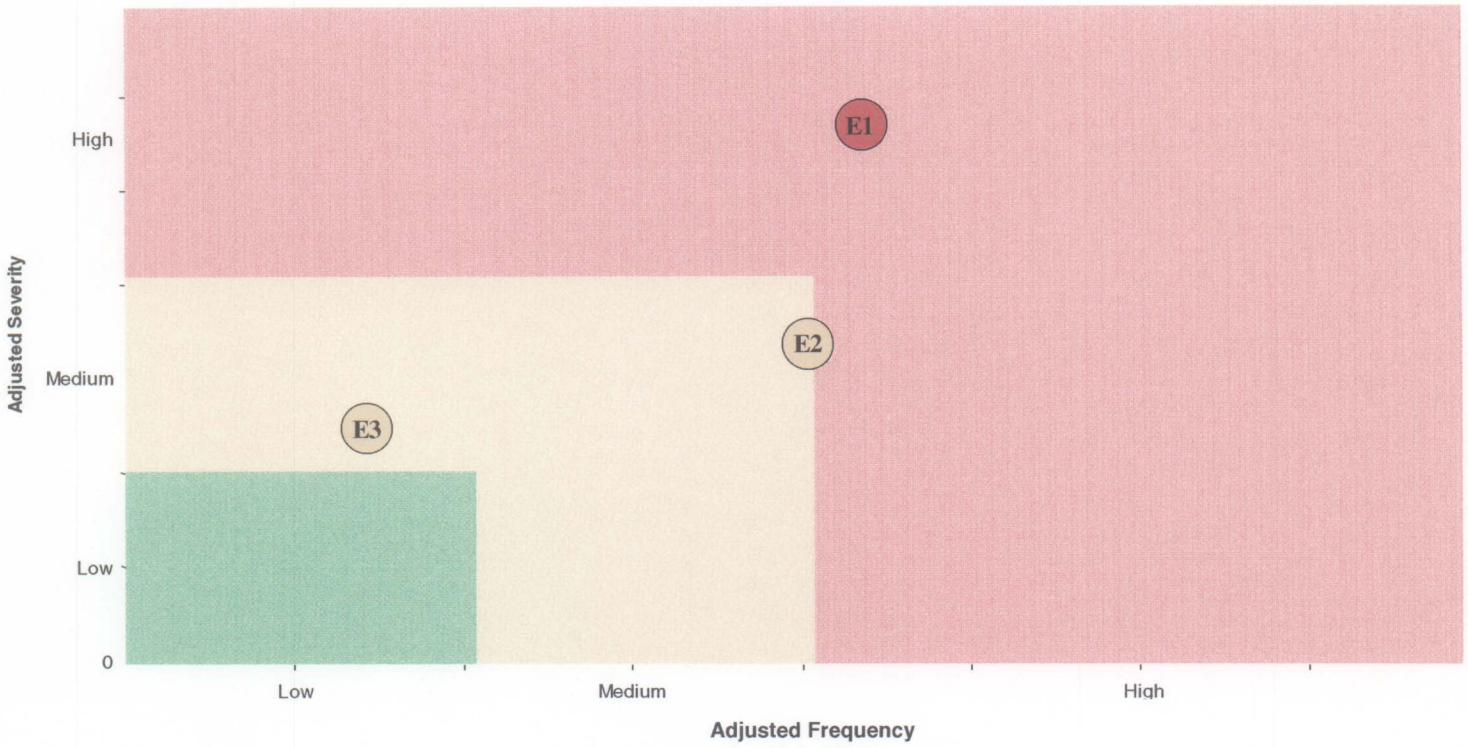
Risk ID	Risk	Risk Owner	Mitigation Strategies
A6 **Score: 9.0**	Terrorism – The inability to maintain Canal operations and expansion productivity in the event of terrorist activity Subcomponents: • Eco-terrorism	• Security • Risk Management	Current: • Insurance for existing canal operations • On-going security measures ACP Recommendations: • Implement USACE recommendations to enhance redundancy, reduce impact on installations and avoid interruption of Canal operation • Enhance risk analysis and information management capabilities Aon Recommendation: • Purchase Terrorism insurance coverage for expansion construction

Risk ID	Risk	Risk Owner	Mitigation Strategies
A7 **Score: 6.4**	Succession planning of key employees - The inability to replace key employees, and their intellectual capital, upon their departure from the ACP. Subcomponents: • Increased attrition during the expansion project due to aging workforce • No mandatory retirement age, potentially leading to loss of productivity	• Human Resources • Operations • Administrator • Board of Directors	Current: • Training programs ACP Recommendations: • Active succession plans updated on regular basis • Communication and training for key personnel Aon Recommendations: • Implement a mandatory retirement age which is the strategic fundamental objective of the PILAP • Develop formalized knowledge transfer protocols

Risk ID	Risk	Risk Owner	Mitigation Strategies
A8 **Score: 3.8**	Information Technology disruption - The inability to sustain expansion operations and productivity due to disruption to the ACP information system, either through an outage, attack, virus, etc. Subcomponents: • Customer billing	• Information Technology • Security	Current: • Firewalls • Virus protection ACP Recommendations: • Disaster recovery plan and business continuity plan • Back up offsite • For expansion, IT will need additional hardware and software items, including: fiber, phones, radios, GPS, CCTV, cameras, security, access control, more licenses, additional personnel and automation of data center Aon Recommendations: • No additional

3.4.2.1 Environmental, Political and Social Risk Map

The Environmental, Political and Social Risk Map plots the score for each risk and graphically summarizes the potential frequency, severity and relative time to impact of each risk. The three risks depicted on this map encompass social, political and environmental aspects.

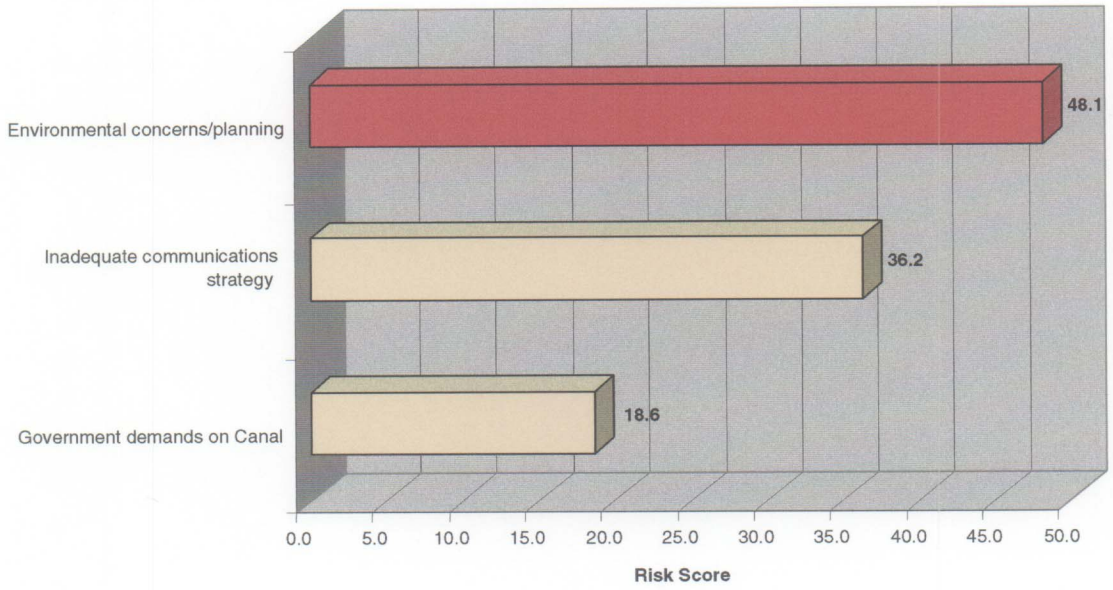


LEGEND

Environmental, Political & Social

E1 – Environmental concerns/planning
E2 – Inadequate communications strategy
E3 – Government demands on Canal

3.4.2.2 Environmental, Political and Social Risks Ranked by Risk Score



3.4.2.3 Environmental, Political and Social Risks Scorecard

Risk ID	Risk	Risk Owner	Mitigation Strategies
E1 Score: 48.1	Environmental concerns/planning - The inability to maintain Canal operations and expansion productivity in the event of adverse environmental concerns Subcomponents: • Environmental impact • Water management • Water quality • Unexploded ordinance site remediation and disposal • Environmental opposition (watershed, disposal sites, etc.)	• Environmental • Expansion Team • Engineering • Public Relations	Current: • Decision-making takes into account concerns of Board of Directors, Environmental Division and other departments/offices • Improved design investigation before starting the project will help reduce the impact of this risk • Watershed management and water quality studies underway • Investment in registering and titling in the watershed • Planned environmental impact studies ACP Recommendation: • Communicate water supply plan to the public Aon Recommendation: • Evaluate the partial transfer of environmental risk through the purchase of environmental insurance

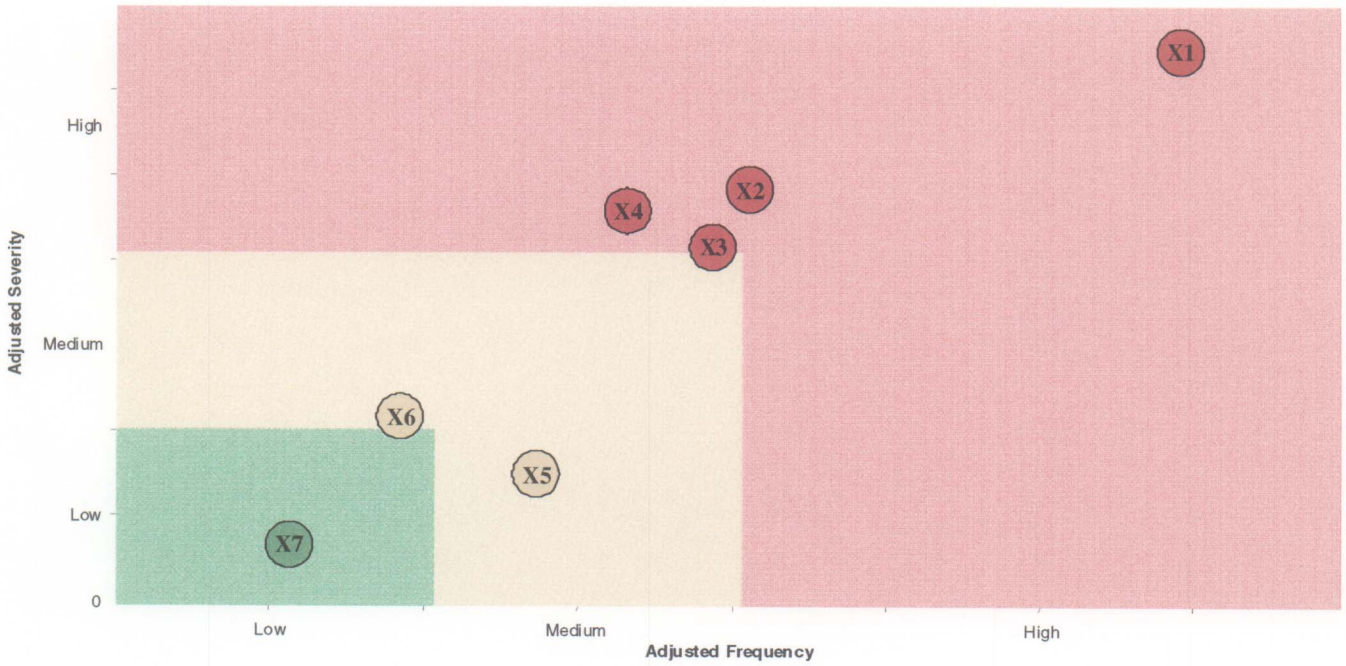
Risk ID	Risk	Risk Owner	Mitigation Strategies
E2 Score: 36.2	Inadequate communications strategy – The inability to conduct effective and timely communications internally and externally Subcomponents: • Reactive planning	• Executive Administration (Public Relations) • Administrator	Current: • Participation in educational/informational events regarding the expansion at schools, universities, fairs, etc. • Internal and external expansion approval surveys • Proposed communications plan ACP Recommendations: • There needs to be more communication before decisions are made as limited communications may lead to frustration among executives • Prepare mass media and communications management plan, and implement in a timely manner • External Board communications must attain consistency with regard to the expansion project • Revise communications organization Aon Recommendation: • Create an internal Public Relations department or hire an external public relations agency now

Risk ID	Risk	Risk Owner	Mitigation Strategies
E3 Score: 18.6	Government demands on Canal - The inability to meet government demands while sustaining current Canal operations and Canal expansion project productivity	• Administrator • Legal • Finance • Board of Directors	Current • Monitor agreements • Possible dividend policy under evaluation
	Subcomponents: • Changes in the ACP payments for Panamanian government agencies service • Changes in tonnage payment • Changes in government • Regulatory changes • Changes in government requirements • Risk of the government taking any funds borrowed from international financing community and not using them for the expansion project		ACP Recommendation: • Establish a formal structure, such as a Governmental Affairs Committee, to address lobbying and legislative relations Aon Recommendation: • Create a mechanism to protect borrowed funds related to the expansion project

3.4.3 Execution Risks

3.4.3.1 Execution Risk Map

The Execution Risk Map plots the score for each risk and graphically summarizes the potential frequency, severity and relative time to impact of each risk. The seven risks depicted on this map are associated with realization and fulfillment of the expansion project.

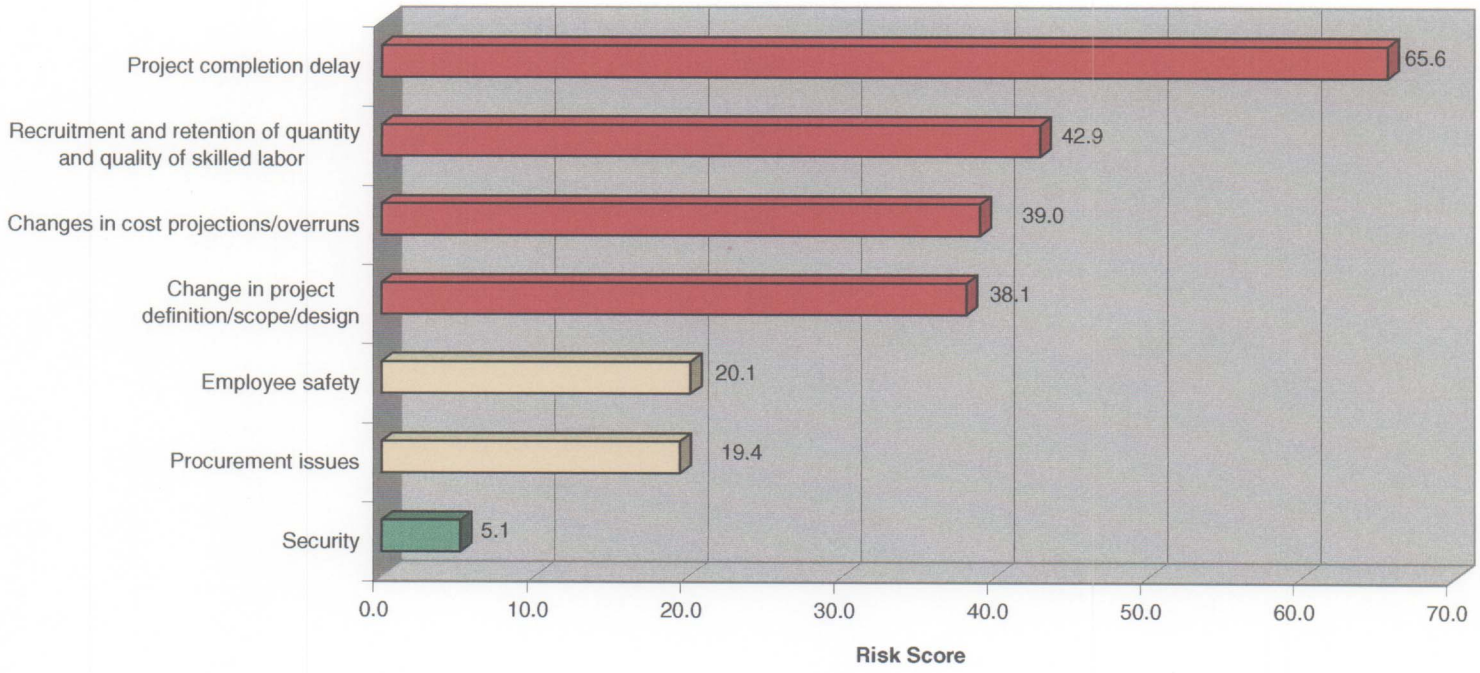


LEGEND

Execution

X1 – Project completion delay
X2 – Recruitment and retention of quality and quantity of skilled labor
X3 – Change in cost projections/overruns
X4 – Change in project definition/scope/design
X5 – Employee safety
X6 – Procurement issues
X7 – Security

3.4.3.2 Execution Risks Ranked by Risk Score



3.4.3.3 Execution Risks Scorecard

Risk ID	Risk	Risk Owner	Mitigation Strategies
X1 Score: 65.6	Project completion delay - The inability to complete the Canal expansion project within the timeframe set forth by the ACP due to unforeseen occurrences Subcomponents: • Contractor delays • Delays due to equipment/ supply availability • Damage to gates during transit • Logistics coordination • Labor disputes/ strikes • Equipment malfunction • Weather	• Expansion Team • Project Manager	Current: • Standardizing the design of the gates • Peer review/external review of the design of the dike in the Miraflores area • Backup disposal site • Contingency plan for dredging equipment – keep old dredge as backup • Maintain old and new equipment and training provided on both • Proposed new equipment for 2006 • Working on equipment replacement programs • Significant engineering, structural design and hydraulic management efforts underway • Studying contracting models to determine the best delivery method Aon Recommendations: • See Section 4 for Recommendations

Risk ID	Risk	Risk Owner	Mitigation Strategies
X2 Score: 42.9	Recruitment and retention of quantity and quality of skilled labor - The inability to recruit and retain enough qualified and skilled labor resources to sustain current operations and the expansion project Subcomponents: • Skilled contractor personnel • Aging workforce • Absenteeism • Panamanian workforce • Multi-national workforce	• Human Resources • Project Manager	Current: • Assessment of internal restructuring • Assessment of expansion project labor needs • Assessment of available workforce • HR and administration leading partnering effort with professional schools to train the types of workers needed to implement the project Aon Recommendations: • See Section 4 for Recommendations

Risk ID	Risk	Risk Owner	Mitigation Strategies
X3 Score: 39.0	Change in cost projections/ overruns - The ability to afford monetary increases in the financing of the expansion project due to unforeseen occurrences Subcomponents: • Commodity price increasesUnexpected geological findings • Integration of design	• Finance • Engineering	Current: • Budgetary monitoring • Adequate contingency reserve in project cost estimates • Project cost estimates follow international best practices of major projects Aon Recommendations: • See Section 4 for Recommendations

Risk ID	Risk	Risk Owner	Mitigation Strategies
X4 Score:38.1	Change in project definition/scope/design - The inability to maintain Canal expansion cost and time performance objectives when faced with possible changes in project definition, scope and/or design Subcomponents: • Project planning • Errors in design • Logistics • Geo-technical studies (site worse than expected, archeological find)	• Expansion Team • Project Manager • Engineering	Current: • ISO certified Quality Management System • Training program for procurement personnel • Periodic improvement of procurement regulations • Careful selection of procurement personnel to fill vacancies • Audit of procurement actions by Office of IG and Comptroller General • Have geo-technical designs and studies from prior work (locks, earthquakes, etc) • Excavation and dredging will be under control of the ACP as it is experienced with this work • ACP will need a contract management partner and budget to provide support ACP Recommendations: • Invest in studies, designs, hydraulic models, etc. to reduce the construction risks • Careful selection of main contractor(s) • Training of project personnel Aon Recommendations: • See Section 4 for Recommendations

Risk ID	Risk	Risk Owner	Mitigation Strategies
X5 **Score:20.1**	Employee safety - The inability to keep employees and contract personnel from incurring or causing injury during the expansion project Subcomponents: • Incidents • Training • Specialization • Certification	• Human Resources • Safety • Security	Current: • Training • HR and administration leading partnering effort with professional schools to train the types of workers that it will need to complete the project ACP Recommendations: • Start training people (ACP personnel and contractors) on safety matters, with the ACP-specific standards • Award safety and maintenance certifications • Create programs to develop key positions (e.g. officers and explosive personnel) • Incorporate down-side ramifications for not meeting safety performance goals Aon Recommendations: • See Section 3.7.2.3

Risk ID	Risk	Risk Owner	Mitigation Strategies
X6 **Score: 19.4**	Procurement issues - The inability to effectively and efficiently contract and procure resources in order to sustain expansion productivity Subcomponents: • Potential malpractice of procurement personnel (corruption, bribery, fraud) • Inadequate procurement process • Trade agreements/ requirement • Contract document risksJurisdiction	• Expansion Team • Finance • Legal • Engineering • Project Manager • Inspector General	Current: • Outside legal counsel setup • Received advice on procurement and bid protest best practices • Evaluation of contract delivery method underway • Ethics and Conduct Rules • Training • Monitoring ACP Recommendations: • Sufficient internal head count to manage the process • External support team (lawyers, project managers, risk analysts, etc.) • Promote potential contractor participation in bidding process • Internationally recognized standards for contract document and procedures Aon Recommendations: • No additional

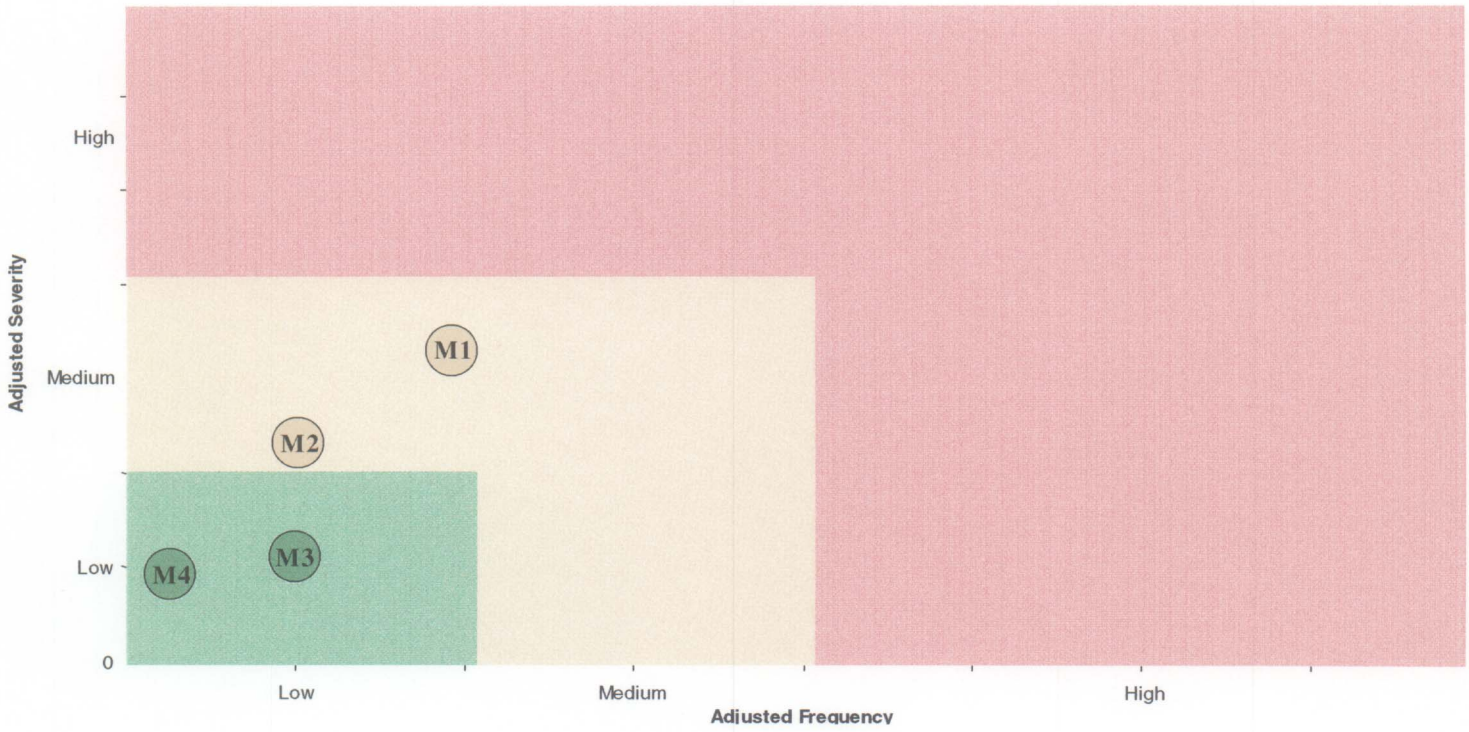
Risk ID	Risk	Risk Owner	Mitigation Strategies

X7
Score: 5.1
	Security - The inability to ensure the defense and protection of the ACP property and personnel (excluding Terrorism which was identified as a separate risk)
	
	Subcomponents:
	• Theft of equipment
	• Theft of materials
		• Security	Current:
			• Security based in Risk Management –
			  • Avoid (spread/ move or remove assets)
			  • Reduce Vulnerability (training)
			  • Protect (increase asset protection)
			  • Transfer (transfer risk to insurance company)
			• Use 4D philosophy: Deter, Detect, Detain and Delay
			• Inventory management
			
			Aon Recommendation:
			• Major security losses can be covered through insurance on a cost effective basis

3.4.4 Market Risks

3.4.4.1 Market Risk Map

The Market Risk Map plots the score for each risk and graphically summarizes the potential frequency, severity and relative time to impact of each risk. The four risks depicted on this map are associated with market variables such as demand, pricing strategy, competition and global economic trends.

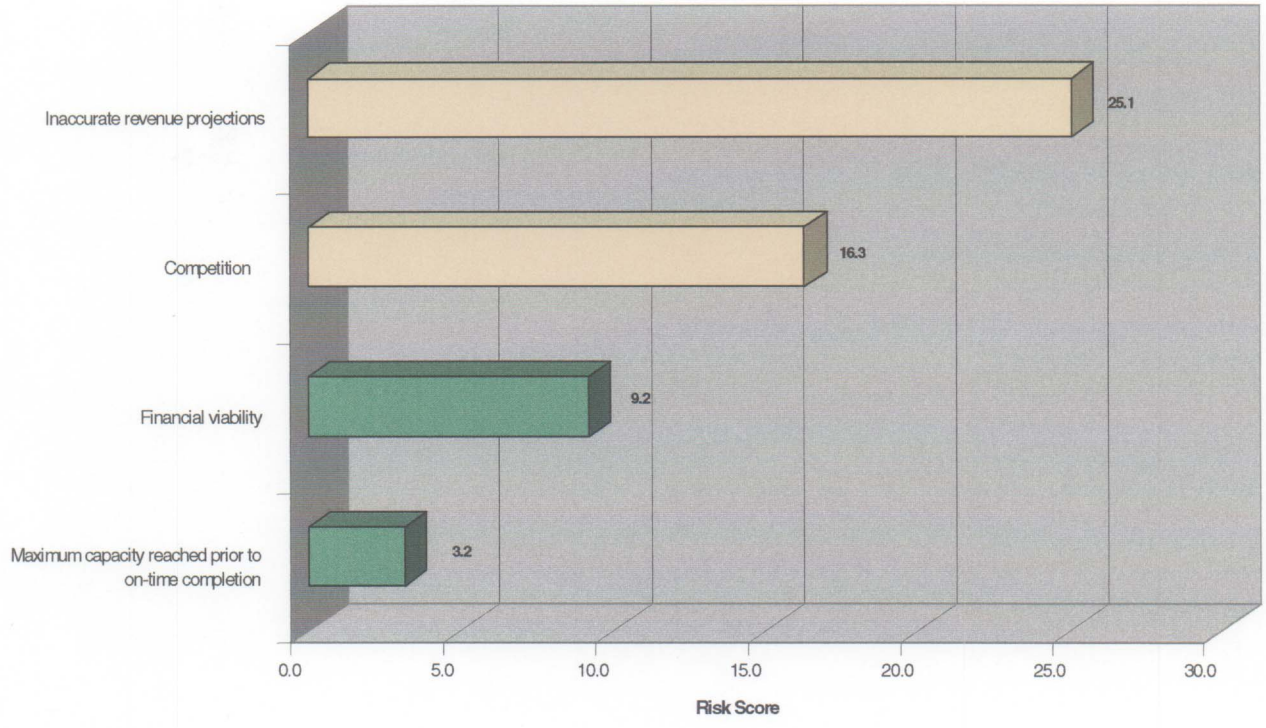


LEGEND

Market

M1 – Inaccurate revenue projections
M2 – Competition
M3 – Financial viability
M4 – Maximum capacity reached prior to on-time completion

3.4.4.2 Market Risks Ranked by Risk Score



3.4.4.3 Market Risks Scorecard

Risk ID	Risk	Risk Owner	Mitigation Strategies
M1 **Score: 25.1**	Inaccurate revenue projections - The inability to accurately project revenue resulting from the Canal expansion Subcomponents: • Inability to increase tolls • Drastic reduction of demand • Trends in Post-Panamax vessel construction	• Finance • Marketing	Current: • Quarter forecast review • Completion of Mercer Market Demand Forecast study • Communications with customers, ports, etc. • Study impact of expansion on other economies • Finance project by having customers pay by increasing tolls ACP Recommendations: • Regular revisions of short and long term forecast • Peer review of demand model Aon Recommendations: • No additional

Risk ID	Risk	Risk Owner	Mitigation Strategies
M2 **Score: 16.3**	Competition - The inability to sustain market share due to alternative shipping routes/mechanisms Subcomponents: • Intermodal • Routes	• Marketing • Administrator	Current: • External communications efforts • Competitive analysis and monitoring ACP Recommendations: • Develop a business intelligence system Aon Recommendations: • No additional

Risk ID	Risk	Risk Owner	Mitigation Strategies
M3 Score: 9.2	Financial viability - The inability to obtain the necessary funds/capital to sustain the expansion project Subcomponents: • Cash flow • Lender requirements • Issued securities • Securing credit rating • Panama's country risk negatively impacts the ACP's credit rating • Organic law limiting partners or share equity	• Finance	Current: • Coordination with outside attorneys for specialized consulting ACP Recommendations: • Develop creative partnership to generate, guarantee revenue • Consider lobbying/ negotiating with customers to generate, guarantee revenue • Lender relations • Lobby for changes in organic law Aon Recommendations: • Establish own rating/shadow rating if permissible by law • Create a mechanism to protect borrowed funds related to the expansion project
Risk ID	**Risk**	**Risk Owner**	**Mitigation Strategies**
M4 Score: 3.2	Maximum capacity reached prior to on-time completion - The inability to operate the Canal without loss of potential financial earnings	• Operations • Marketing • Administrator • Finance	Current: • Market assessment ACP Recommendations: • In order to take advantage of almost certain growth, it is optimal to start the canal expansion project in the next 2 to 3 years Aon Recommendations: • No additional

3.5 Critical Risks

Based on the ACP's risk rankings, ten risks were deemed to exceed the ACP's risk tolerance and materiality threshold. The table below identifies the risks and type of analysis to be conducted.

Risk Category	Risk	Analysis Method
Administrative & Operational	• Inefficient organizational structure • Channel disruption risks	• Benchmarking • Quantitative model
Environmental, Political and Social	• Environmental concerns/planning • Inadequate communications strategy	• ACP effort underway • ACP effort underway
Execution	• Project completion delay • Change in cost projections/overruns • Change in project definition/scope/design • Recruitment and retention of quality and quantity of skilled labor • Employee safety	• Quantitative model • Quantitative model • Quantitative model • Quantitative model • Benchmarking
Market	• Inaccurate revenue projections	• ACP effort underway

It should be noted that Aon does not fully agree with the ACP's risk rankings. Aon believes the impact of the Inefficient Organizational Structure risk is underestimated and that Employee Safety should be eliminated as a critical risk since it does not reach the ACP's materiality threshold for the project. Elaboration of Aon's opinion is found in Section 3.7 of this report.

3.6 Quantitative Risk Modeling

For this project, a stochastic risk model was created by Aon to quantify the potential and probable monetary and operational impact of a subset of risks associated with project delays and cost overruns. Macroeconomic and competitive environments were also incorporated and were taken from a study performed by Mercer Management Consulting Corporation.

3.6.1 Risk Modeling Objective

The objective of the risk-modeling phase was to develop and provide the ACP with a tool that could be used on an ongoing basis that measures the financial impact selected risks have upon the canal expansion project. A stochastic model was built to better understand the distribution of possible financial outcomes of the expansion project. A stochastic model integrates randomness to variables and core assumptions to produce both results and the associated probability of those results occurring. Consequently, a stochastic model can easily demonstrate the expected outcome of the project, probability of breaking-even on the project as well as best-case and worst-case scenarios.

For the ACP model, randomness was applied to a subset of the identified risks. These select risk factors are discussed in detail later in this report. These random variables feed into financial and operational calculations that measure the value of the canal expansion project. To calculate a distribution of results, the model was run through 10,000† iterations. For each iteration, the modeling software assigns all random variables a new value based on their individual probability distribution. The model then calculates and stores specific financial and operational variables associated with this individual scenario. When the simulation is complete, a distribution, as opposed to a single point estimate, of financial results is returned.

The number of iterations chosen is important in two respects. First, the accuracy of the modeled results is proportional to the number of iterations run. An adequate number of simulations must be run to give unlikely events a chance to occur. For example, if the probability of a particular event occurring is 1 in 1,000, a run of 100 trials will likely not produce this event. A run of 10,000 trials will more likely produce at least one of these events. It could also be the case that if too small of a sample is chosen, the results may be too heavily influenced by one or two extremely unlikely events. The second consideration is that stochastic models can be quite complex and thus time consuming to run. The benefit of additional iterations must be weighed against the processing time to run the simulation.

Various statistical terms are used in this section. The mean is the average value for a given variable across the 10,000 scenarios. The variance measures the dispersion of values around the mean. The higher the variance, the greater the spread of values produced. Percentile results can be interpreted as the probability of a variable being less than or equal to the amount shown for the particular percentile. Accordingly, the 5th percentile represents the point where 5% of all trials will fall below and 95% will fall above. The 95th percentile is the point where 95% of the trials will fall below, and 5% will fall above. The most commonly used percentile calculation is the median. The median is the value at the 50th percentile. It represents the point where half of all trials will fall below, and half will fall above.

The mean, median and mode of key financial variables produced by sample simulations are summarized in this section. Detailed results and assumptions can be found in Appendices A and B. In addition to these statistics, the detailed tables in Appendix A display the standard deviation as well as results at a number of percentile levels.

It should be noted that all results presented in this report represent a sample case. As cost estimates are refined, pricing strategies change and time passes, the ACP will modify the assumptions in the model, thereby impacting the results ultimately presented to the public.

† 10,000 iterations is a rule of thumb. Tracking the convergence of the mean and standard deviations of key outputs can be used to refine the number of iterations.

3.6.2 Risk Modeling Process Background

Prior to Aon's involvement with the ACP, the ACP had developed a static financial model estimating the value of the expansion project. It was agreed that instead of building a model from the ground up, which would require significant time and duplication of effort, the Aon team would modify the ACP's previously developed static expansion model. This model incorporated a demand model provided by Mercer Management Consulting Corporation that projected revenues under various macroeconomic and competitive environments. Aon assumed the ACP financial model and the Mercer forecasts were accurate. Aon made no attempt to verify the calculations in the ACP model or the results of the Mercer analysis.

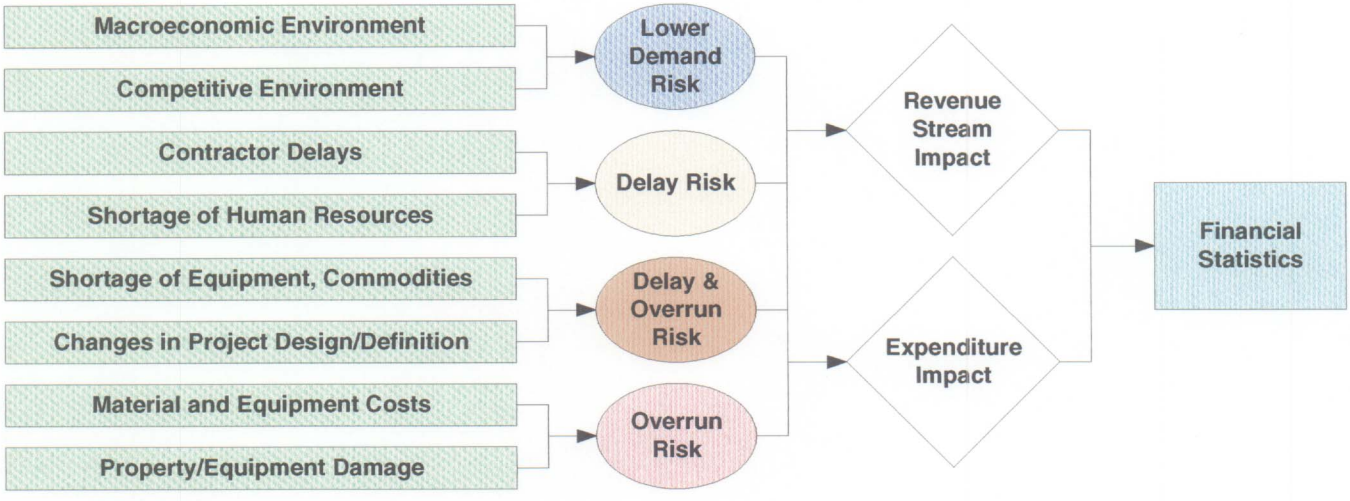
The ACP's static financial model calculated various financial statistics based upon forecasted cash flows until the year 2025. The financial variables captured by the static financial model are as follows:

- Total Dividends
- Total Debt
- Maximum Debt Balance
- NPV of Total Dividends
- Total Debt / Total Investment
- Minimum Coverage Ratio – earnings before interest, taxes, depreciation minus tonnage fees and public service payments over debt service
- ACP Value
- Accounting Rate of Return – average net income over average net assets
- Expansion Program Value
- Total Cost

When variability was built into the model, the following output statistics were added:

- Delay Length
- Cost of Delays
- Salary Overruns
- Equipment Overruns
- Material Overruns
- Changes / Alterations in Scope
- Total Overruns

The following chart displays how a sample of modeled risks are converted into the financial statistics listed above. The green boxes represent static model variable that were transformed into stochastic (not static) variables. As these stochastic variables vary, they impact demand, project timelines and project costs. These costs will either impact the revenue stream or the total cost of the project, which in turn impacts the financial statistics listed above.



3.6.3 Risk Modeling Competitive and Macroeconomic Environments

The first step of the model development process was to merge the ACP financial model with the Mercer macroeconomic and competitive environment forecasts. To accomplish this, the ACP chose three macroeconomic states and three competitive states. These states were defined as optimistic, expected, and pessimistic. The ACP assigned a probability of 20%, 60% and 20% to each of the respective states for the macroeconomic scenario and a probability of 15%, 70% and 15% to each of the respective states for the competitive environment‡. Combining the two environments results in nine categories with the following probabilities:

		Competitive Environment		
		Optimistic	Expected	Pessimistic
Macroeconomic Environment	Optimistic	3%	9%	3%
	Expected	14%	42%	14%
	Pessimistic	3%	9%	3%

The first run of the model varied only the macroeconomic and competitive environments. A sample case simulation of 10,000 Monte Carlo iterations was run and produced the following distribution of potential outcomes (full results can be found in Appendix A, Table 1).

‡ Assigned probabilities can be changed as deemed adequate.

	Mean	Median	*15.001%-ile Breakeven
Total Dividends	17.22	18.03	14.80
Total Debt	1,126	910	438
Maximum Debt Balance	819	645	306
NPV of Total Dividends	819.3	645.2	306.4
Total Debt / Total Investment	12%	11%	11%
Minimum Coverage Ratio	9.7	10.4	6.1
ACP Value	6.6	6.7	5.0
Accounting Rate of Return	28%	29%	22%
Expansion Program Value	1,452	1,636	-
Total Cost	4,665,421	4,665,421	4,665,421

**The breakeven percentile is defined as: the percentile in which the project's NPV is equal to $0.*

From the sample data in the table above, a number of questions can be answered. Based upon the assumed competitive and macro-economic risks faced by the expansion, there is over an 85% chance that the project will produce a positive investment gain. The best estimate of the project gain is the mean of $1,452 million. The median value the ACP will realize from this expansion is $1,636 million. The mean is less than the median implying the distribution of possible expansion values is not symmetric and that downside is potentially significant.

3.6.4 Modeling Additional Risk Factors

Prior to the model development phase of the project, Aon performed various analyses of the Panama Canal Expansion Process. One of these analyses was the risk mapping exercise. As a result of the risk mapping exercise, the critical risks that would be modeled quantitatively were identified. These risks included:

- Delay in selecting contractor
- Contractor qualifications
- Hiring/Retention of Panamanian and foreign workers
- Obtaining equipment
- Obtaining materials
- Material, equipment, and worker differences
- Changes / Alterations in Scope
- Construction errors
- Cost overruns
- Construction delays
- Design flaw fixes
- Construction flaw fixes

In discussion with key members of the ACP it was agreed that the above-mentioned risks would be summarized into two major risk areas: (1) the impact of delays to the expansion project and (2) the impact of cost overruns to the expansion project.

3.6.5 Modeling Delay Risk

A variety of expansion project risks have a potential effect on delays. These include and are not limited to:

- Contractor delays
- Delays due to equipment and supply availability
- Channel disruptions
- Coordination of logistics risks
- Labor strikes
- Delays in procurement process
- Equipment failure
- Geology worse than expected

Delays impact the expansion project in two ways: first, a project delay causes a delay in additional revenue that the expanded canal will generate; second, the potential additional cost will arise from the delay. An example of an additional cost is the payroll expense of having workers on the payroll who are unable to work due to a delay.

Aon, with significant assistance from the ACP and PMAT's construction cost estimates and schedules for heavy civil works, subdivided the expansion project into four key phases. These phases are:

- Pre-Construction Activity
- Pacific Access Channel
- Atlantic Lock
- Pacific Lock

For each of these key phases, major work steps were identified and interrelated dependencies were identified:

Pre-Construction Activity

1. Harmonize lock designs
2. Geotechnical investigations
3. Seismic criteria
4. Hydraulic model preparation
5. Hydraulic model testing – dependent upon the hydraulic model preparation
6. Pre-referendum and referendum process
7. Final design criteria – dependent upon harmonize lock design, geotechnical investigations, seismic criteria, and pre-referendum and referendum process
8. Post-referendum and contractor selection process – dependent upon pre-referendum and referendum process

Pacific Access Channel

1. Dry excavation – dependent on the geotechnical investigations and seismic criteria
2. Dike construction – dependent on the geotechnical investigations and seismic criteria
3. Wet excavation – dependent upon the dry excavation and dike construction
4. Dredging

Atlantic Lock

1. Mobilize excavation equipment – starts 4 months after start of the Pacific locks construction
2. Mobilize the concrete equipment - starts 4 months after start of the Pacific locks construction
3. Excavation start – dependent upon the mobilize excavation equipment
4. Concrete, monoliths and locks – dependent upon mobilize the concrete equipment and excavation start
5. Gates – dependent upon the concrete, monoliths and locks
6. Commissioning – dependent upon the gates

Pacific Lock

1. Mobilize excavation equipment – dependent upon post-referendum and contractor selection process
2. Mobilize the concrete equipment - dependent upon post-referendum and contractor selection process
3. Excavation start – dependent upon the mobilize excavation equipment
4. Concrete, monoliths and locks – dependent upon mobilize the concrete equipment and excavation start
5. Gates – dependent upon the concrete, monoliths and locks
6. Commissioning – dependent upon the gates

For each step, the ACP supplied the planned start date and end date. To construct the delay process, Aon, with the direction of the ACP, first added a variance factor of –1, 0, 1 or 1.5 months to the expected lengths of each major work step. This variance, or "noise," factor accounts for the fact that even when no problems arise in construction, the planned time frame may not accurately reflect the true completion time.

In addition to the noise factor, the impact of problems arising at each step of the process was also modeled. The potential causes of a delay are detailed by major construction step below. For the most part, positively skewed, as opposed to symmetric, distributions were judgmentally chosen. Positively skewed distributions have the advantage of not returning values below a certain point (e.g., zero for cost overruns). Furthermore, they are described have having "fat tails" which allows for the possibility of modeling large, catastrophic events. These distributions have been set up in the model such that the ACP can easily modify their parameters as conditions change.

Pre-Construction Activity

1. The harmonize lock designs, pre-referendum and referendum process, final design criteria, and post-referendum and contractor selection process phases were all assumed to have the following probability of delays.

Type of Problem	Geometric Distribution
No Delay	75.0%
Delay	23.4%
Minor Problem	1.2%
Moderate Problem	0.3%
Major Problem	0.1%

2. For, the geotechnical investigations, seismic criteria, hydraulic model preparation, and hydraulic model testing phases, the potential delay from personnel problems were added.

Type of Problem	Geometric Distribution
No Delay	75.0%
Delay	18.8%
Personnel Problems	4.7%
Minor Problem	1.2%
Moderate Problem	0.3%
Major Problem	0.1%

For the Pacific Access Channel, the Atlantic Lock and the Pacific Lock work steps, delays are modeled as a two-step process. The first step is to determine if there is a delay. The probability a delay occurring is a random variable that varies between 10% and 40%. The intent of carrying the binomial parameter for the potential of a delay occurring is intended to add variability to the outcome of the model. The ACP can easily lock in the probability by setting the low and high ends of the parameter equal to each other. If there is a delay, the second step is to determine the cause of the delay. Below is a list of causes and the associated assumed probabilities given that a delay had been modeled in step one.

Pacific Access Channel

1. Dry excavation and wet excavation

Type of Problem	Uniform Distribution
Delay	37.5%
Personnel Problems	25.0%
Equipment Problems	12.5%

Explosive Issues	12.5%
Contractor Issues	12.5%

As noted above, this distribution only comes into play if a delay event has been modeled. When this happens, the cause of the delay needs to be identified as this impacts the ultimate length of the delay. A random number between 0 and 1 is chosen from a uniform distribution. This is then applied to the cumulated probabilities listed in the table. This distribution is perhaps better described as a discrete distribution with the associated probabilities listed.

2. Dike construction

Type of Problem	Uniform Distribution
Delay	37.5%
Personnel Problems	25.0%
Equipment Problems	12.5%
Contractor Issues	12.5%
Supply Issues	12.5%

3. Dredging

Type of Problem	Uniform Distribution
Delay	75.0%
Equipment Problems	25.0%

Atlantic Lock and Pacific Lock

1. Mobilize excavation equipment and mobilize the concrete equipment

Type of Problem	Uniform Distribution
Delay	33.3%
Equipment Problems	22.2%
Personnel Problems	22.2%
Contractor Problems	22.2%

2. Excavation start – dependent upon the mobilize excavation equipment

Type of Problem	Uniform Distribution
Delay	37.5%
Personnel Problems	25.0%

Equipment Problems	12.5%
Explosive Issues	12.5%
Contractor Issues	12.5%

3. Concrete, monoliths and locks

Type of Problem	Uniform Distribution
Delay	37.5%
Personnel Problems	25.0%
Equipment Problems	12.5%
Contractor Issues	12.5%
Supply Issues	12.5%

4. Gates

Type of Problem	Uniform Distribution
Delay	37.5%
Personnel Problems	25.0%
Equipment Problems	12.5%
Contractor Issues	12.5%
Supply Issues	12.5%
An additional 1/10,000 chance of a catastrophic loss of a gate in transit.	

5. Commissioning – dependent upon gates

Type of Problem	Uniform Distribution
Delay	69.2%
Minor Problem	19.2%
Moderate Problem	7.7%
Major Problem	3.8%

Details of the probability distributions that follow in this report can be found in Appendices A and B.

The cause labeled "delay" represents delays due to uncontrollable events. Weather, earthquakes, and other similar events fall into this group. Any delay that results from this category has no potential recovery, because the cause of the delay is outside the control of the ACP or hired contractors. The delays due to the other categories represent more controllable events that may result in a recovery to the ACP depending on the origin of the delay. For example, a major problem during the Commissioning phase could be the discovery of a structural weakness in the concrete of the locks that requires a major repair for which the ACP may have the ability to collect damages from responsible parties.

The minor, moderate and major problems reflect an event's potential to delay the expansion project. The expected value for the problem increases as the potential delay increases from minor to major. In addition, the tail of the distribution becomes heavier as the potential for delay increases from minor to major. In other words, the probability of a major problem event that results in a delay of one year is greater than the probability of a moderate problem event producing the same result. The probability of a minor event causing a one-year event is almost non-existent.

Once the type of delay is determined, the model calculates the length of the delay, the cost of the delay, and any recoverable amounts from the delay (if applicable). To determine the length of the delay, two different parametric statistical distributions were selected. These were the Poisson distribution and the negative binomial distribution. These distributions were selected due to their skewed nature. These distributions are useful because they can produce the occasional extreme values. The parameters determine the values that the distribution produces. The parameters and the distributions were selected based upon the perceived delay a given problem could generate and can easily be modified by the ACP as conditions and perceptions change.

The cost of the delay was estimated by multiplying an estimate of the Average Monthly Cost of Operation by the simulated length of the delay. The Average Monthly Cost was generated by dividing a simulated point within the maximum and minimum Average Annual Fixed Cost by twelve. The minimum and maximum annual cost was based on ACP/PB estimates. The probability of recovery is based upon a range from 25% to 75%. This is meant to estimate which party is responsible for the delay. If a recovery is indicated, the ACP is entitled to remediation from the contractor who caused the delay.

A sample simulation of 10,000 Monte Carlo iterations was run and produced the following distribution of potential outcomes. For this run, the macroeconomic environment, competitive environment and costs associated with delays were varied in the model (full results can be found in Appendix A, Table 2). The table below details the simulated results of key statistics chosen by the ACP. The mean represents the average value of the identified statistics, the median represents the 50%-ile and the breakeven point is the percentile at which the NPV of the expansion project is zero.

	Mean	Median	*15.011%-ile Breakeven
Total Dividends	17.05	17.88	16.34
Total Debt	1,458	1,246	757
Maximum Debt Balance	1,030	866	535
NPV of Total Dividends	1,029.9	865.8	535.0
Total Debt / Total Investment	14%	13%	12%
Minimum Coverage Ratio	7.5	7.8	4.9
ACP Value	6.4	6.6	5.4
Accounting Rate of Return	27%	28%	22%
Expansion Program Value	1,281	1,492	-
Delay Length	(0.77)	(0.69)	(1.15)
Cost of Delays	245,535	206,925	88,542

Total Cost	4,910,957	4,872,347	4,753,963

**The breakeven percentile is defined as: the percentile in which the project's NPV is equal to $0.*
Comparing these sample results to those computed when only macro-economic and competitive environments were varied, we find the marginal impact delays will have on the project. The difference in means is $171 million.

3.6.6 Cost Overruns

Cost overruns can be the result of many risks. The key risks considered in the model were:

- Changes in scope
- Commodity price increases
- Equipment and supply problems
- Recruitment and retention of skilled labor

Expansion project risks that have an impact on cost overruns were modeled by dividing the cost overruns into four areas:

- Employees
- Equipment
- Material
- Changes / Alterations in Scope

We assumed that the ACP would not be hedging their exposure to employees, equipment and material. If the ACP opts to hedge a risk or multiple risks, the model can be modified to create an offsetting recovery. For example, if the ACP decides to hedge their exposure to concrete, an offsetting recovery can be set up to account for the hedge. A recoverable was set up for the Changes / Alterations in Scope risk similar to the recovery for delays discussed above.

The cost overrun model determines the cost by calculating a factor to increase the capital investment data supplied by the ACP. Based on preliminary expenditure data provided by the ACP, we assumed that for each year, the capital investment data consisted of 50% for salary, 15% for equipment, and 35% for materials. This was a simplifying assumption. The model was designed such that this assumption can be easily altered to reflect what ultimately will be budgeted for the project by year.

3.6.6.1 Employee Cost Overruns

The employee cost overrun represents the cost to the ACP if there is a shortage of workers. We separated employees into three distinct categories: unskilled workers, skilled workers and specialists. We assumed that the probability of there being a shortage varies with skill of the workers. This variability reflects the possibility of other major construction projects being undertaken in other parts of the world concurrently with the Panama Canal expansion project which could impact the demand for skilled and specialist workers.

The potential cost impact also varies with type of worker. We assumed that 50% of the salary costs will be comprised of unskilled workers with skilled and specialist workers each making up 25% of the total costs. This assumption is easily modifiable in the model as projections of these costs are firmed up. Unskilled workers have the smallest impact and the distribution selected was a simple bounded distribution – limiting the potential impact to a set number. The potential cost impact of a shortage of skilled and specialist workers uses a skewed (lognormal) distribution to model the potential for a large impact to the ACP due to shortages in these areas. Refer to Appendix A for a graphical representation of the lognormal distributions used in the model.

3.6.6.2 Equipment Cost Overruns

For Equipment, we choose three potential areas of impact. These were (1) shortage of equipment, (2) damage to equipment, and (3) all other equipment issues. The probability for a shortage of equipment is the smallest; the probability of other equipment issues is the largest. The potential cost impact for other equipment issues is the smallest; potential cost impact of breakdown is the largest. For the potential impact, a skewed lognormal distribution was selected. Refer to Appendix A for a graphical representation of the lognormal distributions used in the model.

3.6.6.3 Material Cost Overruns

For Material, we estimated the potential cost impact due to four types of material. These are Concrete, Steel, Fuel and Other. We separated out Concrete, Steel and Fuel as being the three materials that the ACP may decide to hedge in the future. We assumed that the material costs would be distributed as following:

- Concrete: 40%
- Steel: 30%
- Fuel: 20%
- All Other: 10%

This assumption can easily be altered as the breakdown of the material costs become more accurate. For the potential cost impact, a lognormal distribution was once again selected. Refer to Appendix A for a graphical representation of the lognormal distributions used in the model.

3.6.6.4 Changes / Alterations in Scope Overruns

The final cost overrun component was the estimate of Changes / Alterations in scope by year. For each year of the project, the following Change / Alteration in scope types were estimated along with their probability:

- Minor: 15-40% probability
- Moderate: 10-15% probability
- Major: 5-10% probability

The potential cost of a Change / Alteration in scope was estimated using a lognormal distribution. Refer to the graphs included in Appendix A to see a graph of the lognormal distributions used.

The minor, moderate and major problems reflect an event's potential to increase the costs of the expansion project. The expected value for the problem increases as the potential cost impact increases from minor to major. In addition, the tail of the distribution becomes heavier as the potential for cost overrun increases from minor to major. In other words, the probability of a major problem event that results in the expected costs overrunning the budget by 100% is greater than the probability of a moderate problem producing the same result. The potential of a minor event producing a 100% overrun of the budget is almost non-existent.

For each year, the Changes / Alterations to scope risk has a potential recoverable associated with it. Changes have the potential for a recoverable while alterations to scope are assumed to be prompted by the ACP and thus would not qualify for a recovery. An example of a recovery due to project changes would be a contractor who reinforced a concrete wall incorrectly or placed a key structural support in the wrong location. Deciding to move a lock to a different location would qualify as an alteration to scope.

A sample case of 10,000 Monte Carlo iterations was run and produced the following distribution of potential outcomes. The macroeconomic environment, competitive environment and costs associated with overruns were varied in the model (full results can be found in Appendix A, Table 3).

	Mean	Median	*15.134%-ile Breakeven
Total Dividends	17.02	17.84	16.68
Total Debt	1,733	1,441	962
Maximum Debt Balance	1,201	999	597
NPV of Total Dividends	1,200.8	999.0	596.9
Total Debt / Total Investment	17%	16%	12%
Minimum Coverage Ratio	6.4	6.5	3.8
ACP Value	6.4	6.5	5.3
Accounting Rate of Return	26%	27%	22%
Expansion Program Value	1,216	1,444	-
Delay Length	0.00	0.00	0.00
Salary Overruns	(103,368)	0	(255,562)
Equipment Overruns	(74,119)	0	(186,801)
Material Overruns	(102,299)	(53,820)	(207,945)
Changes / Alterations in Scope	(194,693)	(106,178)	(392,390)
Total Overruns	(474,479)	(380,420)	(825,388)
Total Cost	5,139,900	5,045,470	4,788,831

**The breakeven percentile is defined as: the percentile in which the project's NPV is equal to $0.*

Comparing these sample results to those computed when only macro-economic and competitive environments were varied, we find the marginal impact delays will have on the project. The difference in means is $236 million.

3.6.7 Complete Model Results

A sample simulation of 10,000 Monte Carlo iterations was run and produced the following distribution of potential outcomes when the macroeconomic environment, competitive environment, cost of delays and the cost of overruns were all varied (full results can be found in Appendix A, Table 4).

	Mean	Median	*15.573%-ile Breakeven
Total Dividends	16.83	17.65	16.63
Total Debt	2,141	1,834	1,279
Maximum Debt Balance	1,435	1,242	801
NPV of Total Dividends	1,435.2	1,241.9	800.5
Total Debt / Total Investment	20%	18%	14%
Minimum Coverage Ratio	5.1	5.0	3.1
ACP Value	6.2	6.3	5.3
Accounting Rate of Return	25%	26%	21%
Expansion Program Value	1,027	1,245	-
Delay Length	(0.77)	(0.69)	(1.13)
Cost of Delays	245,535	206,925	90,194
Salary Overruns	(109,613)	0	(267,250)
Equipment Overruns	(78,509)	0	(189,961)
Material Overruns	(108,379)	(56,818)	(216,545)
Changes / Alterations in Scope	(206,515)	(115,355)	(404,539)
Total Overruns	(503,015)	(402,002)	(858,826)
Total Cost	5,413,972	5,320,130	5,000,921

**The breakeven percentile is defined as: the percentile in which the project's NPV is equal to $0.*

Comparing this table to the macro-economic and competitive risk results, we can see the marginal impact of delays and overruns will have on the project. The difference in means is $426 million.

The model provides information on all the variables listed in the table above. The model allows the ACP to perform sensitivity analyses on several variables to evaluate what their marginal impact is on the project. Graphs are easily created with this model that will enable the ACP to communicate the model results to all interested parties.

As noted at the beginning of this section, the objective of the risk-modeling phase was to develop and provide the ACP with a tool that could be used on an ongoing basis that measures the financial impact selected risks have upon the canal expansion project. The stochastic model has been developed such that ACP can easily change cost estimates, timelines and distribution parameters as time passes and better information becomes available.

3.7 Benchmarking Results

Two risks were selected for a benchmarking analysis. These two risks included: inefficient organizational structure and employee safety.

3.7.1 Inefficient Organizational Structure

Inefficient organizational structure risk does not just refer to an inadequate structure given the ACP's strategic plans; it also includes aspects such as lack of adequate authority, leadership and accountability, inefficient processes, etc. As the ACP ventures into an expansion project, it must be prepared to manage the project and clearly segregate current responsibilities with those related to the expansion.

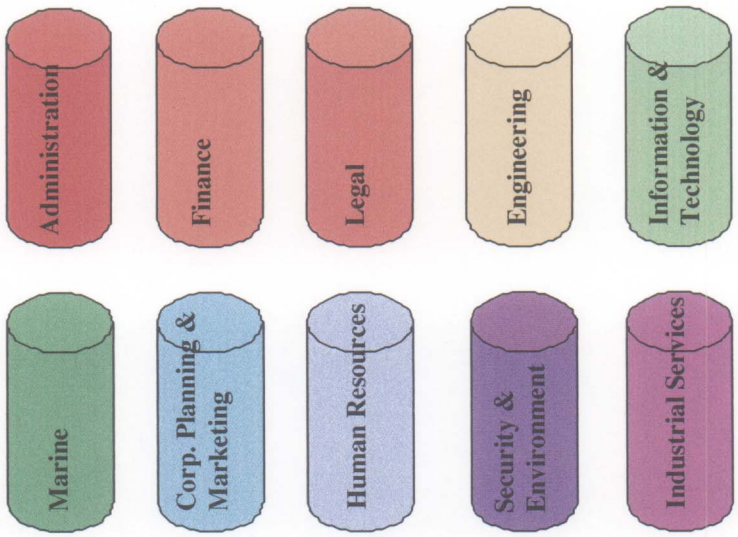
In general, this is a risk that cannot easily be quantified. To determine the best way to mitigate risks associated with organizational issues, specific actions must be taken and the ACP should consider commissioning organization management consultants to perform an in-depth analysis to determine these steps. An analysis of the ACP's organization, in light of the expansion project, should lead to conclusions about what organizational changes are needed, if any, when they should take affect and how these changes address issues that may exist.

The current operating structure of the ACP consists of functional silos that report into the Administrator's office. These silos appear to act more as independent entities as opposed to components of a much larger system despite the fact that numerous activities and data overlap. This will especially hold true for the expansion project. From an enterprise risk perspective, in many instances it appears as if there is little or no integration from one function to another with respect to risk management. While the current structure emanates from the ACP's military history, the relationships and communication between the functional silos must be rectified if the ACP is to effectively execute the expansion project and continue its development as a best in class management organization.

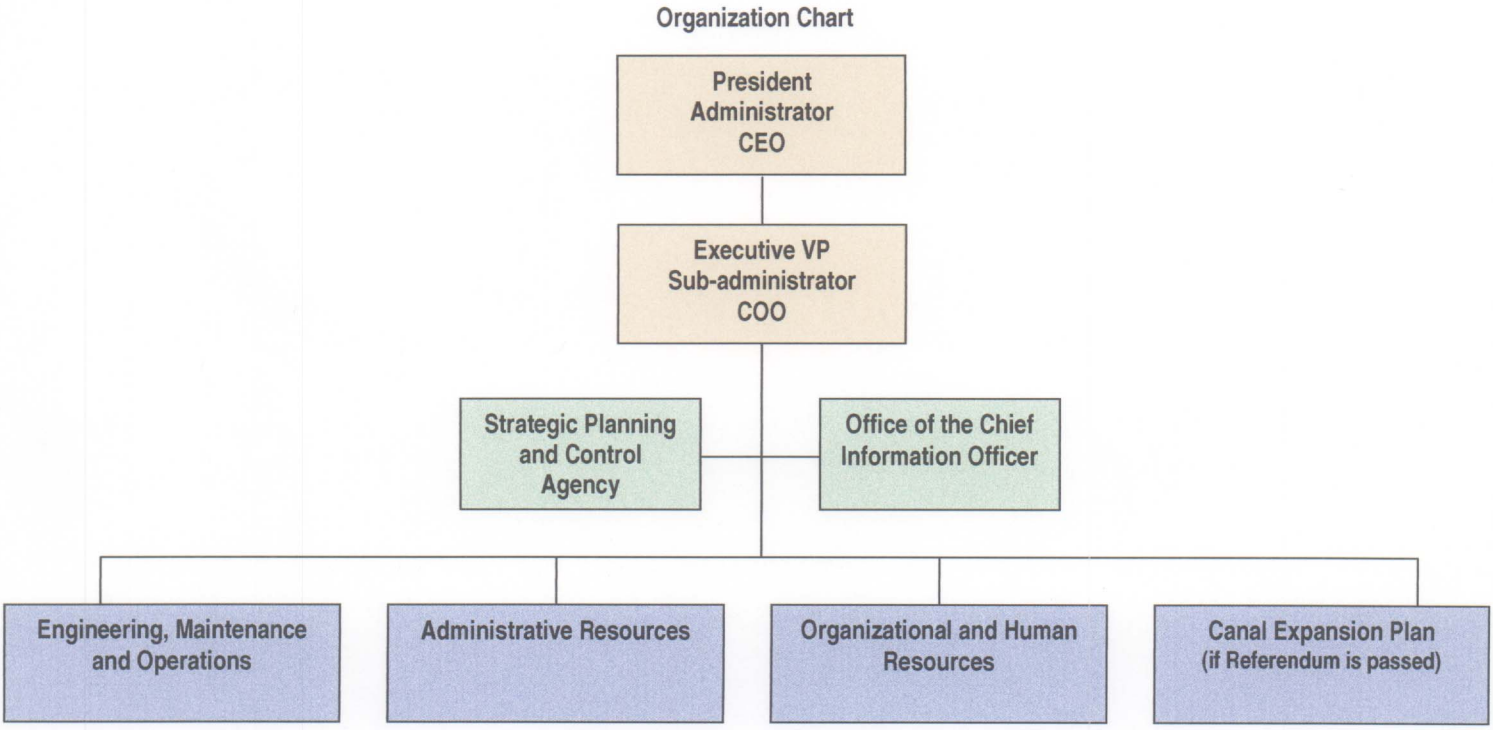
The existing silos within the ACP create inefficiencies by requiring employees to devote unnecessary time and resources toward:

- Deciding between conflicting priorities of day-to-day responsibilities and requests from other areas of the ACP, including the expansion project
- Searching for the person(s) with access to the required information
- Self-managing and coordinating the disconnected information needs
- Submitting duplicate data to multiple functions and working with each independently.

The primary functional silos at the ACP are:



Below is an example of a typical organizational structure that might overcome the current silo issue.



3.7.2 Employee Safety

The risk of employee safety and employee injury was identified as a critical risk to the overall success of the expansion project. Given the size and possibly global nature of the expansion project, significant investment in employee hiring, contractor/sub-contractor monitoring, and employee safety training will be required to mitigate this risk. However, if properly managed, not only would there be a possible substantial reduction in insurance and labor cost overruns, but the ACP will also have an enhanced reputation as a safe work place within the Panamanian labor market.

3.7.2.1 Large Construction Project Data Analysis

In order to determine the possible magnitude of the number and cost of employee injuries associated with the expansion project, Aon called upon its Construction Group resources for assistance with data gathering and analysis for this portion of the project. The following table outlines the data gathered from our Construction Group's experience with other large (primarily US-based) projects:

Large Project Employee Injury Statistics	
Average Project Value	US$1 billion
Average Peak # Employees	1,060
Average Cost of Labor	US$105 million
Average Total Man Hours	3,911,947
Average Injuries/200,000 hours	17.15

3.7.2.2 ACP Extrapolation Results

When estimating the appropriate baseline for benchmarking the expansion project, Aon used the following assumptions for the expansion project:

- Project size in terms of cost – US$4.1 billion
- Estimated average annual number of employees – 3,600
- Estimated peak number of employees – 8,000
- Estimated average annual cost of labor – US$235 million

Aon used the Construction Group's baseline experiences and extrapolated ACP statistics based on the assumptions noted above. The results of this analysis is included in the following table:

Expansion Project Estimated Employee Injury Statistics	
Estimated Total Man Hours	29,524,125
Estimated Injuries/200,000 hours	147.62
Estimated Number of Injuries Over Project Life	2,532
Estimated Average Injuries per Year	253

These extrapolation results were calculated using the peak employee figure as a baseline. Utilizing average cost of labor and project value as a baseline was deemed unsuitable due to the availability of lower cost labor in Panama relative to United States costs. The ACP peak employee usage is 7.55 times that of the average US peak employee usage (8,000/1,060). The average U.S. large project total man hours (3.911 million) was multiplied by 7.55 to arrive at an estimated figure of 29.5 million total man hours for the expansion project. The benchmark average injury rate of 17.15 injuries per year (per 200,000 man hours) was then applied to estimate the number of injuries over the course of the project. This totals 2,532 injures over the course of the expansion project (29.5 million man hours divided by 200,000,multiplied by 17.15). It should be noted that the number of incidents does not refer to only lost time injuries. This is a broader term that could include injuries such as scratches, cuts, contusions or other minor events.

3.7.2.3 Managing Employee Safety

The enormity of the expansion project and the number of contractors and subcontractors will create difficulties in managing employee safety training. While the ACP and many of its large contractors may take safety and safety training seriously, many of the smaller subcontractors may not. One way to more effectively mange the consistency and thoroughness of the safety training is to include this component as a requirement in the wrap-up insurance program. The ACP could then require all contractors and subcontractors to follow a universal safety program.

There are specific actions the ACP should take in order to mitigate the financial impact of employee injury losses. The ACP needs to ensure all contracts include the provision that employee recourse is limited to Panamanian law. Also, Employers' Liability coverage needs to be purchased to cover any suit brought by employees to cover gaps between social security benefits and actual expenses incurred as well as any cases of alleged negligence by the employer.

4. Recommendations

Recommendations for mitigating potential negative consequences are provided for the risks selected in the critical risk analysis. The implementation of several of the recommendations by the ACP will also allow it to capitalize on risk opportunities. Many of these recommendations center around augmenting or adopting proactive and consistent approaches or processes to various organizational issues. It is imperative that the risk owners identified in the previous section take a proactive role in adopting these processes and be responsible and accountable for implementing the recommendations. Senior management will need to communicate and commit its support to the risk owners, thereby providing a needed component to the overall successful adoption and implementation of change.

Our two categories of recommendations include those that: 1. Support the overall risk management process, and 2. Are specific and unique for the key risks.

Each recommendation is prioritized within four critical time periods. The respective prioritization code is placed at end of each recommendation in Sections 4.1 and 4.2 below. The four time periods are:

Code	Time Period
1	Pre Referendum
2	Referendum to Bidding Selection
3	Selection Start Up
4	Post Start Up

For example, a code of 1.1 means that the recommendation should be implemented within the Pre Referendum time period and should be first in terms of priority. It should be noted, that several activities have similar start dates. A Gantt chart is also provided at the end of this section.

4.1 Risk Management Process

Recommendations are divided into the four basic elements of the risk management process: risk administration, risk assessment, risk control and risk financing.

4.1.1 Risk Administration

- Adopt a vision and plan established and backed by the Administrator, who sets the tone. Resources within the ACP with the capacity, authority and experience to efficiently implement an ERM approach must be identified and utilized. Objectives, performance measures and early warning indicators must be determined and set in order to evaluate and monitor performance. Finally, ERM must be integrated into the ACP's strategic plan and operations. (1.5)
- Adopt a clearly defined enterprise risk management structure, including a Enterprise Risk Management Steering Committee structure. (1.9)
- Continue development of a risk management policy statement and manual and expand to include: linkage to the ACP's overall strategies, guidance on acceptable risk levels, and roles and responsibilities of risk owners. The manual should provide a general overview of risk

management policies and procedures and be accessible on-line. This should also serve as an educational and training tool for employees. (2.16)

- Utilize a Risk Management Information System (RMIS) to facilitate the capture and management of loss and insurance information. A feature for real-time enterprise risk reporting, monitoring and management of enterprise risks should also be considered. These systems will support data collection and analysis to promote enhanced decision-making across the organization. (2.29)
- Further details for best practices in implementing ERM within the ACP is addressed in Section 5 of this report.

4.1.2 Risk Assessment

- Perform a formalized risk assessment process on an-ongoing and consistent basis for continual review and monitoring during the expansion project. This should include planned and periodic physical inspection of construction activities, with reports on findings and conclusions. These findings should be communicated to the Administration. (2.17)
- Interview key contractors, management and operating personnel to stay informed about events and changes in expansion events and plans. (3.4)

4.1.3 Risk Control

- Develop formal written succession plans for key persons and/or positions. (1.10)
- Develop a formal contract review methodology and legal escalation process, in order to ensure contract consistency and dispute resolution. Diligent contract review and comparison will be critical in advance of and during the expansion project. Adopt the ACP preferential language to include in contracts. (2.3)
- Develop and provide training on project management processes. Adopt escalation process for deviations from project plan to minimize negative consequences of deviations from plan. Ensure that project definitions are understood from the beginning by all involved parties. (2.6)
- Test current risk controls in order to evaluate the breadth and effectiveness of such plans, processes and activities. (2.30)
- Monitor effectiveness of risk control activities and measure results against established performance standards and objectives. (3.10)
- Ensure employees and contact personnel are appropriately trained on risk control procedures. Due to the nature of the expansion activities, some unique training, such as in the area of explosives, excavation and construction, will need to be accomplished as well. (3.6)

4.1.4 Risk Finance

- Adopt a materiality threshold to evaluate and monitor deviations from expected results. (2.11)
- Continue evaluation and purchase of applicable insurance for expansion activities. Given the unique nature of the expansion activities, the ACP should protect exposures of worker safety, liabilities and construction delays. (3.2)

4.2 Specific Recommendations for Key Risks

For selected risk, further recommendations are provided.

4.2.1 Channel Disruption

- Document navigational rules and communicate to necessary parties. Given the multitude of activities that will be occurring during construction, strict adherence of navigational rules will be essential. (2.10)
- Undertake specific assessment of landslide vulnerabilities. (2.31)
- Provide training in oil spill clean up to minimize any potential environmental or property damage. (3.7)
- Evaluate and construct dams and spillways, as necessary. (4.2)
- Be prepared to impose drought restrictions to maintain water level. (4.3)

4.2.2 Project Completion Delay

- Establish public relations protocol for communications to provide periodic and timely communications. (1.1)
- Standardize designs and equipment to degree possible, with the focus being on gate design. Adopt peer review process before implementation of any design. (1.2)
- Modernize critical equipment components, especially dredging equipment. Given the critical nature of dredging activities and the age of the canal's current equipment, the Board must quickly approve purchase of such equipment. Purchases should also anticipate critical spare parts to have in inventory, thereby minimizing possible delays from lack of spare parts. (1.3)
- The ACP must quickly make critical decisions on the contract delivery model (e.g., design/bid/build or value engineered design); contractor selection process; preferred contract terms, language and provisions; employee hiring and training in order to start the expansion once the referendum is passed. (1.6)
- Begin now to coordinate the efforts of engineering and environmental issues to mitigate delays upon expansion approval. (1.11)
- Identify weaknesses in technical capability and upgrade as necessary. (1.12)
- Revise current contract approval procedures to allow the ACP to keep pace with the project decision time-lines. (2.1)
- Place provisions in the contracts to ensure maximum performance from the contractors. These provisions may include: guaranteed maximum price, liquidated damages, formal labor dispute resolutions, etc. (2.5)
- Implement an Owner Controlled Insurance Program ("OCIP"), including physical damage to assets (on-site and in transit), along with advance loss of profits covering fixed expenses caused by insured delays. (3.1)
- Incorporate weather scenarios into project management planning (wet and dry season variations). (3.9)

4.2.3 Recruitment and Retention of Quantity and Quality of Skilled Labor

- Minimize strike exposure by working with Minister of Labor to create a law specifically for the expansion project to avoid labor disputes or work with the main unions to negotiate contract clauses, regarding changes to work environment, safety and scheduling, to minimize downtime. (2.2)
- In order to accurately plan for the type and amount of employees needed to complete the expansion project, a clear and detailed scope of the expansion and its phases is needed. (2.4)
- Place formal labor dispute resolutions and force majeure provisions in the contracts to ensure that the contractor is responsible for delivery and protocols are in place to resolve disputes or find alternative workforce. (2.8)
- Identify necessary expansion skill sets and evaluate against current work force. (2.12)
- Adopt robust, yet flexible, recruitment policy, including specific hiring qualifications of public labor. (2.13)
- The ACP must determine hiring qualifications of public labor and inventory the available workforce to identify gaps and training needs. (2.14)
- Hire a contractor with a proven health and safety program in place to improve recruitment. (2.19)
- Begin training and cross-training of workers to ensure necessary skill sets are available during expansion activities. Project and contract management skill sets will be essential. Other opportunities for training include increasing slots in career intern and upward mobility programs to expand the pool of personnel qualified in procurement and other areas essential to the Canal's future success. (2.26)
- Partner with schools and companies to begin training for needed skill sets. (2.27)
- Adopt a formal safety training program, or integrate its current safety program requirements, as a required component under the wrap-up insurance program. The ACP could require all contractors and subcontractors to follow a universal safety program and would allow for ease in monitoring and compliance. (3.5)

4.2.4 Change in Project Projections/Overruns

- Include a guaranteed maximum price provision in the contract to keep the contractors financially incented to perform. (2.9)
- Thoroughly assess the financial strength and integrity of the contractors. (2.15)
- Engage in fixed priced contracts in advance with major suppliers of cement and steel. (2.20)
- Investigate the use and/or availability of Contractor Default insurance, Professional Liability insurance, and performance bonds, though the usefulness outside of the US market may be limited, if available. (2.21)
- Evaluate hedging strategies for key commodities and utilize as appropriate. (2.22)
- Ensure project planning in place and followed. (2.23)
- Consider and incorporate logistical considerations into project planning and management. (2.24)
- Deploy an aggressive value engineering peer review program during the contracting phase to improve the number of qualified bids and to improve pricing efficiencies. (2.25)

- Perform ongoing assessment of raw materials supply and pricing in order to secure and finance the project. (2.28)
- Encourage and foster information sharing among its divisions as well as with the contractors and subcontractors. (3.3)
- Establish and monitor budgetary reserves. (3.8)

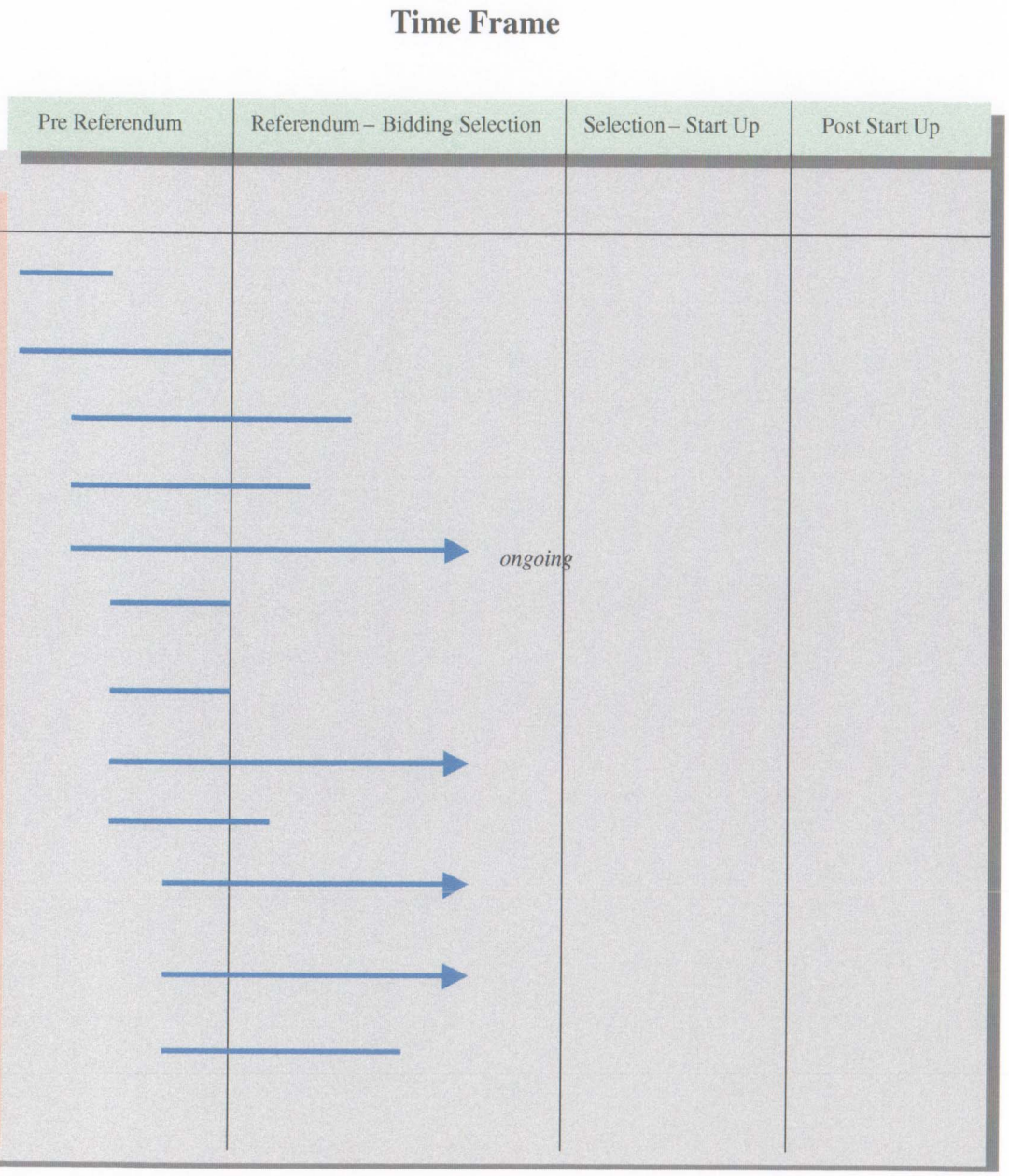
4.2.5 Changes in Project Scope, Design or Definition

- Invest in studies, designs, hydraulic models, etc. to reduce the construction risks. (1.4)
- Evaluate the appropriate contract delivery model (e.g. design/bid/build or value engineered design), design quality and contractor selection process. (1.7)
- Allow the expansion project personnel access to training or external resources in order to effectively manage this project. (1.8)
- Evaluate using a strong contract management partner to provide support in managing the large number of contractors and subcontractors. (2.7)
- Utilize collaborative information technologies to improve project oversight and control over change order management, or select a contractor with this resource. (2.18)
- Consider and incorporate logistical considerations into project planning and management. (2.24)
- Utilize its existing resources in the areas of excavation and dredging to control the scope of these project areas. (4.1)

Recommendations

Pre Referendum

1.1	Establish public relations protocol for communications
1.2	Standardize and peer review designs with focus on gate designs
1.3	Modernize critical equipment components
1.4	Invest in studies, designs, etc. to reduce construction risks
1.5	Adopt a vision and plan. Integrate ERM into strategic plan
1.6	Make critical decisions on contract delivery model
1.7	Evaluate appropriate contract delivery model
1.8	Allow personnel access to training/external resources
1.9	Adopt a clearly defined ERM structure
1.10	Develop formal written succession plans for key persons/positions
1.11	Coordinate efforts of engineering/environmental issues to mitigate delays
1.12	Identify weaknesses in technical capability



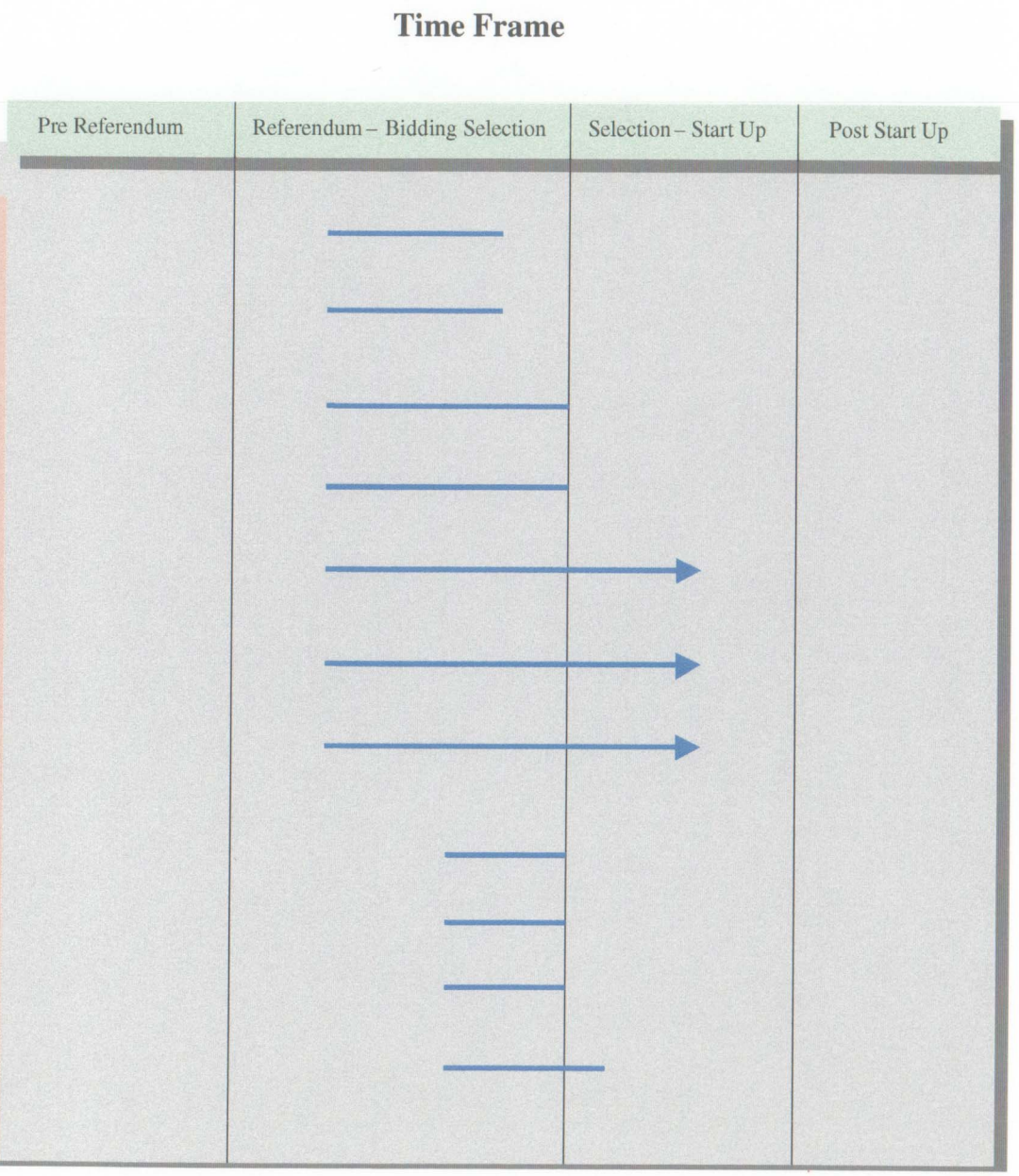
Recommendations

Time Frame

		Pre Referendum	Referendum – Bidding Selection	Selection – Start Up	Post Start Up
Referendum to Bidding Selection					
2.1	Revise current contract approval procedures				
2.2	Work to create a law to avoid labor disputes				
2.3	Develop formal contract review methodology and legal escalation process				
2.4	Develop a clear and detailed scope of expansion project				
2.5	Place provisions in contracts to ensure maximum performance from contractors				
2.6	Develop/provide training on project management processes				
2.7	Evaluate using a strong contract management partner				
2.8	Place formal labor dispute resolutions in the contracts				
2.9	Include a guaranteed maximum price provision in the contract				
2.10	Document navigational rules and communicate to necessary parties				
2.11	Adopt a materiality threshold to evaluate/monitor deviations				

Recommendations

2.12	Identify necessary skill sets and evaluate against current workforce
2.13	Adopt robust, yet flexible, recruitment policy
2.14	Determine hiring qualifications, identify gaps and training needs
2.15	Assess financial strength/integrity of contractors
2.16	Continue development of a risk management policy statement and manual
2.17	Perform a formalized risk assessment process during expansion project
2.18	Utilize collaborative information technologies to improve project oversight/control
2.19	Hire contractor with a proven health and safety program
2.20	Engage in fixed price contracts in advance
2.21	Investigate use/availability of Contractor Default/Professional Liability insurance
2.22	Evaluate hedging strategies for key commodities



Time Frame

Recommendations		Pre Referendum	Referendum – Bidding Selection	Selection – Start Up	Post Start Up
2.23	Ensure project planning in place and followed				
2.24	Consider and incorporate logistical considerations into project planning/management				
2.25	Deploy aggressive value engineering peer review program during contracting phase				
2.26	Train/cross train workers to ensure necessary skill sets				
2.27	Partner with schools and companies to begin training				
2.28	Perform ongoing assessment of raw materials supply/pricing				
2.29	Utilize RMIS to facilitate capture and management of loss/insurance information				
2.30	Test current risk controls				
2.31	Undertake specific assessment of landslide vulnerabilities				
Selection to Start Up					
3.1	Implement OCIP				
3.2	Continue evaluation and purchase of applicable insurance				
3.3	Encourage/foster information sharing among divisions and contractors				

Recommendations

Time Frame

		Pre Referendum	Referendum – Bidding Selection	Selection – Start Up	Post Start Up
3.4	Interview key contractors, management and operating personnel to stay informed				
3.5	Adopt formal safety training program				
3.6	Ensure employees/contractors are appropriately trained on risk control procedures				
3.7	Provide training in oil spill clean up				
3.8	Establish and monitor budgetary reserves				
3.9	Incorporate weather scenarios into project management planning				
3.10	Monitor effectiveness of risk control activities and measure results				
Post Start Up					
4.1	Utilize existing resources in excavation and dredging to control scope				
4.2	Evaluate and construct dams and spillways as necessary				
4.3	Be prepared to impose drought restrictions to maintain water level				

5. An Overview of Enterprise Risk Organizational Structures Best Practices

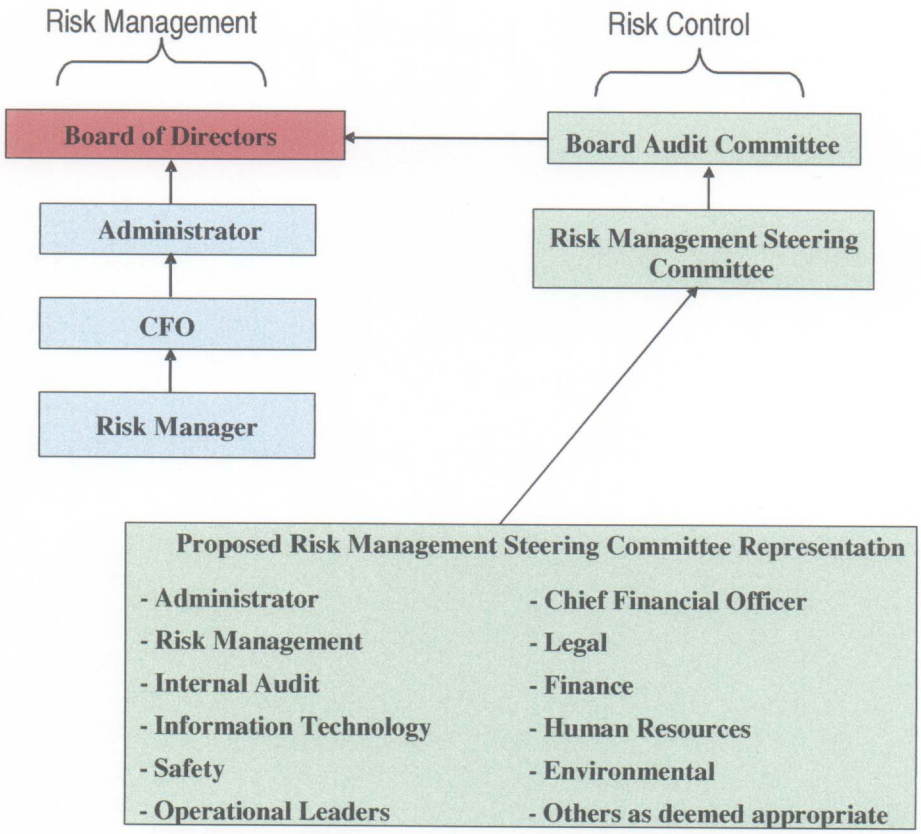
On the best practices horizon, there are differing philosophies about the "proper" structure for a risk management framework. Aon has found that organizations, even within the same industry and facing similar risks, will often choose different risk management actions because their organizations have unique risk strategies, objectives and/or tolerances. What is clear is that companies that strive to advance the identification and measurement of risk will be more effective allocating capital and determining the most efficient way to manage risk.

ACP has already begun the ERM process by engaging Aon to perform a risk assessment of its most critical risks. The next challenge is to develop a leading practices framework to more effectively identify, mitigate, and manage risk response techniques, as well as communicate responsibilities and results within the organization. To accomplish this, a plan must be established and backed by the Administrator who sets the tone within the ACP. Resources within the ACP that possess the capacity, authority and experience to efficiently implement an ERM approach must be identified and utilized. Objectives, performance measures and early warning indicators must be determined and implemented in order to evaluate and monitor performance. Finally, this ERM framework must be integrated into corporate business plans and operations.

Our research and experience have shown that the most effective way to implement broader awareness and coordination of enterprise risk efforts within an organization is to divide the roles and responsibilities into two discreet functions: risk management and risk control. This is necessary in order to avoid conflicts and inefficiencies that can occur when the functions are divided among various operational silos.

Typically, responsibility for oversight of risk management is assigned to a Risk Manager, while responsibility for oversight of risk control resides with a Risk Management Steering Committee. Currently, only risk management formally oversees normal operating exposures. For the expansion project, the responsibilities are less defined and neither area appears to be formally in place.

The organizational structure below has proven to be highly effective at other best in class entities.



According to an Aon sponsored-study of over 400 organizations, 34% have appointed a Risk Management Steering Committee (RMSC) to oversee the risk control function. Ideally, this committee would report directly to the Audit Committee of the Board.

Generally, the RMSC's role is to audit risk management practices, enforce policies, and represent findings to the Board. The Audit Committee in turn ensures that the RMSC has all of the information and resources required to validate risk identification and analysis and best practices. This enables the RMSC to protect the interests of organizational stakeholders, while overseeing compliance with relevant regulations. Some key responsibilities of the RMSC are included in the following exhibit:

The RMSC's Typical Responsibilities

- **Assist in the management of risks:** Accept and monitor the low-priority risks. For other risks, develop and implement a specific management plan which includes consideration of funding
- **Monitor and review treatment methods:** Monitor and review the performance of the risk management system and changes which might affect it
- **Communicate and consult:** Communicate and consult with internal and external stakeholders as appropriate at each stage of the risk management process and concerning the process as a whole
- **Validate findings:** Affirm the results of risk assessment, risk modeling, and risk treatment activities

Based on our findings, we recommend that the ACP put in place a risk management structure that divides the roles and responsibilities into a risk management function and a risk control function. This new risk control function would ideally be overseen by the RMSC. This committee would manage the implementation of several of the recommendations identified in Section 4 of this report. The RMSC would also monitor and support the risk owners to ensure accountability for implementing risk mitigation treatments. This approach would allow the ACP it to capitalize on risk opportunities and improve the likelihood of successful adoption and implementation of desired change.

Appendix A

Risk Modeling Outputs

Appendix A

Table 1:	Results of the Competitive and Macro-economic Modeling
Table 2:	Results of the Competitive, Macro-economic and Delay Modeling
Table 3:	Results of the Competitive, Macro-economic and Overrun Modeling
Table 4:	Results of the Competitive, Macro-economic, Delay and Overrun Modeling
Graph 1:	Results of the Competitive and Macro-economic Modeling
Graph 2:	Results of the Competitive, Macro-economic and Delay Modeling
Graph 3:	Results of the Competitive, Macro-economic and Overrun Modeling
Graph 4:	Results of the Competitive, Macro-economic, Delay and Overrun Modeling
Graph 5a – 5f:	Distributions used in Delay Modeling
Graph 6a – 6i:	Distributions used in Overrun Modeling

Table 1: Results of the Competitive and Macro-economic Modeling

	Total Dividends	Total Debt	Maximum Debt Balance	NPV of Total Dividends	Total Debt / Total Investment	Minimum Coverage Ratio	ACP Value	Accounting Rate of Return	Expansion Program Value
Mean	17.35	1,146	834	834.2	11.9%	9.66	6.63	28.4%	1,492.0
Standard Deviation	2.21	840	638	637.8	2.3%	2.01	1.11	4.3%	1,079.3
10.0%	11.72	355	262	261.7	10.6%	5.14	4.17	19.0%	(819.3)
20.0%	17.83	648	406	406.1	10.8%	9.37	6.43	27.5%	982.6
30.0%	18.18	834	558	557.6	11.1%	9.37	6.78	28.7%	1,681.5
40.0%	18.18	896	645	645.2	11.1%	10.25	6.78	28.8%	1,681.5
50.0%	18.18	910	645	645.2	11.1%	10.44	6.78	28.9%	1,681.5
60.0%	18.18	920	659	658.8	11.1%	10.44	6.78	28.9%	1,681.5
70.0%	18.18	1,110	853	853.5	11.1%	10.44	6.78	28.9%	1,681.5
80.0%	18.35	1,236	1,003	1,003.3	11.9%	10.44	7.36	31.5%	2,330.9
90.0%	18.55	3,017	2,040	2,039.9	17.3%	11.19	8.15	34.4%	2,969.7
95.0%	19.01	3,286	2,376	2,375.5	17.3%	12.52	8.26	34.5%	2,969.7
99.0%	19.01	3,783	2,915	2,914.5	17.6%	12.52	8.26	34.8%	3,185.0
99.5%	19.01	3,949	3,172	3,172.0	17.6%	12.52	8.26	34.8%	3,185.0

Table 2: Results of the Competitive, Macro-economic and Delay Modeling

	Total Dividends	Total Debt	Maximum Debt Balance	NPV of Total Dividends	Total Debt / Total Investment	Minimum Coverage Ratio	ACP Value	Accounting Rate of Return	Expansion Program Value	Year	Cost of Delays
Mean	17.30	1,222	884	884.1	12.4%	9.12	6.57	27.9%	1,433.8	2014	160,380
Standard Deviation	2.21	877	661	661.5	2.5%	2.04	1.11	4.2%	1,077.3	0	243,994
10.0%	11.72	427	283	283.0	10.2%	5.14	4.17	19.0%	(819.3)	2013	0
20.0%	17.80	730	495	494.5	10.7%	7.93	6.38	26.9%	932.2	2013	0
30.0%	17.83	902	629	628.8	11.0%	8.87	6.48	27.5%	1,387.1	2013	0
40.0%	18.12	930	653	653.5	11.1%	9.37	6.70	28.2%	1,602.1	2013	0
50.0%	18.16	975	686	685.7	11.5%	9.63	6.75	28.6%	1,652.6	2013	64,992
60.0%	18.18	1,046	753	752.5	11.9%	10.06	6.78	28.8%	1,681.5	2014	117,358
70.0%	18.18	1,162	859	859.2	12.5%	10.39	6.78	28.9%	1,681.5	2014	183,821
80.0%	18.33	1,308	1,016	1,016.4	13.8%	10.46	7.31	31.1%	2,281.1	2014	287,532
90.0%	18.55	3,017	2,045	2,044.5	17.1%	10.74	8.08	33.4%	2,857.6	2014	466,151
95.0%	18.99	3,488	2,539	2,538.8	17.8%	11.96	8.21	34.3%	2,969.7	2014	650,904
99.0%	19.01	4,033	3,172	3,172.0	19.7%	12.61	8.26	34.7%	3,185.0	2015	1,120,091
99.5%	19.01	4,191	3,351	3,351.0	20.6%	12.71	8.26	34.8%	3,185.0	2015	1,333,658

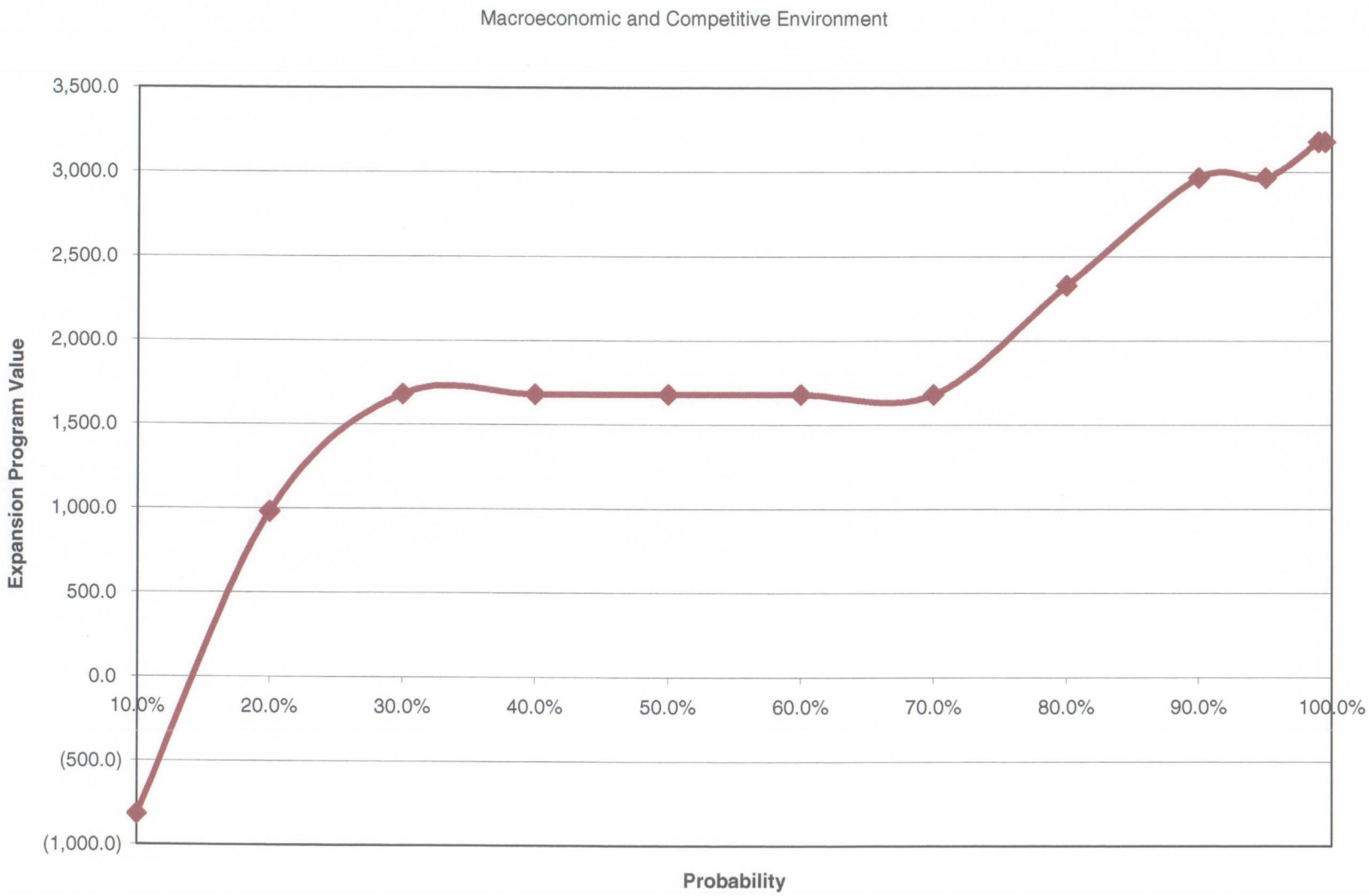
Table 3: Results of the Competitive, Macro-economic and Overrun Modeling

	Total Dividends	Total Debt	Maximum Debt Balance	NPV of Total Dividends	Total Debt / Total Investment	Minimum Coverage Ratio	ACP Value	Accounting Rate of Return	Expansion Program Value	Salary Overruns	Equipment Overruns	Material Overruns	Mistake Overruns	Total Overruns
Mean	17.16	1,754	1,217	1,216.8	17.2%	6.41	6.39	26.6%	1,255.0	103,579	74,517	102,092	194,830	475,018
St Dev	2.26	1,077	767	766.9	6.1%	2.54	1.13	4.2%	1,100.5	162,683	171,303	144,936	262,611	397,769
10.0%	11.62	793	471	470.5	11.1%	3.23	4.09	18.4%	(887.3)	0	0	0	4,134	87,271
20.0%	17.55	1,065	679	678.7	12.3%	4.18	6.09	24.7%	703.9	0	0	0	18,193	158,079
30.0%	17.77	1,208	788	787.8	13.4%	4.91	6.32	26.0%	974.3	0	0	8,309	38,745	226,060
40.0%	17.92	1,329	902	902.3	14.6%	5.64	6.46	26.7%	1,364.5	0	0	31,023	64,515	301,183
50.0%	18.02	1,454	1,008	1,008.4	15.9%	6.47	6.59	27.3%	1,495.1	0	0	54,014	102,467	379,483
60.0%	18.09	1,595	1,131	1,130.8	17.3%	7.19	6.68	27.8%	1,581.2	60,454	2,747	82,700	154,103	463,859
70.0%	18.14	1,785	1,298	1,297.5	19.0%	7.94	6.76	28.4%	1,662.0	128,609	24,259	117,180	219,817	575,955
80.0%	18.22	2,117	1,588	1,587.6	21.3%	8.74	7.17	29.6%	2,108.6	207,376	110,586	170,566	319,995	733,915
90.0%	18.46	3,635	2,495	2,495.1	24.9%	9.70	7.81	31.3%	2,595.6	329,118	277,112	264,762	497,934	981,548
95.0%	18.88	4,332	2,916	2,916.1	28.5%	10.38	8.08	33.0%	2,856.0	430,333	409,768	372,768	692,642	1,221,505
99.0%	18.98	5,336	3,658	3,657.9	37.0%	11.52	8.21	34.1%	3,045.0	678,629	725,557	667,330	1,160,725	1,820,131
99.5%	18.99	5,586	3,924	3,924.4	42.8%	12.23	8.23	34.3%	3,118.6	821,627	856,814	819,387	1,451,694	2,153,931

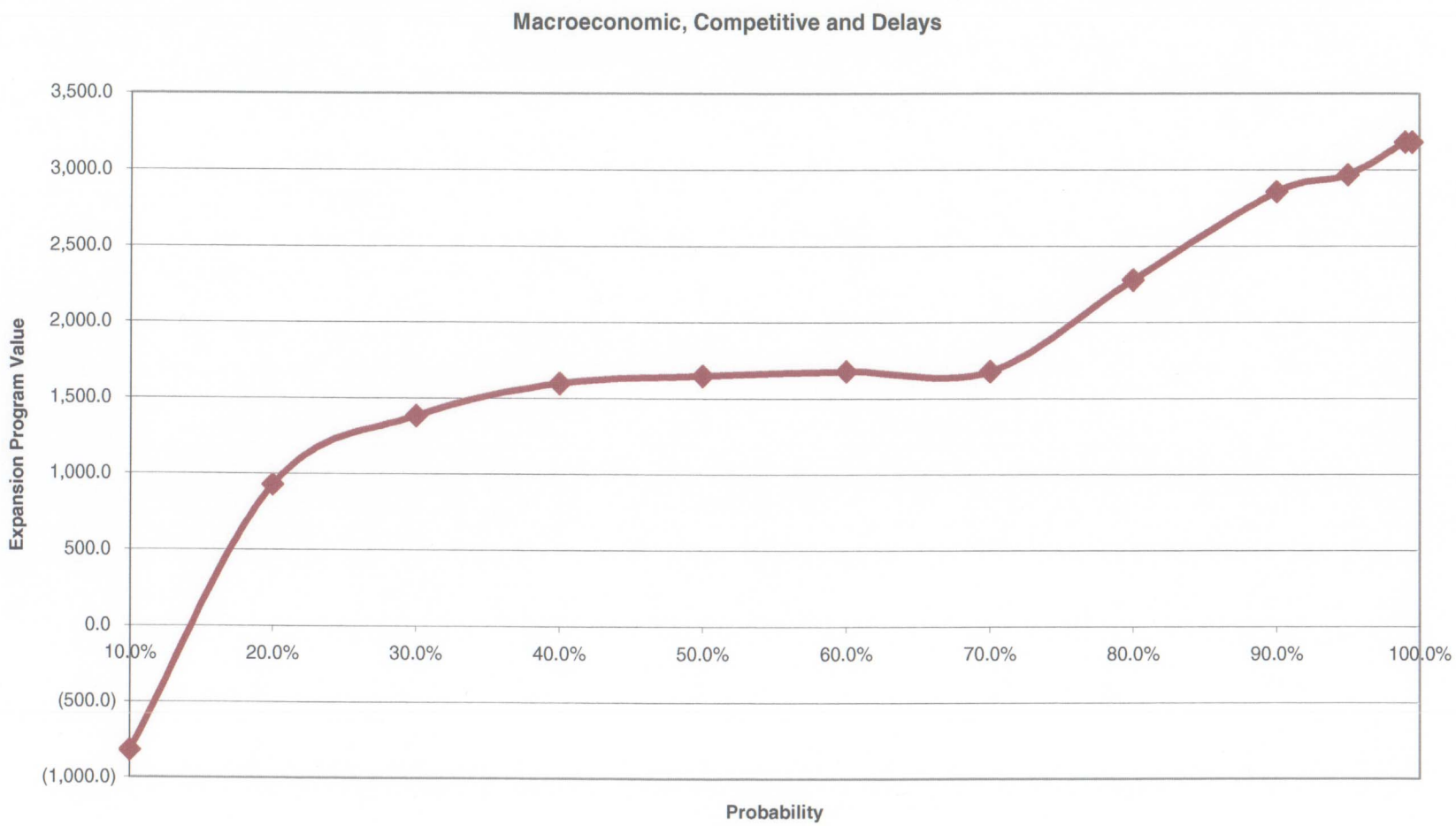
Table 4: Results of the Competitive, Macro-economic, Delay and Overrun Modeling

	Total Dividends	Total Debt	Maximum Debt Balance	NPV of Total Dividends	Total Debt / Total Investment	Minimum Coverage Ratio	ACP Value	Accounting Rate of Return	Expansion Program Value	Year	Cost of Delays	Salary Overruns	Equipment Overruns	Material Overruns	Mistake Overruns	Total Overruns
Mean	17.10	1,850	1,276	1,275.9	17.6%	6.10	6.33	26.1%	1,190.8	2014	160,380	107,542	77,492	106,081	202,473	493,587
St Dev	2.26	1,120	794	794.4	6.2%	2.44	1.13	4.2%	1,100.1	0	243,994	169,735	178,703	151,065	268,238	412,004
10.0%	11.57	869	509	509.1	11.4%	3.08	4.05	18.2%	(927.0)	2013	0	0	0	0	6,199	93,293
20.0%	17.48	1,130	712	712.4	12.6%	3.99	6.00	24.1%	629.1	2013	0	0	0	0	22,026	166,792
30.0%	17.71	1,278	839	838.8	13.8%	4.67	6.25	25.5%	928.7	2013	0	0	0	8,452	43,481	236,995
40.0%	17.83	1,406	951	950.8	15.0%	5.34	6.39	26.2%	1,287.5	2013	0	0	0	32,116	70,702	312,496
50.0%	17.95	1,532	1,060	1,060.2	16.3%	6.10	6.53	26.8%	1,431.0	2013	64,992	0	0	56,297	109,464	394,850
60.0%	18.04	1,680	1,189	1,189.0	17.7%	6.79	6.63	27.4%	1,529.0	2014	117,358	62,073	2,889	85,691	160,631	483,471
70.0%	18.11	1,883	1,359	1,359.1	19.5%	7.50	6.73	28.0%	1,632.1	2014	183,821	132,813	25,282	121,560	227,863	599,164
80.0%	18.18	2,234	1,652	1,652.3	21.7%	8.32	7.10	29.1%	2,028.9	2014	287,532	215,555	113,852	177,391	329,349	760,823
90.0%	18.40	3,754	2,559	2,558.9	25.4%	9.30	7.72	30.9%	2,508.9	2014	466,151	339,946	288,874	276,002	512,348	1,015,169
95.0%	18.83	4,514	3,031	3,030.5	28.9%	9.99	8.00	32.4%	2,792.8	2014	650,904	445,756	426,062	387,436	709,156	1,259,694
99.0%	18.97	5,543	3,869	3,869.0	37.9%	11.14	8.18	33.7%	2,969.7	2015	1,120,091	709,700	759,594	691,038	1,193,344	1,915,233
99.5%	18.99	5,957	4,193	4,193.4	44.3%	11.71	8.21	34.0%	3,058.6	2015	1,333,658	841,931	894,532	854,555	1,465,040	2,261,382

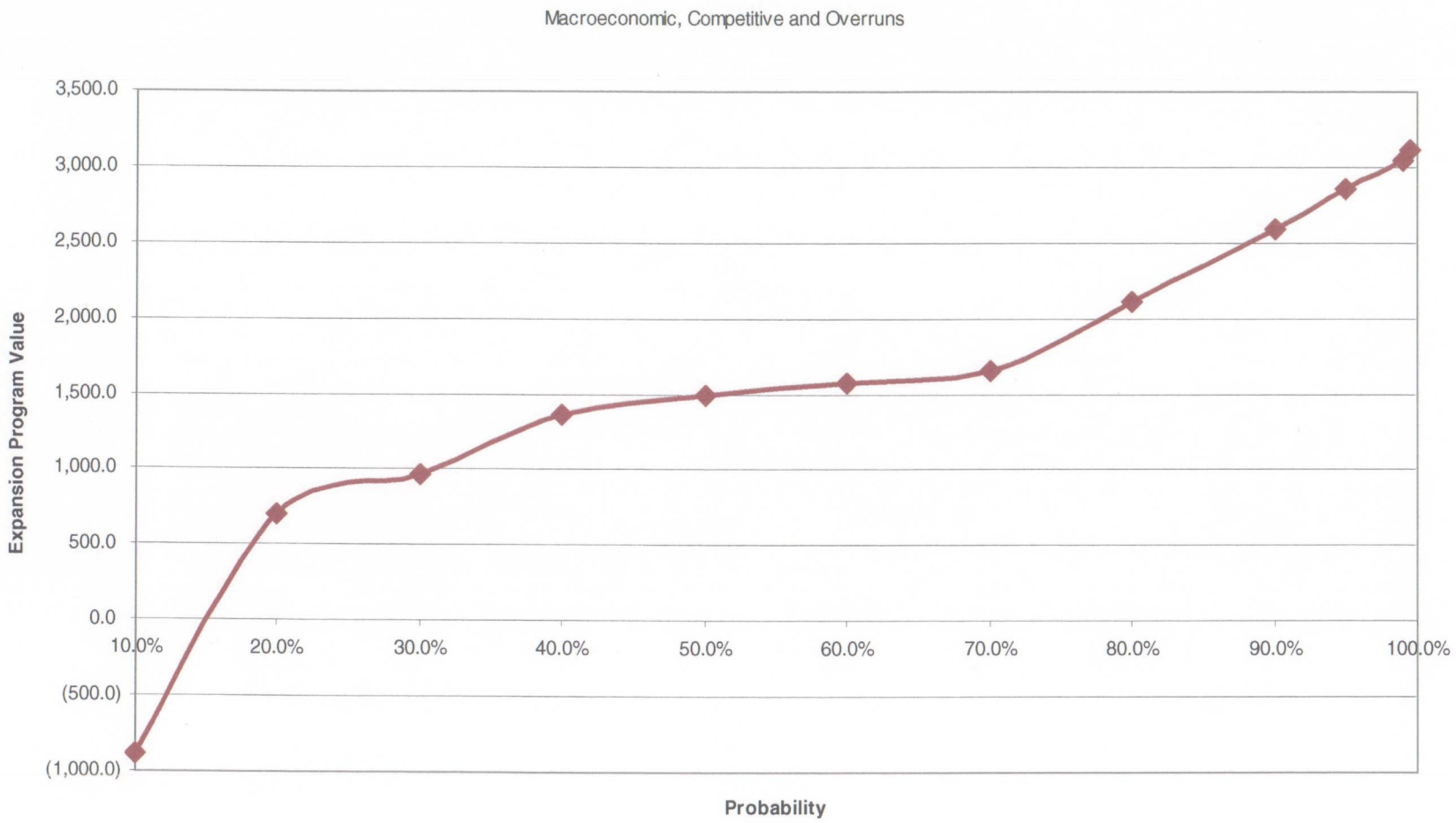
Graph 1: Results of the Competitive and Macro-economic Modeling



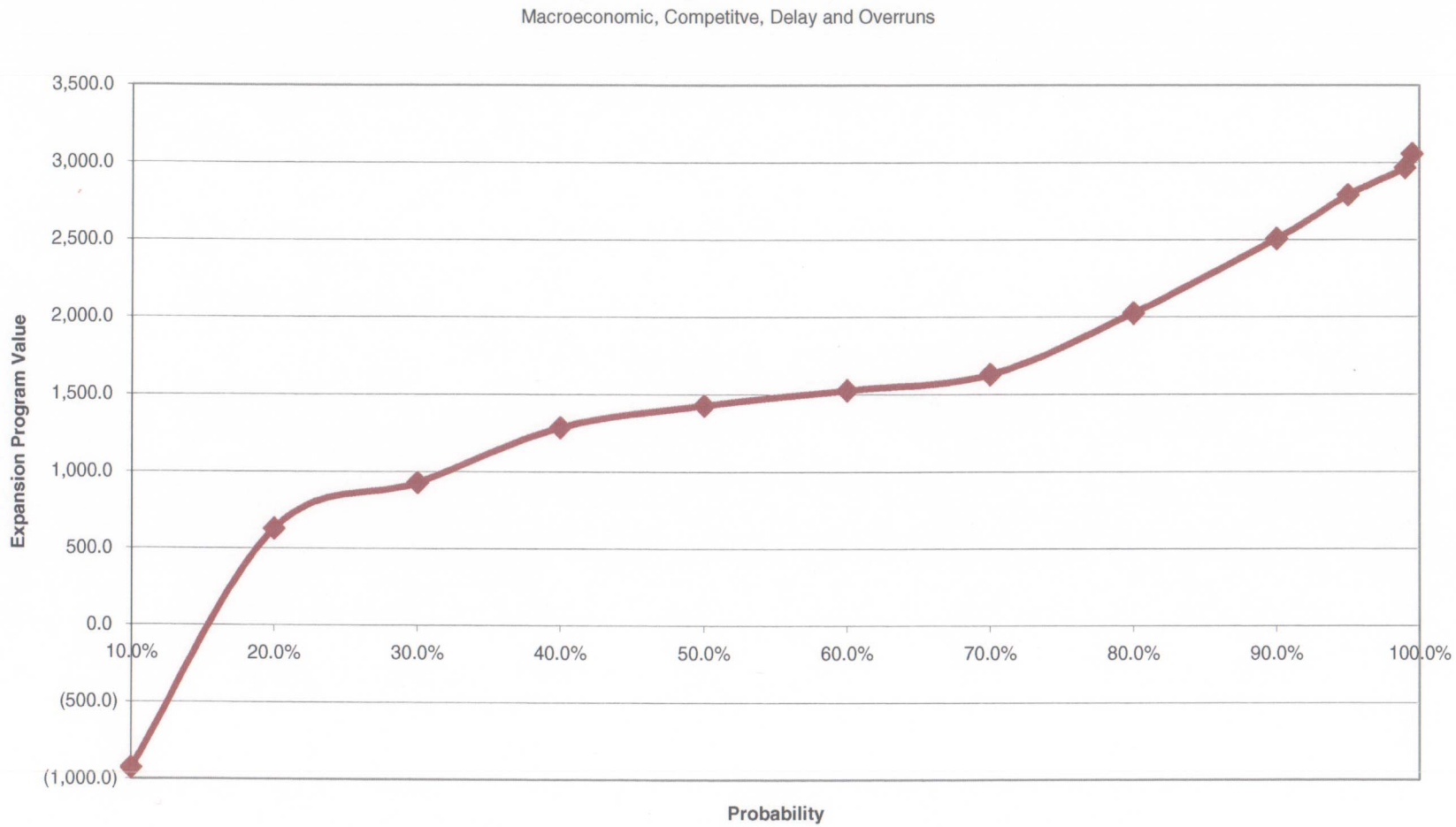
Graph 2: Results of the Competitive, Macro-economic, and Delay Modeling



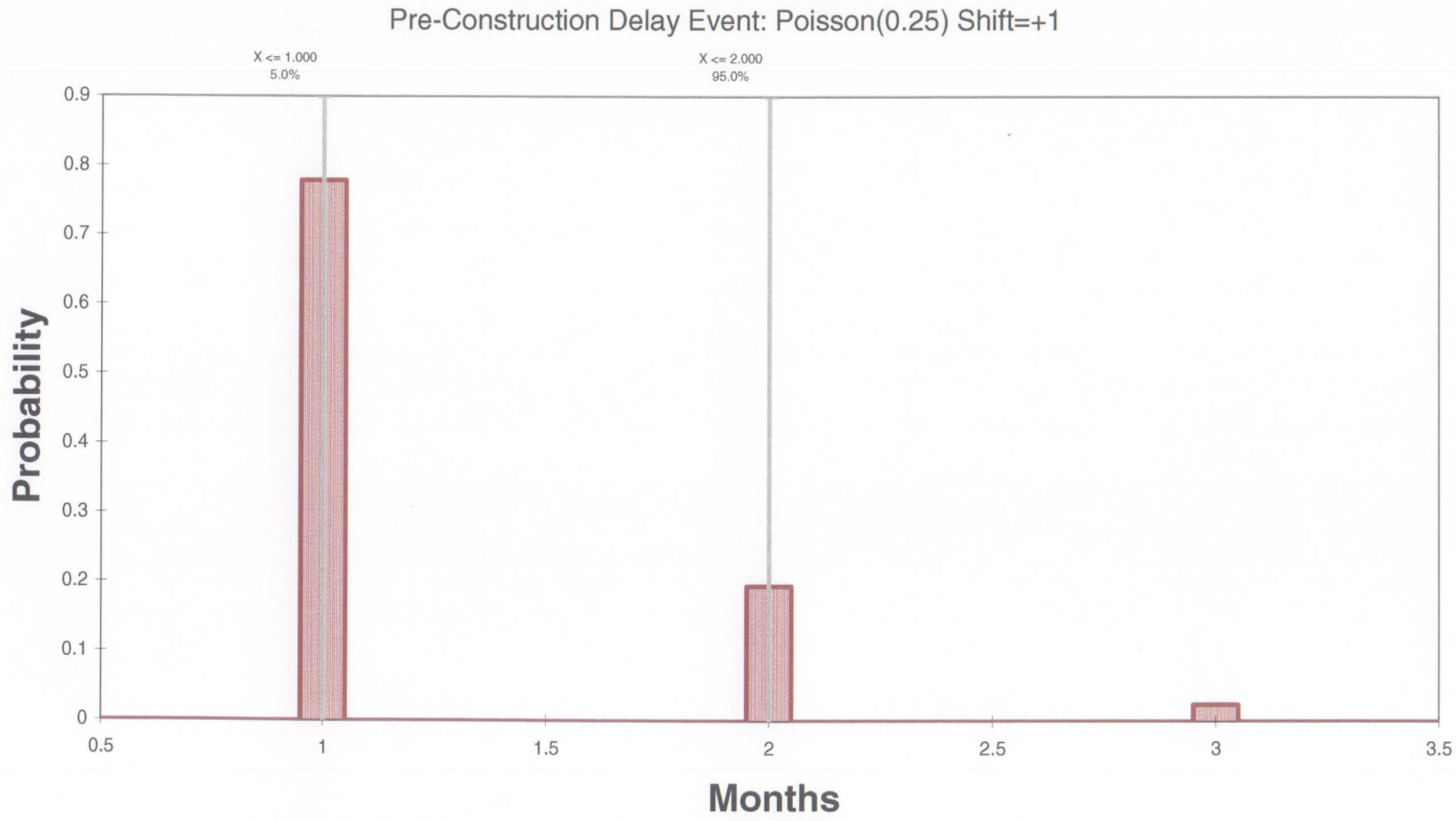
Graph 3: Results of the Competitive, Macro-economic, and Overrun Modeling



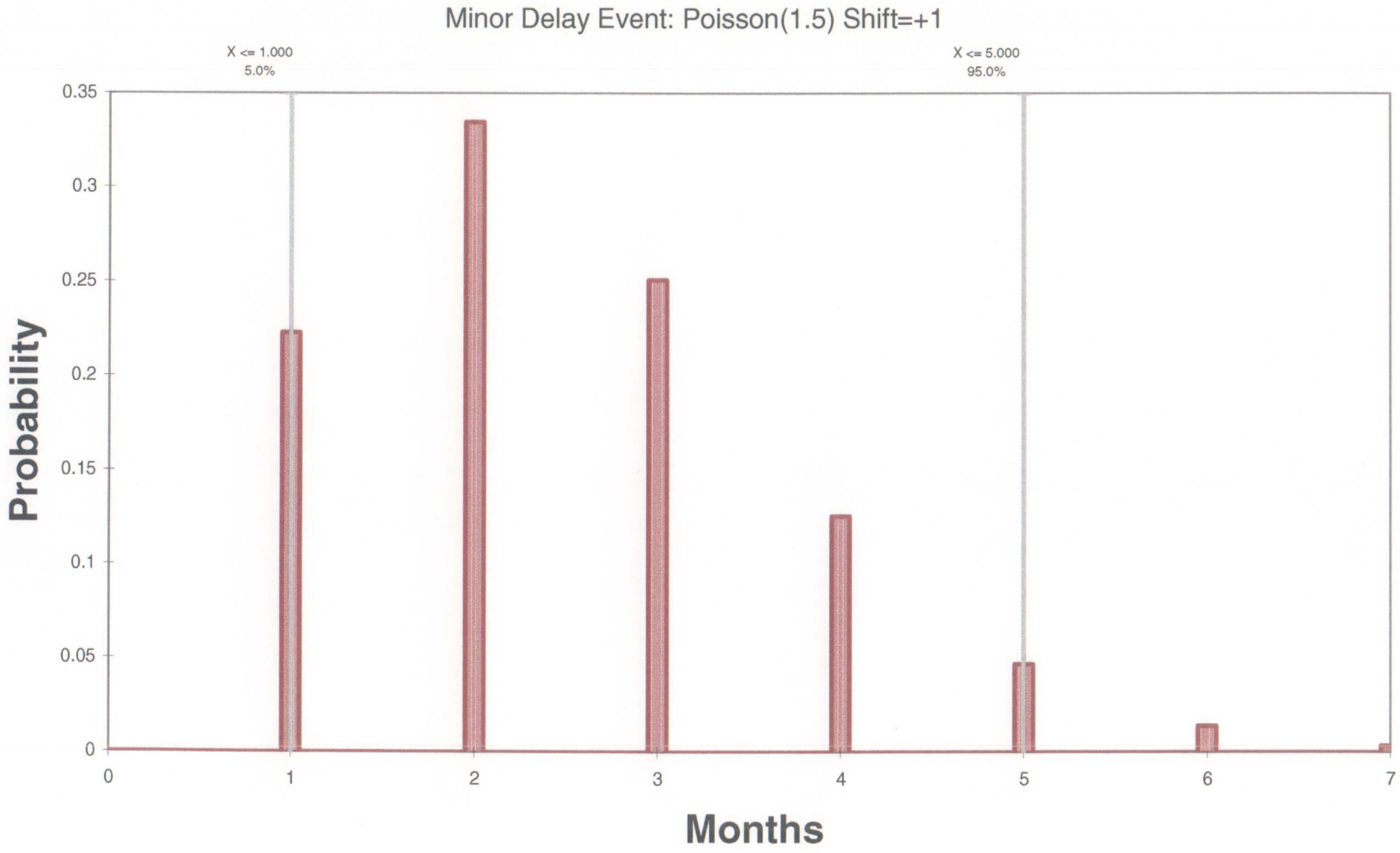
Graph 4: Results of the Competitive, Macro-economic, Delay and Overrun Modeling



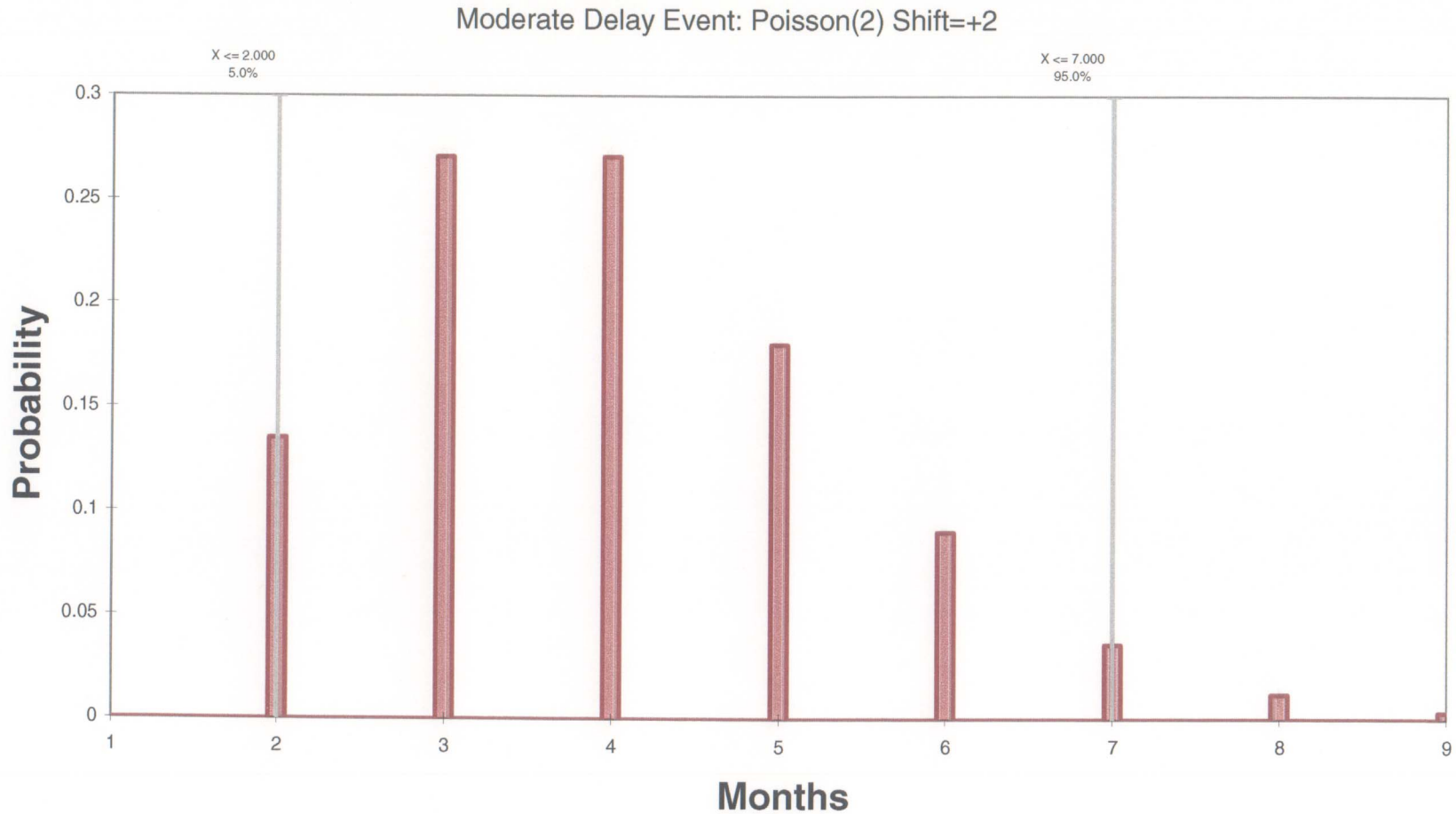
Graph 5a: Distributions used in Delay Modeling



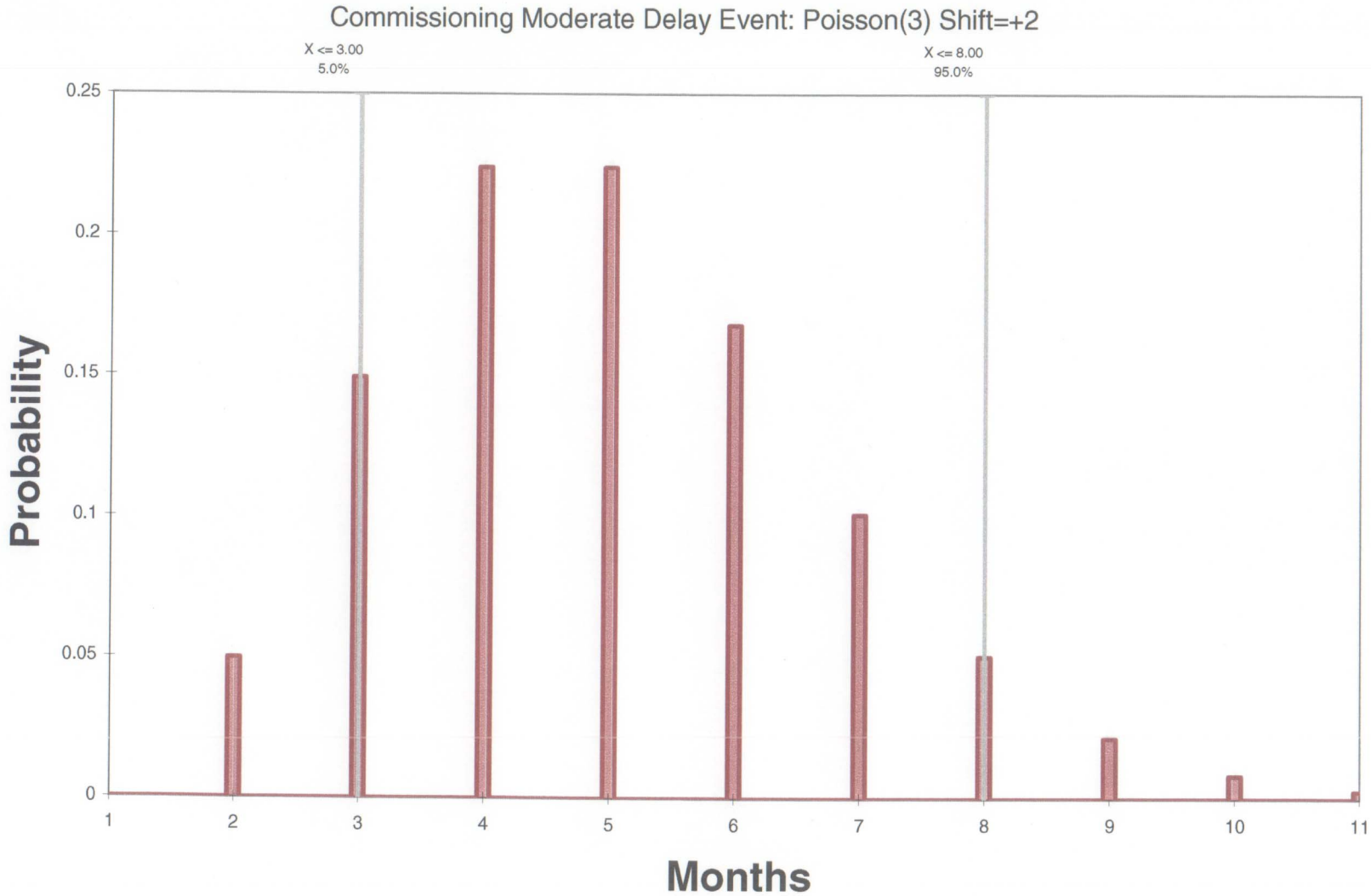
Graph 5b: Distributions used in Delay Modeling



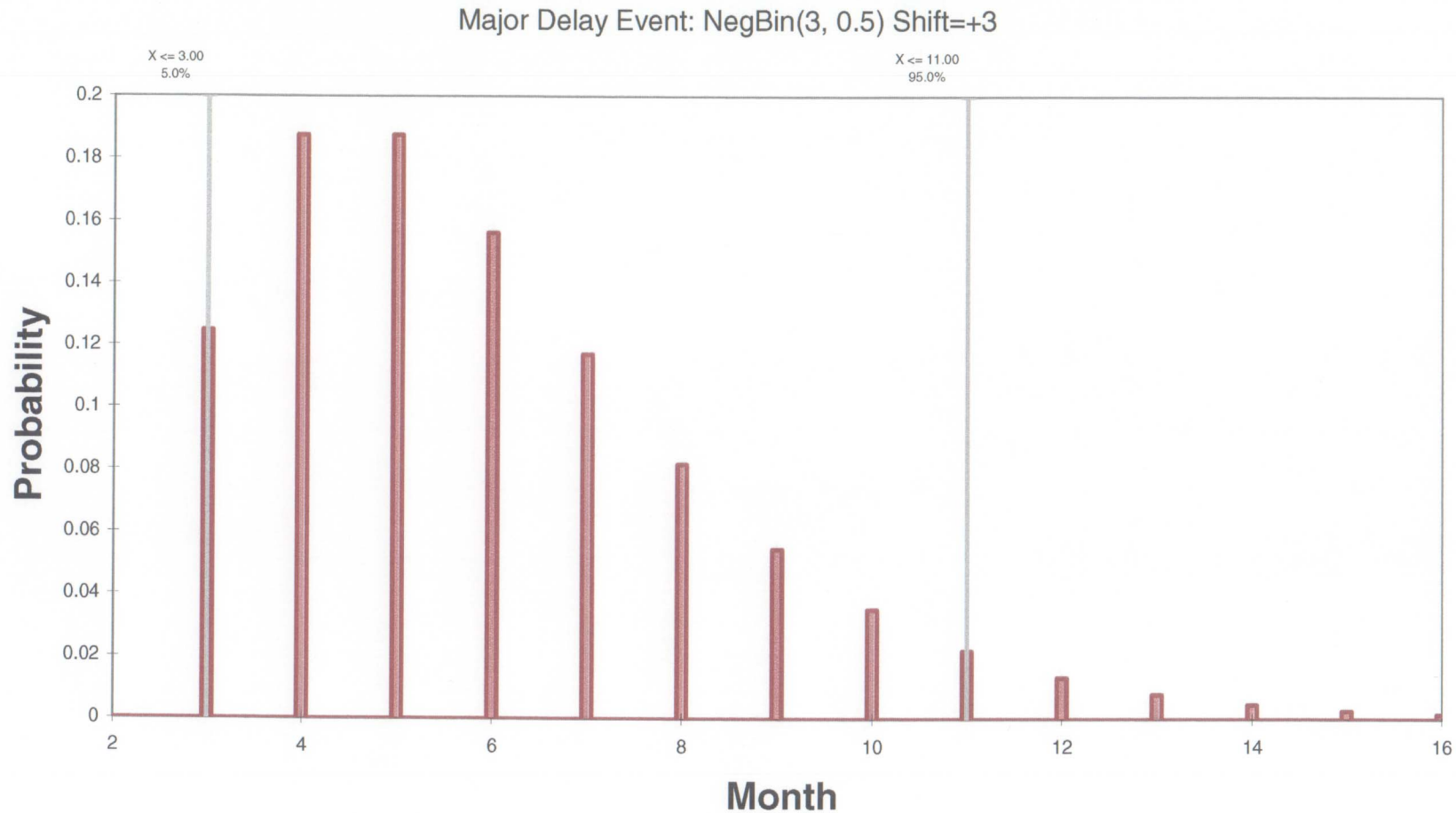
Graph 5c: Distributions used in Delay Modeling



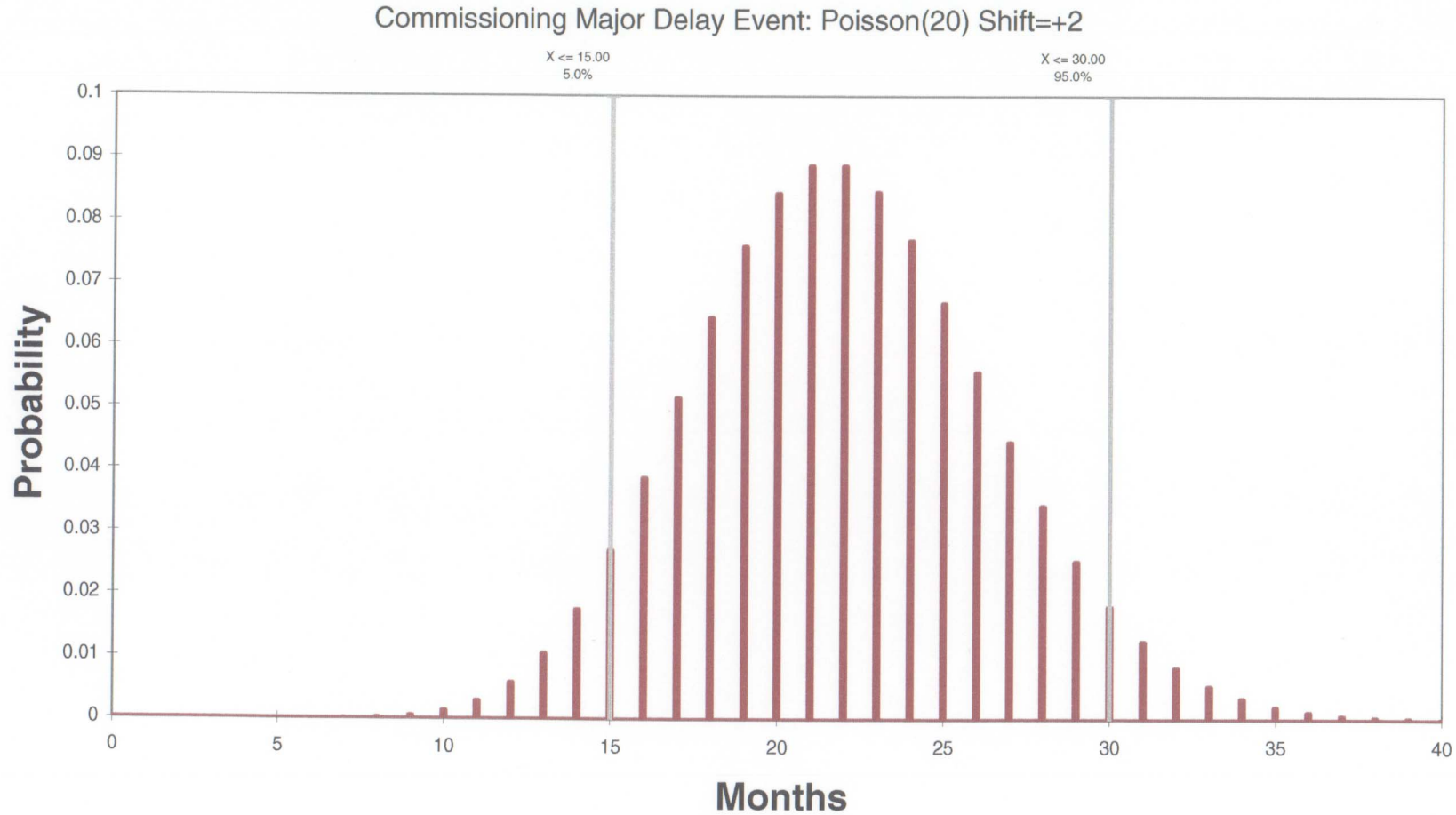
Graph 5d: Distributions used in Delay Modeling



Graph 5e: Distributions used in Delay Modeling

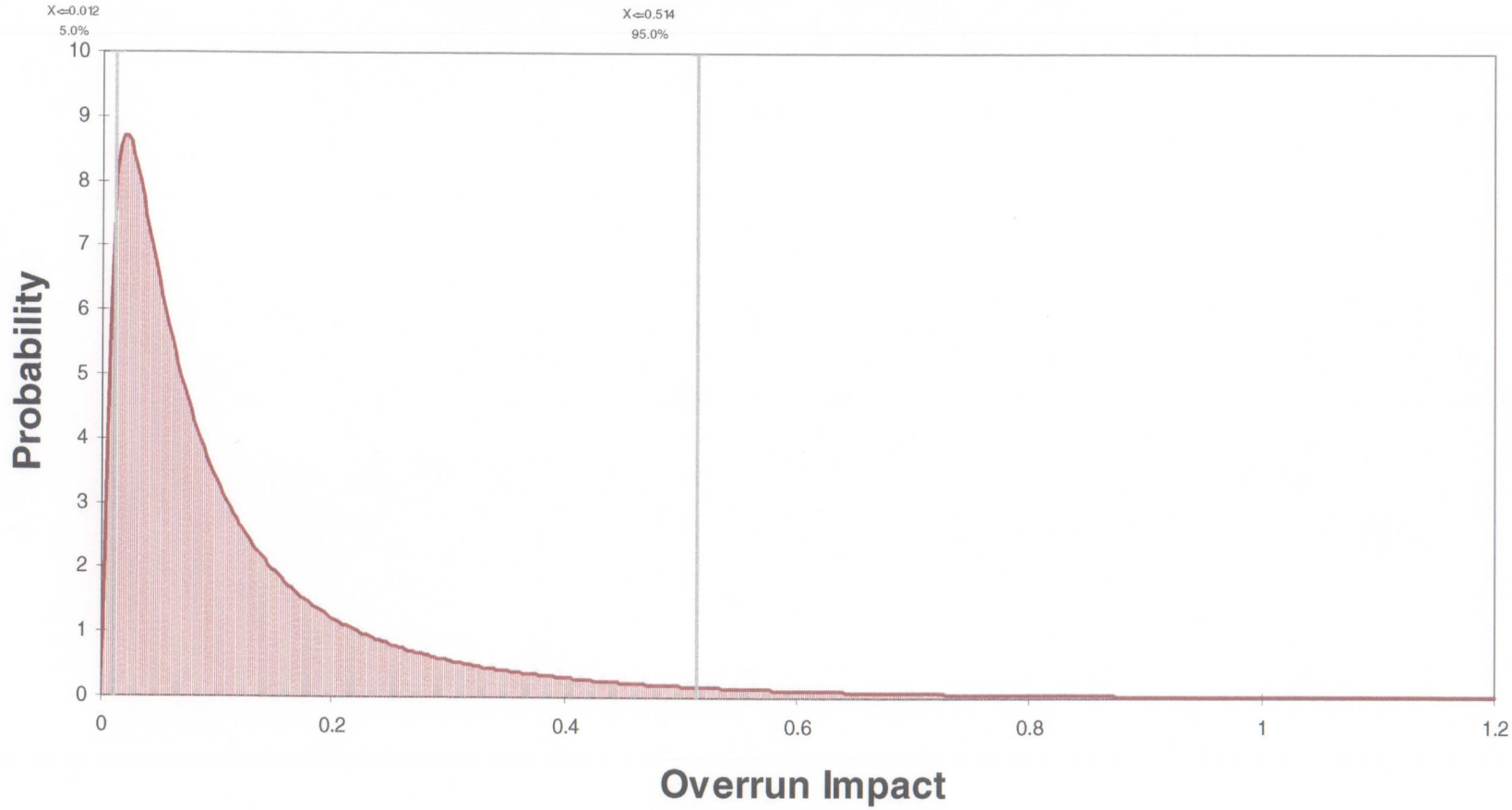


Graph 5f: Distributions used in Delay Modeling



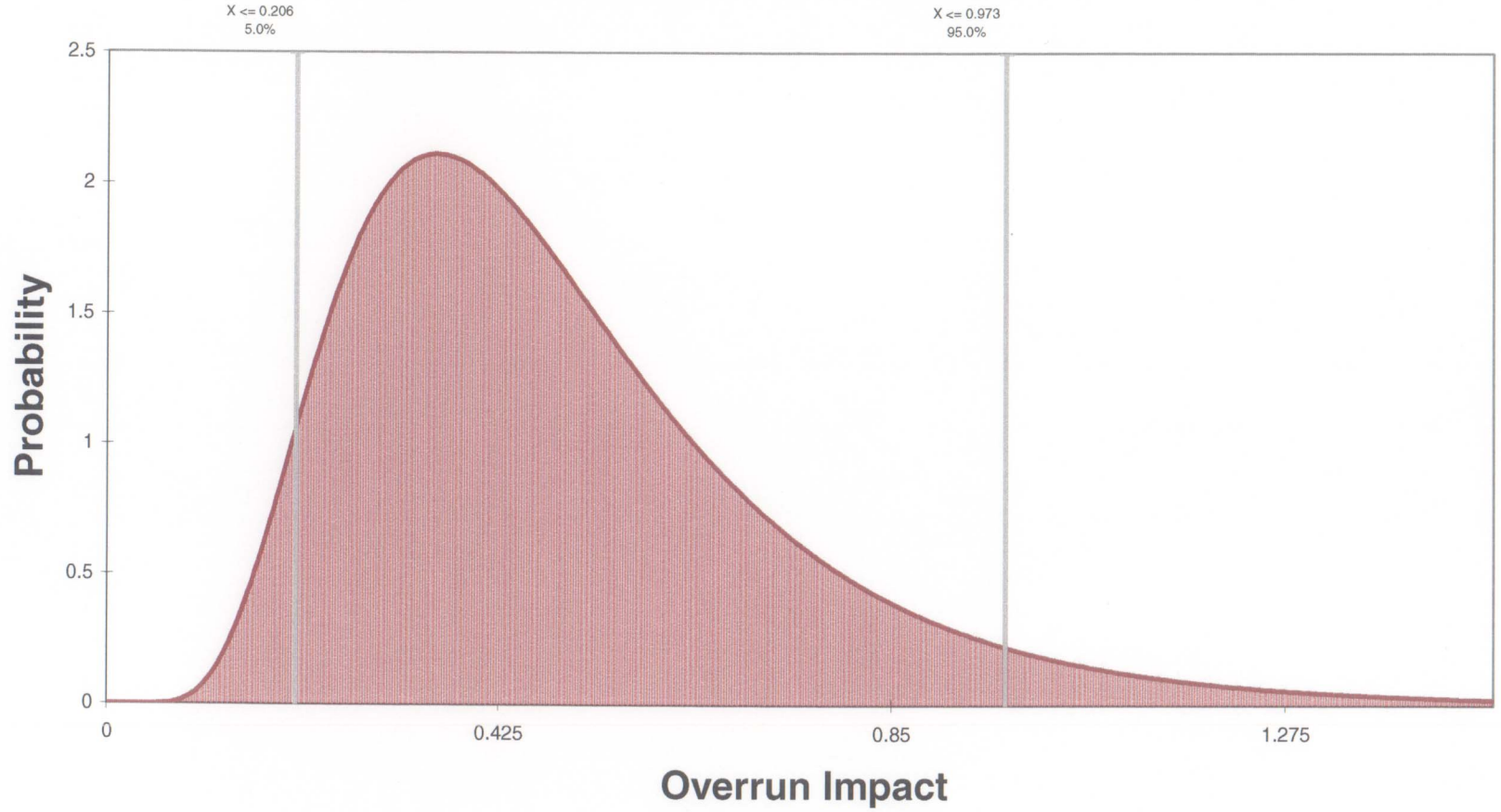
Graph 6a: Distributions used in Overrun Modeling

Skilled Workers Salary Impact: Lognorm(0.15, 0.25)

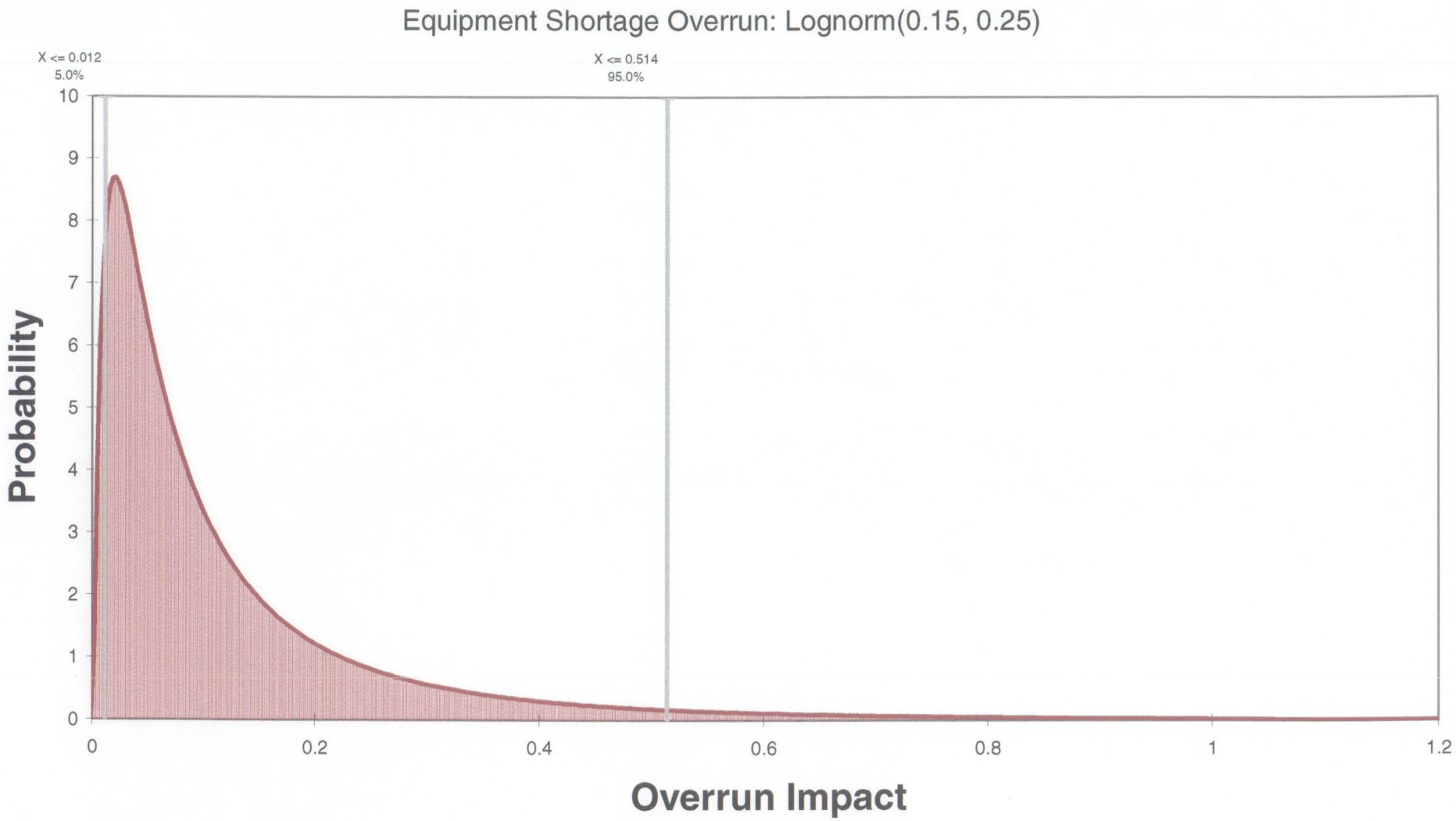


Graph 6b: Distributions used in Overrun Modeling

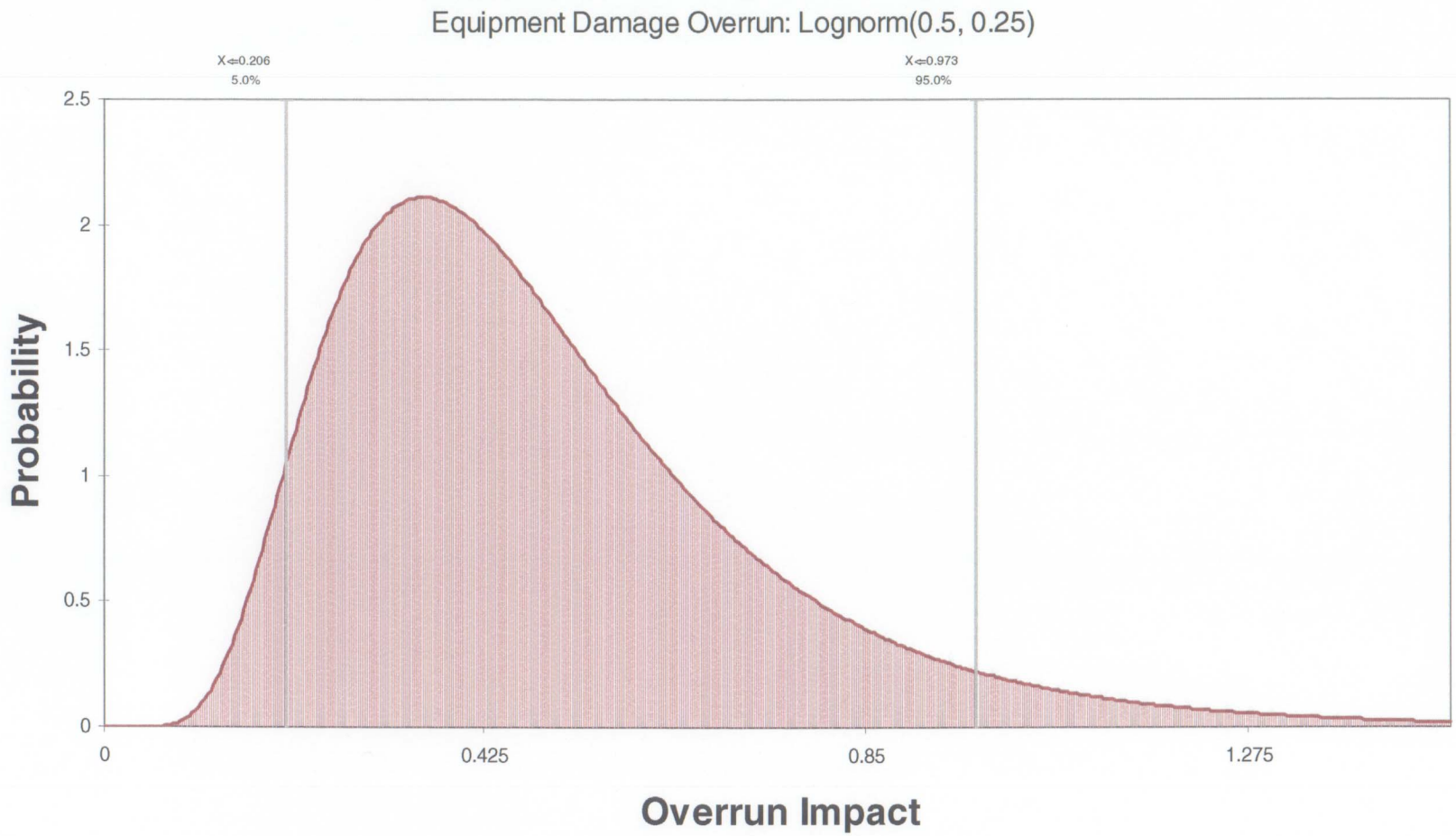
Specialist Worker Salary Impact: Lognorm(0.5, 0.25)



Graph 6c: Distributions used in Overrun Modeling

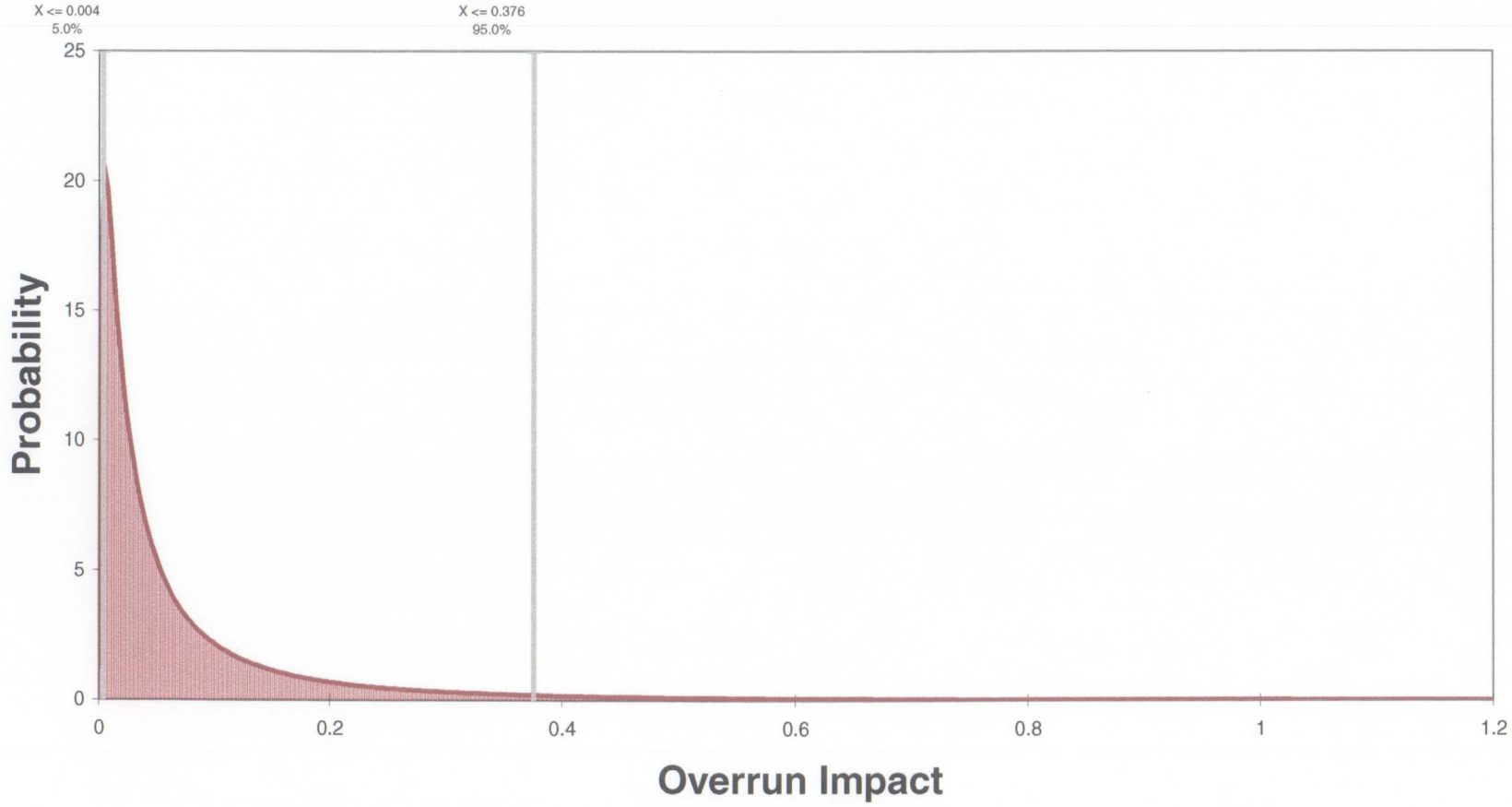


Graph 6d: Distributions used in Overrun Modeling

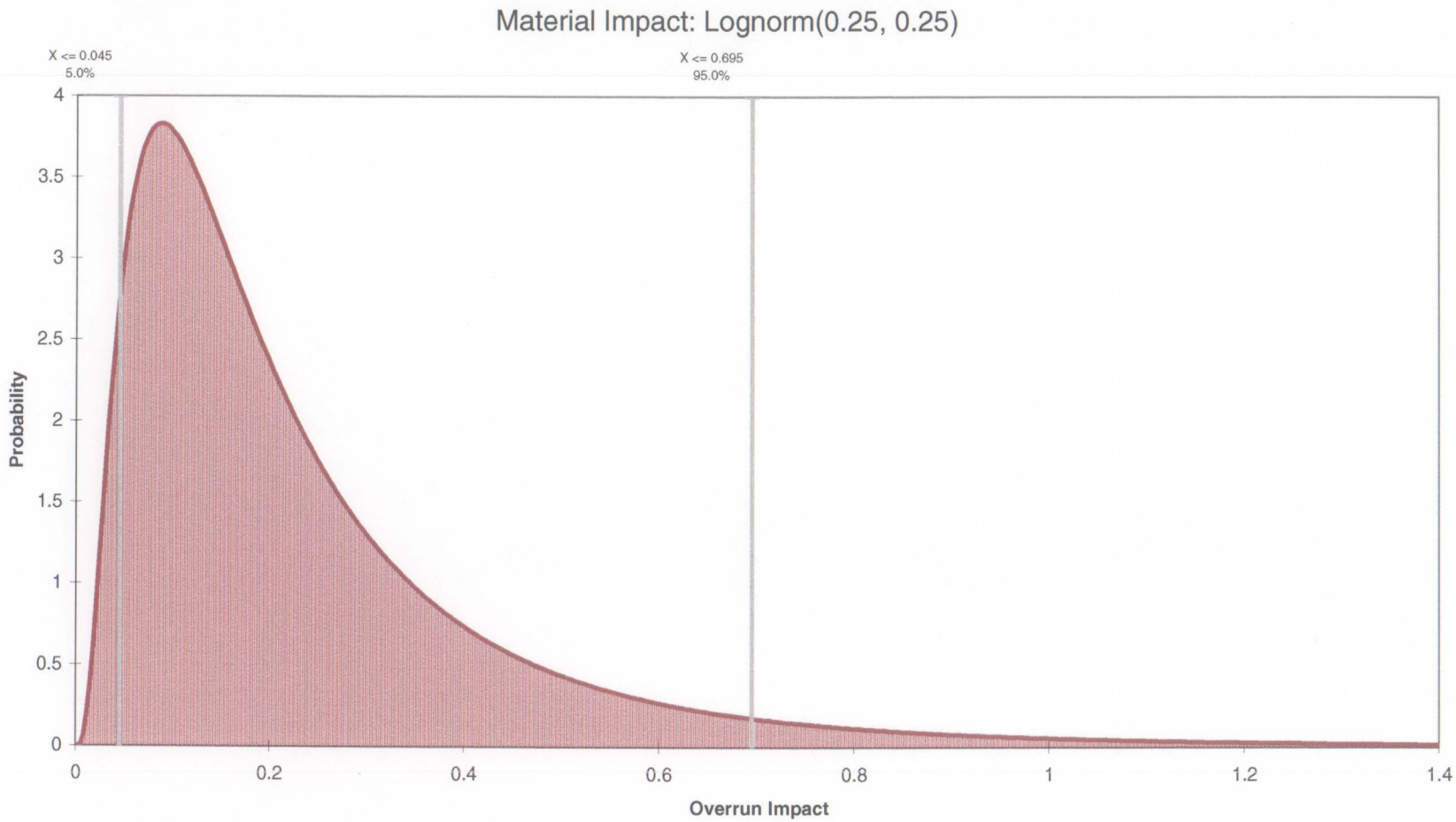


Graph 6e: Distributions used in Overrun Modeling

Other Equipment Overruns: Lognorm(0.1, 0.25)

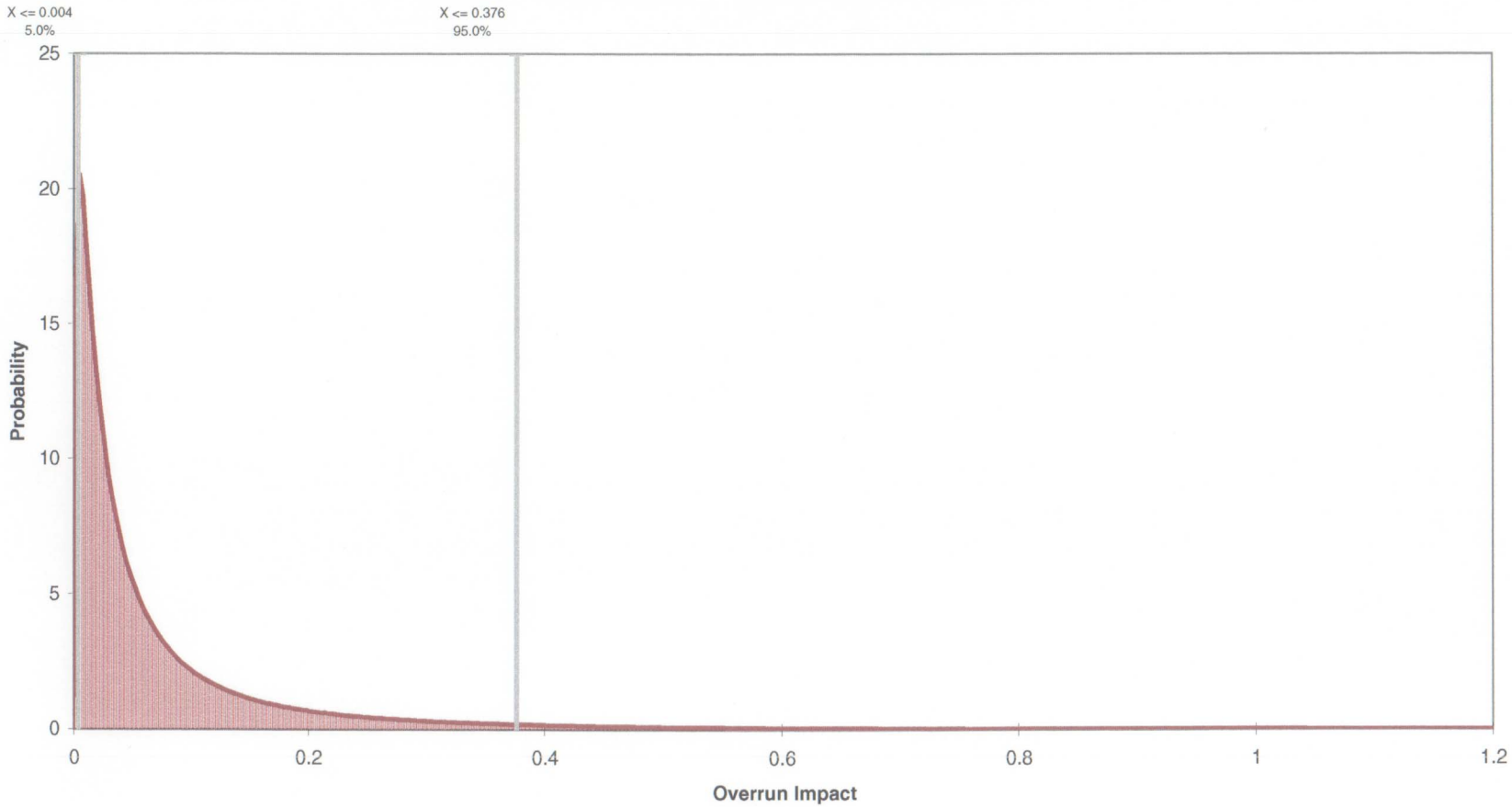


Graph 6f: Distributions used in Overrun Modeling

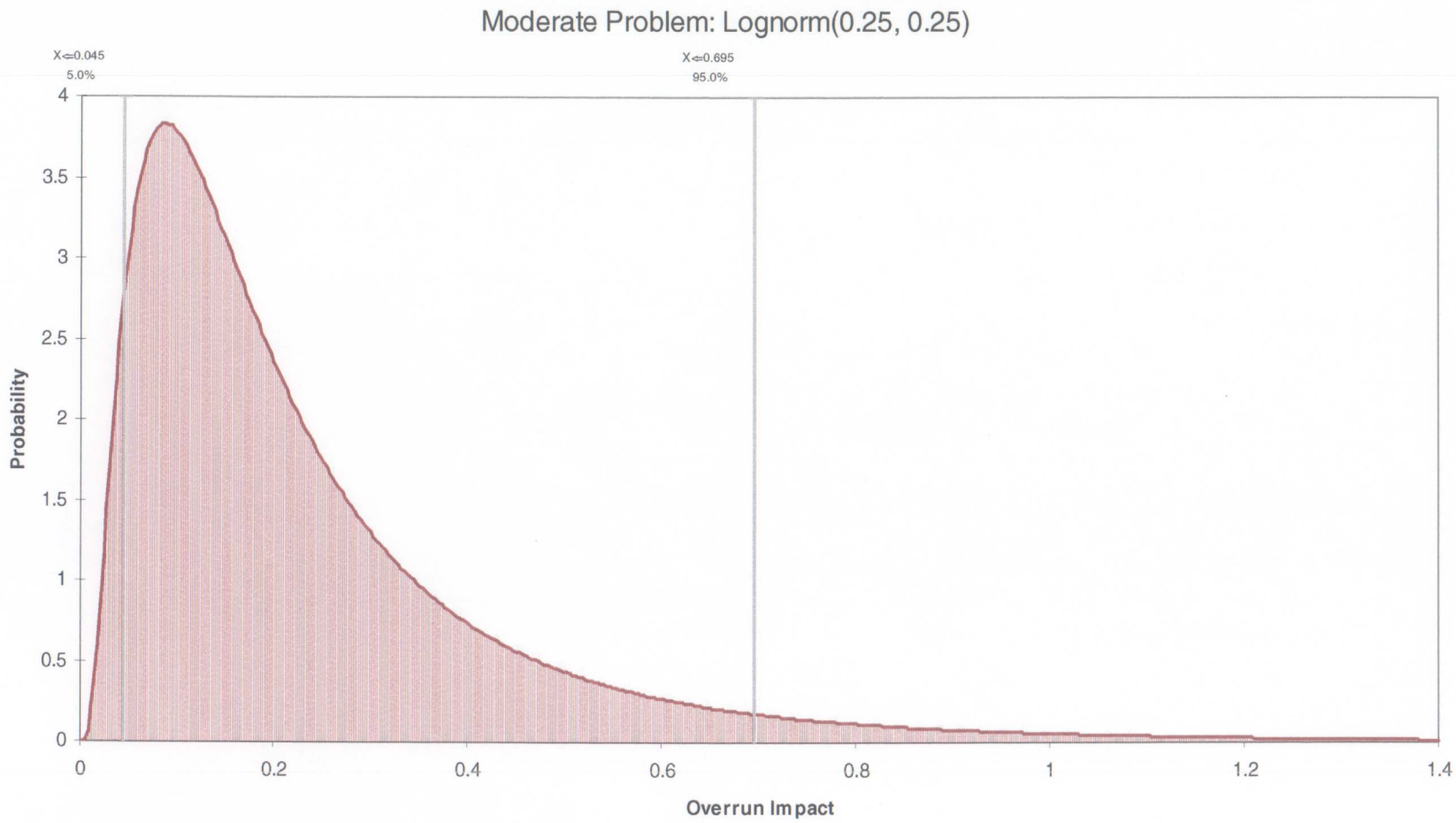


Graph 6g: Distributions used in Overrun Modeling

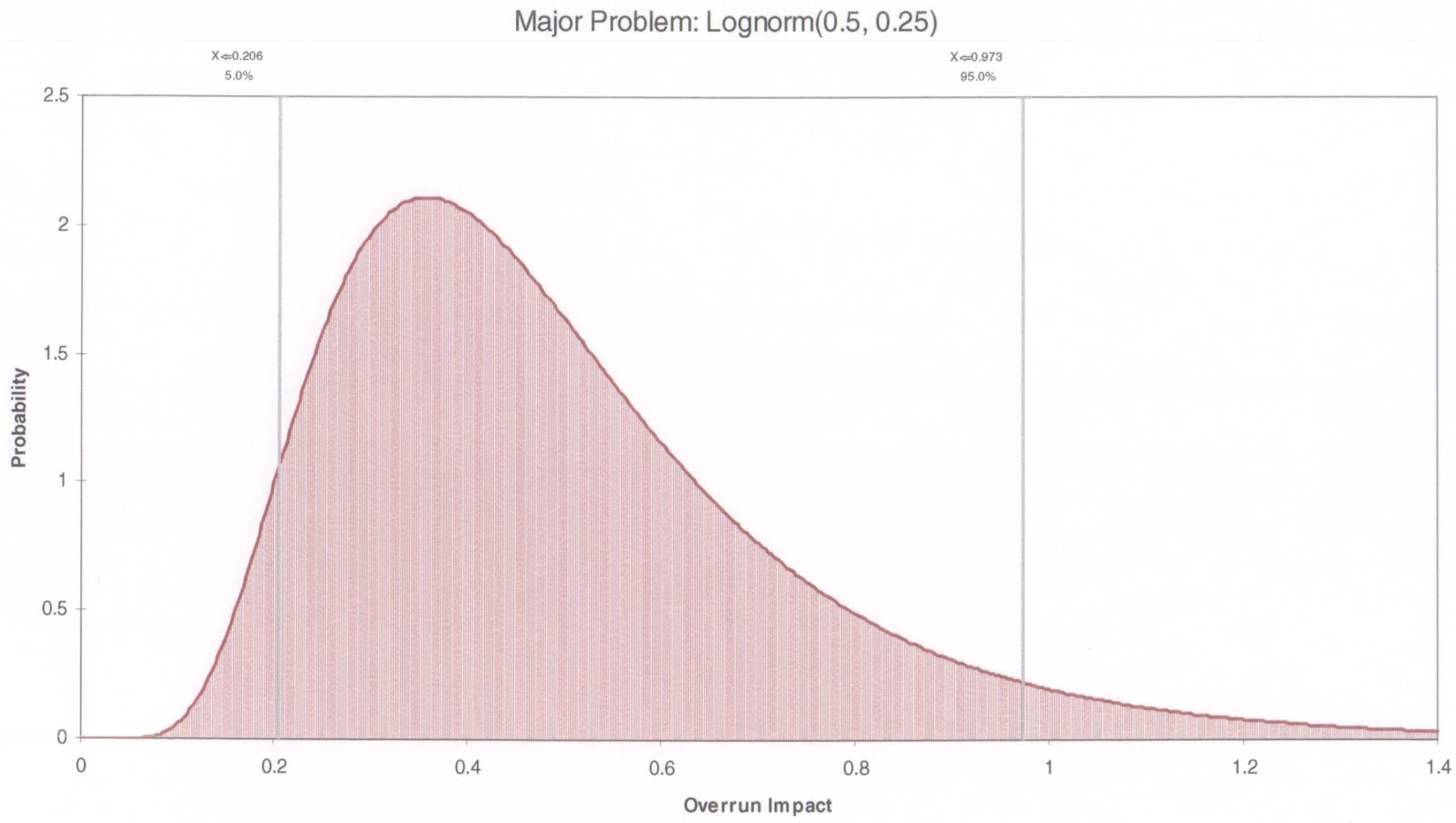
Minor Problem: Lognorm(0.1, 0.25)



Graph 6h: Distributions used in Overrun Modeling



Graph 6i: Distributions used in Overrun Modeling



Appendix B

Distribution Information

Demand Module

Scenario Selection Variable	Cell: H7	Used to determine the Macroeconomic, Competitive Environment
Distribution		Uniform
Parameters Min Max	 0% 100%	Range of a probability distribution. The value selected here will be matched up to the selected macroeconomic/competitive environment probabilities selected.
Mean	50%	Probable – Probable combination
Reasoning		The macroeconomic – competitive environment combination is a joint probability distribution function that was defined by the ACP. Instead of building a random variable based upon the joint PDF that would have to be updated whenever the ACP modified the environment probabilities, it is easier to create a random variable that will "back-into" the selected environmental conditions.

Time Line

Probability of a Problem	Cell: D3	Used to determine the probability of an event creating a delay arising.
Distribution		Uniform
Parameters: Min Max	 10% 40%	Parameters selected to give the desired mean.
Mean	25%	Determined to be reasonable probability of a delay occurring.
Reasoning		Used to add some variability in the model due to parameter risk in selecting the probability of a delay event occurring.

Monte Carlo	Column: M	Used to add an element of randomness to the ACP time estimates for the project, independent of a problem arising.
Distribution		Discrete Probability
Parameters: -1 month 0 month 1 month 1.5 months	 9.1% 45.4% 27.3% 18.2%	Selected to have a slight bias towards increasing the estimate to the project taking one month longer than one month less, with the majority of the estimates being unchanged.
Mean	0	Meant to keep the original estimates unchanged.
Reasoning		Since the project time line is based on estimate that stretches twenty years, there is a chance that the estimates are not going to be accurate independent from there being an event that results in a delay.

I Pre-Construction Activities	Column: N	Used to determine if there is a delay event and what the delay event is.
Distribution		Risk Geometric
Parameters: p	 0.75	Geometric distribution assigns less probability to higher values in a regular way.
Mean	1/3	Geometric distribution is a discrete distribution that returns whole numbers. The mean is closest to zero, which is the value with the highest probability of occurring.
Reasoning		Distribution produces the probability distribution desired to model the combined probability of no delay event and type of delay event.

Time Line *(continued)*

Stage II, III, IV Problem	Column: N	Used to determine if there is a delay event. Type of Event is determined in the Delays section.
Distribution		Bernoulli
Parameters: p	Probability of a Problem (detailed above)	Simple trial to determine if there is a delay event or not.
Mean	0.25	
Reasoning		Bernoulli distribution is used for simple binary options. In this case, the two options are a delay event occurs or doesn't occur.

Delays

Annual Cost of Operation	Cells: D2	Used to estimate the cost of a delay.
Distribution		Uniform
Parameters Min: Max:	 15,000 100,000	
Mean	530,378	Average yearly cost of the project.
Reasoning		Delays will result in the duplication of costs.

Probability of Recovery	Cells: D3	Used to estimate the probability of a recovery for the ACP.
Distribution		Uniform
Parameters: Min: Max:	 25% 50%	Selected to create a mean probability of recovery equal to 50%.
Mean	50%	Equal probability of a delay event arising due to the ACP or a contractor.
Reasoning		Potential delay events are numerous, each with a different probability of originating from the ACP or a contractor. Using a 50% probability is a decent estimate of the average across all potential delay events. The range around the probability is to try to account for the parameter risk associated with this assumption.

Delay Scale Factor	Cell: D4	Used to add more variability to the model.
Distribution		Uniform
Parameters: Min: Max:	 0.50 1.50	Selected to create a mean probability equal to 1.00.
Mean	1.00	No adjustment to the estimates.
Reasoning		There is parameter risk associated with any model. By adding this scale factor, it helps capture some of the parameter risk. Doesn't address parameter risk associated with selecting wrong distributions.

Delays *(continued)*

I Pre-Construction Activities: Delay	Cells: C12, C23, C35, C47, C58, C71, C82, C93	Used to estimate the length of a short delay due to events beyond the control of the ACP during the Pre-Construction Phase of the project.
Distribution		Poisson
Parameters λ Shift	 0.25 1.00	This Poisson distribution has a short tail. The probability for anything larger than 3 is very small. The shift forces the minimum value to be 1 month.
Mean	1.00	Most likely delay would be 1 month.
Reasoning		The Poisson distribution is a good distribution to model delays. These parameters were chosen due to the quick drop off in the tail of the distribution. Figured that the Pre-Construction Activities have little exposure to this type of risk.

I, II, III, IV – Minor Problem, Delay, & Personnel Problems	Cells: C13, C24, C25, C36, C37, C48, C49, C60, C61, C72, C83, C94, L11, L12, L22, L23, L33, L34, L44, U11, U13, U21, U23, U31, U32, U42, U43, U53, U54, U70, U71, AD11, AD13, AD21, AD23, AD31, AD32, AD42, AD43, AD53, AD54, AD70, AD71	Used to estimate the length of a short delay.
Distribution		Poisson
Parameters λ Shift	 1.5 1.0	This Poisson distribution has a slightly longer tail. The probability for anything larger than 6 months is very small. The shift forces the minimum value to be 1 month.
Mean	3.00	Most likely delay is 3 months.
Reasoning		The Poisson distribution is a good distribution to model delays. These parameters were chosen due to the probabilities associated with a value between 1 and 6 months.

Delays *(continued)*

I, II, III, IV – Moderate Problem, Equipment, Explosive, Contractor, Supply Problems	Cells C14, C26, C38, C50, C62, C73, C84, C95, L13, L14, L15, L24, L25, L26, L35, L36, L37, L45, U12, U14, U22, U24, U33, U34, U35, U44, U45, U46, U55, U56, U57, AD12, AD14, AD22, AD24, AD33, AD34, AD35, AD44, AD45, AD46, AD55, AD56, AD57	Used to estimate the length of a moderate delay.
Distribution		Poisson
Parameters λ Shift	 2.0 2.0	This Poisson distribution has a longer tail. The probability for anything larger than 9 months is very small. The shift forces the minimum value to be 2 months.
Mean	4.00	Most likely delay is 4 months.
Reasoning		The Poisson distribution is a good distribution to model delays. These parameters were chosen due to the probabilities associated with a value between 1 and 9 months.

I Pre-Construction Activities: Major Problem	Cells: C15, C27, C39, C51, C63, C74, C85, C96	Used to estimate the length of a long delay due to events beyond the control of the ACP during the Pre-Construction Phase of the project.
Distribution		Negative Binomial
Parameters p n Shift	 0.5 3.0 3.0	As the Poisson parameter increases, the more symmetric the distribution. A skewed distribution was viewed as more appropriate here, so the switch to the negative binomial.
Mean	6.00	Most likely delay would be 6 months.
Reasoning		The Poisson distribution for higher parameters becomes symmetric. Negative Binomial can produce a skewed distribution over the range of values desired. Results above 16 months are very unlikely with this distribution.

Delays *(continued)*

III, IV Commissioning: Moderate Problem	Cells: U72, AD72	Used to estimate the length of a moderate delay during the commissioning of the canal.
Distribution		Poisson
Parameters λ Shift	 3.0 2.0	This Poisson distribution has a slightly longer tail than the other moderate delay distribution. The shift forces the minimum value to be 2 months.
Mean	5.00	Most likely delay would be 5 months.
Reasoning		The Poisson distribution is a good distribution to model delays. These parameters were chosen due to the tail being slightly longer than the other moderate distribution. The reasoning behind the longer tail is that additional work during the commissioning stage would require removing the work already present in addition to whatever changes were needed.

III, IV Commissioning: Major Problem	Cells: U73, AD73	Used to estimate the length of a major delay during the commissioning of the canal.
Distribution		Poisson
Parameters λ Shift	 20.0 2.0	This distribution is symmetric.
Mean	22	Most likely delay would be 22 months.
Reasoning		The Poisson distribution is a good distribution to model delays. A symmetric distribution was deemed to be more appropriate than a skewed distribution. For a major repair work, the probability of the work taking less time than the mean seemed as likely as the work taking more time than the mean.

Gate Catastrophe Probability of Occurrence	Cells: S63	Used to model a catastrophic problem with the gates.
Distribution		Discrete
Parameters p	 1/10000	Probability of a gate sinking in transit.
Mean	0	No catastrophic problem with gate.
Reasoning.		In discussion with the ACP, determined that the probability of this event is exceptionally remote. Any smaller a probability wouldn't have a chance of happening in 10,000 simulations.

Delays *(continued)*

Gate Catastrophe Length of Delay	Cells: U63	Used to model the delay due to a catastrophic problem with the gates.
Distribution		Triangle
Parameters Min Most Likely Max	 11 12 18	Minimum number of months to replace a gate was set to 11 months. Most likely number of months to replace a gate was set to 12 months. Maximum number of months to replace a gate was set at 18 months. Most likely value has the highest probability, with linearly decreasing probability as the length of the delay approach the min and a max.
Mean	14	14 months to replace a gate.
Reasoning.		In discussion with the ACP, it was determined a gate takes 1 year to construct.

Overruns

Overrun Scale Factor	Cell: M2	Used to add more variability to the model.
Distribution		Uniform
Parameters: Min: Max:	 0.50 1.50	Selected to create a mean probability equal to 1.00.
Mean	1.00	No adjustment to the estimates.
Reasoning		There is parameter risk associated with any model. By adding this scale factor, it helps capture some of the parameter risk. Doesn't address parameter risk associated with selecting wrong distributions.

Probability of Recovery	Cells: M3	Used to estimate the probability of a recovery for the ACP.
Distribution		Uniform
Parameters: Min: Max:	 25% 50%	Selected to create a mean probability of recovery equal to 50%.
Mean	50%	Equal probability of a delay event arising due to the ACP or a contractor.
Reasoning		Potential delay events are numerous, each with a different probability of originating from the ACP or a contractor. Using a 50% probability is a decent estimate of the average across all potential delay events. The range around the probability is to try to account for the parameter risk associated with this assumption.

Overruns *(continued)*

Probability of Worker Shortage	Cells: C4, C5, C6	Used to determine if there is a shortage or not.
Distribution		Bernoulli
Parameters: Unskilled: Skilled: Specialist:	 10% 10% - 25% 15% - 50%	The potential labor pool shrinks as the necessary skills move from unskilled to skilled to specialist. If many more large-scale projects come on-line during the construction of the Panama Canal expansion, the probability of a shortage increases as the necessary skills increase.
Mean Unskilled: Skilled: Specialist:	 10% 17.5% 32.5%	Most likely probability of shortage for each type of labor.
Reasoning		Bernoulli trials are used when dealing with variables with only two states. In this case, the existence of a shortage or not. The variable probabilities underlying the Bernoulli trials is to account for the potential for other large-scale projects taking competing for manpower with the ACP.

Cost of Unskilled Worker Shortage	Cells: D4	Impact on cost estimates due to not enough unskilled workers to fill the ACP's needs.
Distribution		Uniform
Parameters Min: Max:	 0.030 0.100	
Mean	0.065	If there is a shortage, expected impact to the costs is 6.5%.
Reasoning		Even with a shortage of unskilled worker, the additional cost to help fill the need shouldn't be all that significant.

Cost of Skilled Worker Shortage	Cells: D5	Impact on cost estimates due to not enough skilled workers to fill the ACP's needs.
Distribution		Lognormal
Parameters μ: σ:	 0.15 0.25	
Mean	0.15	If there is a shortage, expected impact to the costs is 15%.
Reasoning		Lognormal distributions are very skewed distributions. Most of the values produced are clustered around the mean, but large values are possible.

Overruns *(continued)*

Cost of Specialist Worker Shortage	Cells: D6	Impact on cost estimates due to not enough skilled workers to fill the ACP's needs.
Distribution		Lognormal
Parameters μ: σ:	 0.50 0.25	
Mean	0.50	If there is a shortage, expected impact to the costs is 50%.
Reasoning		Lognormal distributions are very skewed distributions. Most of the values produced are clustered around the mean, but large values are possible.

Probability of Equipment Problem	Cells: C13, C14, C15	Used to determine if there is a shortage or not.
Distribution		Bernoulli
Parameters: Shortage: Damage: Other:	 3% - 8% 10% - 25% 15% - 35%	Estimated that the risk of there being an equipment shortage is slim. Since the other category is encompasses all other equipment problems but damage and shortage, assigned it a higher probability of occurring.
Mean Shortage: Damage: Other:	 5.5% 17.5% 25.0%	Most likely probability of each equipment problem.
Reasoning		Bernoulli trials are used when dealing with variables with only two states. In this case, the existence of a problem or not.

Cost of Equipment Shortage	Cells: D13	Impact on cost estimates due to not enough equipment to fill the ACP's needs.
Distribution		Lognormal
Parameters μ: σ:	 0.15 0.25	
Mean	0.15	If there is a shortage, expected impact to the costs is 15%.
Reasoning		Lognormal distributions are very skewed distributions. Most of the values produced are clustered around the mean, but large values are possible.

Overruns *(continued)*

Cost of Damaged Equipment	Cells: D14	Impact on cost estimates due to repairs and replacement.
Distribution		Lognormal
Parameters μ: σ:	 0.50 0.25	
Mean	0.50	If there is a shortage, expected impact to the costs is 50%.
Reasoning		Lognormal distributions are very skewed distributions. Most of the values produced are clustered around the mean, but large values are possible.

Cost of Damaged Equipment	Cells: D15	Impact on cost estimates due to repairs and replacement.
Distribution		Lognormal
Parameters μ: σ:	 0.10 0.25	
Mean	0.50	If there is a shortage, expected impact to the costs is 10%.
Reasoning		Lognormal distributions are very skewed distributions. Most of the values produced are clustered around the mean, but large values are possible.

Probability of Material Cost Overruns	Cells: C22, C23, C24, C25	Used to determine if there is an overrun due to material costs.
Distribution		Bernoulli
Parameters: Concrete, Steel, Fuel: Other:	 10% - 50% 5% - 25%	Assumed that the probability for the other category is half that of the three other materials, due to the project's significant exposure to the other three. The range is account for both the change in commodity prices as well as potential for other large-scale projects coming on line driving up demand for these commodities.
Mean Concrete, Steel, Fuel: Other:	 30% 15%	
Reasoning		Bernoulli trials are used when dealing with variables with only two states. In this case, the existence of a problem or not.

Overruns *(continued)*

Cost of Material Impact	Cells: D22, D23, D24, D25	Impact on cost estimates due to overruns from material costs.
Distribution		Lognormal
Parameters μ: σ:	 0.25 0.25	
Mean	0.25	If there is a shortage, expected impact to the costs is 25%.
Reasoning		Lognormal distributions are very skewed distributions. Most of the values produced are clustered around the mean, but large values are possible.

Detail of the 1st year Changes / Alterations in Scope shown. Other years follow same logic.

Probability of Changes / Alterations in Scope year 1	Cells: C33, C34, C35	Used to determine if there is a shortage or not.
Distribution		Bernoulli
Parameters: Minor: Moderate: Major:	 15% - 40% 10% - 15% 5% - 10%	The probability of a problem arising should be inversely related to its severity. Due to the size of the project and various unknowns (i.e. selected contractor), there is a lot of uncertainty around the probability of Changes / Alterations in Scope. The range is trying to account for the parameter risk.
Mean Shortage: Damage: Other:	 27.5% 12.5% 7.5%	
Reasoning		Bernoulli trials are used when dealing with variables with only two states. In this case, the existence of a problem or not.

Cost of Minor Change / Alteration in Scope	Cells: D33	Impact on cost estimates due to minor Changes / Alterations in Scope.
Distribution		Lognormal
Parameters μ: σ:	 0.10 0.25	
Mean	0.10	If there is a shortage, expected impact to the costs is 10%.
Reasoning		Lognormal distributions are very skewed distributions. Most of the values produced are clustered around the mean, but large values are possible.

Overruns *(continued)*

Cost of Moderate Change / Alteration in Scope	Cells: D34	Impact on cost estimates due to moderate Changes / Alterations in Scope.
Distribution		Lognormal
Parameters μ: σ:	 0.25 0.25	
Mean	0.25	If there is a shortage, expected impact to the costs is 25%.
Reasoning		Lognormal distributions are very skewed distributions. Most of the values produced are clustered around the mean, but large values are possible.

Cost of Major Change / Alteration in Scope	Cells: D35	Impact on cost estimates due to major Changes / Alterations in Scope.
Distribution		Lognormal
Parameters μ: σ:	 0.50 0.25	
Mean	0.50	If there is a shortage, expected impact to the costs is 50%.
Reasoning		Lognormal distributions are very skewed distributions. Most of the values produced are clustered around the mean, but large values are possible.